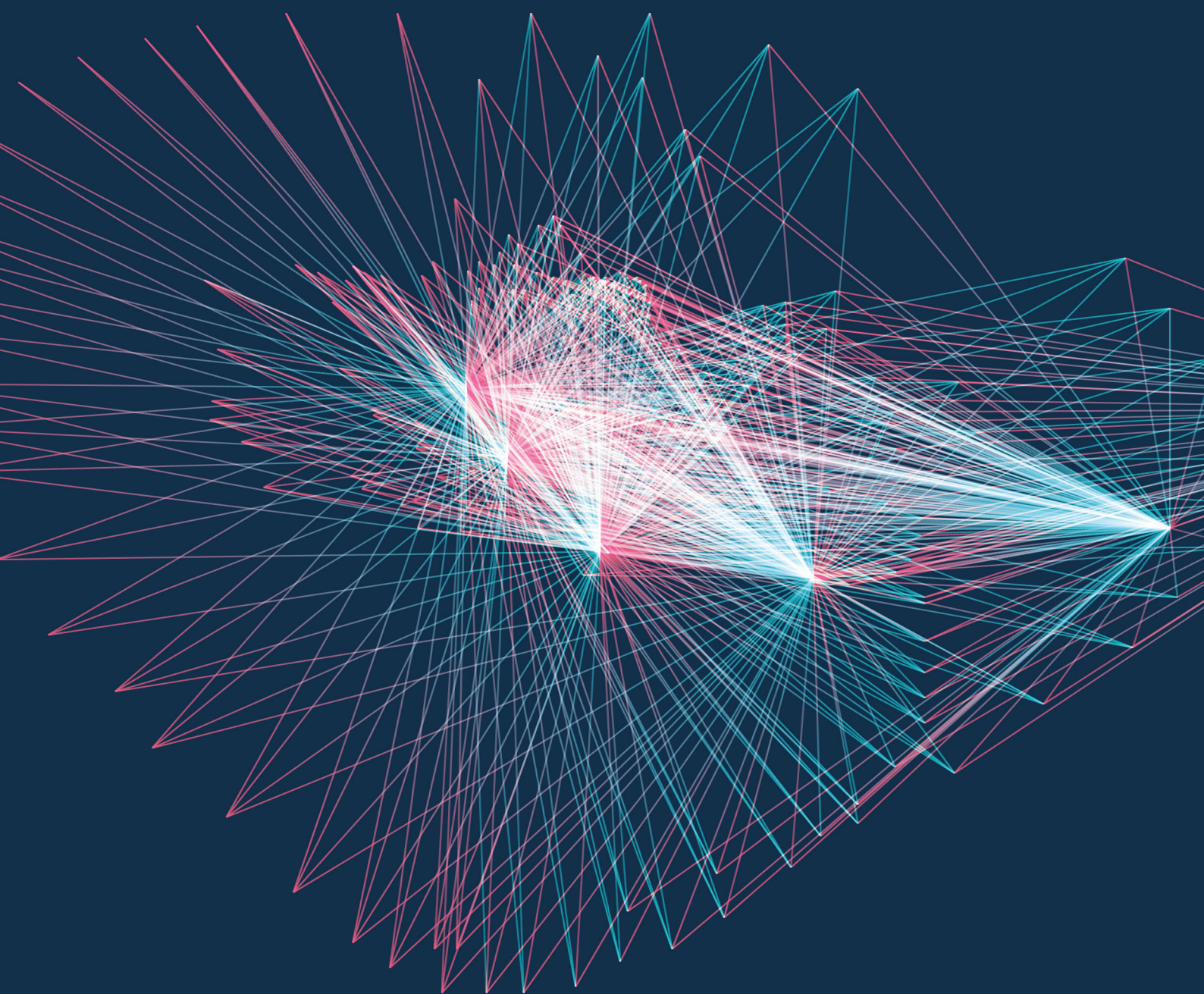


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Chiang Mai University's Faculty of Dentistry publishes academic research articles in the newly titled - **Oral Sciences Reports**, which was previously known as *Chiang Mai Dental Journal (CMDJ)*. The journal was originally established for the purposes of publishing academic research articles by the Faculty of Dentistry at Chiang Mai University in 1977. In the current report, editors and experts in their respective fields review articles received from authors prior to being published to ensure that the content of all articles is up-to-date, universal, logical, and in accordance with academic principles so the reader can apply knowledge and cite works in the development of dentistry for the purposes of advancing future research while being beneficial to patients and society.

At present, Oral Sciences Reports openly receives all submissions through an online journal review process system. The new online system also allows reviewers and researchers an ability to read 3 issues each year.

Aim and Scope of the journal

To compile research and content that is up to date and usable to all branches of dentistry and related fields. The articles in Oral Sciences Reports are fundamental research work, including original articles, review articles, case reports/series, short communications, and letters to the editor.

Policy

Accepted articles will be fairly reviewed by the editors and experts with full transparency through the following process.

1. The articles must be correct according to academic principles and not duplicate works that have been previously published.
2. The articles will be considered and reviewed through a non-bias process by concealing the names of authors and related persons in the considered documents while also concealing the names of the experts and reviewers who review the articles (double-blind review).
3. The review process can be tracked online. The article authors can review the status of their article and are able to follow up on the article evaluation through the online process. The duration of each step is closely monitored so that the articles can be published on time.
4. Authors of articles are responsible to review and verify the accuracy of the text, images, tables in the articles before publication.
5. Articles published in Oral Sciences Reports are the copyright of Oral Sciences Reports, which forbids anyone from duplicating published articles for any purpose without explicit permission from Oral Sciences Reports.

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Types of Submission

Oral Sciences Reports invites the following submissions:

1. Original Articles Original contributions of research reports or unpublished recent academic research to the development and applications in dentistry and related fields. The original article must not exceed 4000 words in length and must contain no more than 10 figures and tables in total.
2. Review Articles Comprehensive reviews of special areas of focus in dentistry and related fields. Articles that contain important collected data from numerous books or journals and from the writer's experience. Information should be described, reviewed, compared, and analyzed. The review article must not exceed 4000 words in length and must contain no more than 10 figures and tables in total.
3. Systematic Reviews Clearly formulated reviews that uses systematic and reproducible methods to identify, select and critically appraise all relevant research, and to collect and analyze data from the studies that are included in the review.
4. Case Reports/Series Original findings that highlight novel technical and/or clinical aspects in dentistry and related fields which include clinical symptoms, diagnosis, patient care, treatment, follow-up, and evaluation. The report must not exceed 2500 words in length and must contain no more than 5 figures.
5. Letters to the Editor Commentaries on published papers in the journal and other relevant matters that must not exceed 1000 words in length
6. Short Communications Original contributions describing new developments of high impact that justify expedited review. The report must not exceed 2000 words in length and must contain no more than 3 figures.

Submission Checklist

Authors should ensure to prepare the following items for submission. Failure to complete the required items may contribute to the delay of publication process. Please check the relevant section in this guideline for more details.

1. Title page Must include title of the article, author names and affiliations. One author has been designated as the corresponding author with contact details (e-mail address and full postal address) (see 'Title page' section for more information and an example)
2. CRediT Contribution Author will be asked to provide CRediT Contributions as well as their degree of contribution at the time of the original submission. CRediT Contribution is a high-level classification of the diverse roles performed in the work leading to a published research output in the sciences. Its purpose to provide transparency in contributions to scholarly published work, to enable improved systems of attribution, credit, and accountability.
3. Abstract Must not exceed 250 words. Relevant keywords (up to five keywords) must be included at the end of the abstract. (see the 'Abstract' section for more details)
4. Main Manuscript Author details and affiliation must not be included. (see 'Manuscript' section for more details)
5. Figures Should include relevant captions. (see the 'Figures' section for more details)
6. Tables Should include titles, description, and footnotes. (see the 'Tables' section for more details)
7. Supplementary data (if applicable)

Additional considerations the author should confirm before submission:

1. Manuscript must be 'spell-checked', 'grammar-checked', and 'plagiarism-checked'.
2. All figures, tables, and references mentioned in the text should match the files provided.
3. Permission must be obtained for use of copyrighted material from other sources (including the internet).
4. Authors must provide conflicts of interest statement, even if there is no conflict of interests to declare.

Ethical Guidelines

Authors must acknowledge to the following ethical guidelines for publication and research.

A. Authorship and Author Contributions

The policy of Oral Sciences Reports that only ONE corresponding author is accepted. Where there is any uncertainty regarding authorship, the editor of the journal reserves the right to contact the corresponding author of the study for further information. Authors must acknowledge that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Journal. Authors are required to identify the contributions for which they are responsible. Author will be asked to provide CRediT Contributions as well as their degree of contribution at the time of the original submission. CRediT Contribution is a high-level classification of the diverse roles performed in the work leading to a published research output in the sciences. Its purpose to provide transparency in contributions to scholarly published work, to enable improved systems of attribution, credit, and accountability.

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(b) Written confirmation (e-mail, letter) from all authors that they agree with the addition, removal, or rearrangement.

In case of addition or removal of authors, these must be confirmed from the author being added or removed. Please be informed that changes of the authorship cannot be made in any circumstances after the manuscript has been accepted.

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All studies using human or animal subjects should include an explicit statement in the Material and Methods section identifying the review and ethics committee's approval for each study. Experimentation involving human subjects will only be published if such research has been conducted in full accordance with the World Medical Association Declaration of Helsinki (version 2008) and the additional requirements or with ethical principles of the country where the research has been carried out. Manuscripts must be accompanied by a statement that the experiments were undertaken with the understanding and written consent of each subject and according to the above-mentioned principles.

Experimentation involving animal subjects should be carried out in accordance with the guidelines laid down by the National Institute of Health (NIH) in the USA or with the European Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations. Editors reserve the right to reject papers if there is doubt as to whether appropriate procedures have been used.

C. Clinical Trials

All clinical trials must register in any of the following public clinical trials registries:

- Thai Clinical Trials Registry (TCTR)
- NIH Clinical Trials Database
- EU Clinical Trials Register
- ISRCTN Registry

The clinical trial registration number and name of the trial register should be included in Materials and Methods of the manuscript. For epidemiological observational trials, authors of epidemiological human observations studies are required to review and submit a 'strengthening the reporting of observational studies in Epidemiology' (STROBE) checklist and statement. Compliance with this must be detailed in Materials and Methods.

D. Systematic Review

The abstract and main body of the systematic review should be reported using the PRISMA for Abstract and PRISMA guidelines respectively. Authors submitting a systematic review should register the protocol in one of the readily-accessible sources/databases at the time of project inception and not retrospectively (e.g. PROSPERO database, OSF registries). The protocol registration number, name of the database or journal reference should be provided at the submission stage in Materials and Methods. A PRISMA checklist and flow diagram (as a Figure) should also be included in the submission material.

E. Conflicts of Interest

All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Potential sources of conflict of interest include (but are not limited to) patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. If there are no interests to declare, please state 'The authors declare no conflict of interest'. Authors must disclose any interests in the section after acknowledgments.

F. Submission Declaration and Verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract, a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright- holder. The conference proceedings are allowed to be part of the article if the contents do not exceed 70% of the article.

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Manuscript Preparation

All texts in the submitted manuscript are required to be inclusive language throughout that acknowledges diversity, conveys respect to all people, is sensitive to differences, and promotes equal opportunities. Authors should ensure that writing is free from bias, for instance by using 'he or she', 'his/her' instead of 'he' or 'his', and by making use of job titles that are free of stereotyping (for instance by using 'chairperson' instead of 'chairman' and 'flight attendant' instead of 'stewardess'). Articles should make no assumptions about the beliefs or commitments of any reader, should contain nothing which might imply that one individual is superior to another on the grounds of race, sex, religion, culture, or any other characteristic.

A. Title page

The title page will remain separate from the manuscript throughout the peer review process and will not be sent to the reviewers. It should include these following details:

- Title should be concise, information-retrieval, and not exceed 30 words. Please avoid abbreviations and formulae where possible.
- Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author are accurately spelled. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript number immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and the e-mail address of each author.
- Corresponding author will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. Please ensure that the e-mail address and contact details given are kept up to date by the corresponding author.

B. Abstract

Abstract must not exceed 250 words with concise and informative explanations about the article. Authors must prepare an abstract separately from the main manuscript using Microsoft Word processing software (.doc or .docx). Please avoid references and uncommon abbreviations, but if essential, abbreviations must be defined at their first mention in the abstract itself. Abstract structure of the original articles must consist of 'Objectives, Methods, Results, and Conclusions'.

Abstract of other types of submitted articles should be summarized in one paragraph. Up to five keywords relevant to the articles must be provided and arranged in alphabetical order.

C. Manuscript

Oral Sciences Reports adheres to a double-blinded review. The main body of the paper (including the references, figures, tables and any acknowledgements) must not include any identifying information, such as the authors' names. The layout of the manuscript must be as simple as possible with double-spaced, single column format with Sans Serif font and uploaded as an editable Microsoft Word processing file (.doc or .docx). Complex codes or hyphenate options must be avoided, but the emphatic options such as bold face, italics, subscripts, and superscripts, etc. are encouraged.

1. Original article

- *Introduction* should include literature reviews of previous studies, research questions, and the rationale for conducting the study. The Introduction should not be too long and should be easy to read and understand while avoiding a detailed literature survey or a summary of the results.

- *Methods* should provide sufficient details in a logical sequence to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized and indicated by a reference. If quoting directly from a previously published method, use quotation marks and cite the source. Any modifications to existing methods should also be described.

- *Results* should show the data gained from the study's design in text, tables and/or illustrations, as appropriate, and be clear and concise.

- *Discussion* is criticism, explanation, and defense of the results from the standpoint of the author, and comparison with other peoples' reports. The discussion can include criticism of materials, methods and study results, problems, and difficulties, pointing out the benefits of adoption and providing feedback where appropriate. Discussions should explore the significance of the results of the work, not repeat them. Avoid extensive citations and discussion of published literature.

- *Conclusions* refers to a summary of the study or research results.

- *Acknowledgments*: Please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study.

Formatting of funding source:

This work was supported by the 1st organization name [grant numbers xxxx]; the 2nd organization name [grant number yyyy]; and the 3rd organization name [grant number zzzz].

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant or funding from funding agencies in the public, commercial, or not-for-profit sectors.

- *References* should be confined to documents relating to the author's article or study. The number should not exceed 80, placed in order and using numbers which are superscripted and put in parentheses, starting with number 1 in the article and in reference document's name. (see 'References' section for more information regarding reference formatting)

2. Review articles should be divided into Introduction, Review and Conclusions. The Introduction section should be focused to place the subject matter in context and to justify the need for the review. The Review section should be divided into logical sub-sections in order to improve readability and enhance understanding. Search strategies must be described, and the use of state-of-the-art evidence-based systematic approaches is expected. The use of tabulated and illustrative material is encouraged. The Conclusion section should reach clear conclusions and/or recommendations on the basis of the evidence presented.

3. Systematic review

- Introduction should be focused to place the subject matter in context and to justify the need for the review.
- Methods should be divided into logical sub-sections in order to improve readability and enhance understanding (e.g. details of protocol registration, literature search process, inclusion/exclusion criteria, data extraction, quality assessment, outcome(s) of interest, data synthesis and statistical analysis, quality of evidence).
- Results should present in structured fashion (e.g. results of the search process, characteristics of the included studies, results of primary meta-analysis, additional analysis, publication bias, quality of evidence).
- Discussion should summarize the results, highlighting completeness and applicability of evidence, quality of evidence, agreements and disagreements with other studies or reviews, strength and limitations, implications for practice and research.
- Conclusion(s) should reach clear conclusions and/or recommendations on the basis of the evidence presented.

4. Case reports/series should be divided into Introduction, Case report, Discussion and Conclusions. They should be well illustrated with clinical images, radiographs and histologic figures and supporting tables where appropriate. However, all illustrations must be of the highest quality.

There are some necessary considerations which should be comprehended and consistent throughout the article:

1. Abbreviations: define abbreviations at their first occurrence in the article: in the abstract and in the main text after it. Please ensure consistency of abbreviations throughout the article.
2. Mathematical expressions: the numbers identifying mathematical expressions should be placed in parentheses after the equation, flush to the right margin; when referring to equations within text, use the following style: Eq. (5), Eqs. (3-10), [see Eq. (4)], etc.
3. Nomenclature: abbreviations and acronyms should be spelled out the first time they are used in the manuscript or spelled out in tables and figures (if necessary). Units of measure and time require no explanation. Dental nomenclature in the manuscript should be complete words, such as maxillary right central incisor. Numbering of teeth from pictures or tables should follow the FDI two-digit system.
4. Units: use the international system of units (SI). If other units are mentioned, please give their equivalent in SI.
5. Product identification: all products mentioned in the text should be identified with the name of the manufacturer, city, state, and country in parentheses after the first mention of the product, for example, The ceramic crown was cemented on dentin surface with resin cement (RelyXTM U200, 3M ESPE, St. Paul, MN, USA)...

D. Figures

Figures should be prepared and submitted separately from the main manuscript. Color artworks are encouraged at no additional charge. Regardless of the application used other than Microsoft Office, when the electronic artwork is finalized, please 'save as' or 'export' or convert the images to **EPS, TIFF, or JPEG format with the minimum resolution of 300 dpi**. Keep the artwork in uniform lettering, sizing, and similar fonts. Please do not submit graphics that are too low in resolution or disproportionately large for the content. Authors must submit each illustration as a separate file.

Please ensure that each illustration has a caption according to their sequence in the text and supply captions separately in editable Microsoft Word processing file (.doc or .docx), not attached to the figure. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

E. Tables

Please submit tables as editable Microsoft Word processing files (.doc or .docx), not as images, and avoid using vertical rules and shading in table cells. Each table should be placed on a separate page, not next to the relevant text

in the article. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body while ensuring that the data presented in them does not duplicate results described elsewhere in the article.

F. References

Citation in text

Any citations in the text should be placed in order and using numbers which are superscripted and put in parentheses. Please ensure that all citations are also present in the reference list consecutively in accordance with their appearance in the text.

Reference style

All references should be brought together at the end of the paper consecutively in accordance with their appearance in the text and should be in the Vancouver reference format. Please follow these examples of correct reference format below:

1. Journal article

1.1. One to six authors

Author(s) – Family name and initials. Title of article. Abbreviated journal title. Publication year;volume (issue);pages.

Example:

Parvez GM. Pharmacological activities of mango (*Mangifera Indica*): A review. *J Pharmacognosy Phytother.* 2016;5(3): 1-7.

Or

Choi YS, Cho IH. An effect of immediate dentin sealing on the shear bond strength of resin cement to porcelain restoration. *J Adv Prosthodont.* 2010;2(2):39-45.

Or

Firmino RT, Ferreira FM, Martins CC, Granville-Garcia AF, Fraiz FC, Paiva SM. Is parental oral health literacy a predictor of children's oral health outcomes? Systematic review of the literature. *Int J Paediatr Dent.* 2018;28(5):459-71.

1.2. More than six authors

Author(s) – Family name and initials of the first six authors, et al. Title of article. Abbreviated journal title. Publication year;volume(issue);pages.

Example:

Vera J, Siqueira Jr JF, Ricucci D, Loghin S, Fernández N, Flores B, et al. One-versus two-visit endodontic treatment of teeth with apical periodontitis: a histobacteriologic study. *J Endod.* 2012;38(8):1040-52.

1.3. Article in press

Authors separated by commas – Family name and initials. Title of article. Abbreviated journal title in italics. Forthcoming - year of expected publication.

Example:

Cho HJ, Shin MS, Song Y, Park SK, Park SM, Kim HD. Severe periodontal disease increases acute myocardial infarction and stroke: a 10-year retrospective follow-up study. *J Dent Res.* Forthcoming 2021.

2. Books

2.1. Book with author (s)

Author(s) – Family name and initials (no more than 2 initials with no spaces between initials)– Multiple authors separated by a comma. After the 6th author add - "et al". Title of book. Edition of book if later than 1st ed. Place of publication: Publisher name; Year of publication.

Example:

Sherwood IA. Essentials of operative dentistry. Suffolk: Boydell & Brewer Ltd; 2010.

Or

Abrahams PH, Boon JM, Spratt JD. McMinn's clinical atlas of human anatomy. 6th edition. Amsterdam: Elsevier Health Sciences; 2008.

2.2. Book with no author

Title of book. Edition of book if later than 1st ed. Place of publication: Publisher name; Year of publication.

Note: Do not use anonymous. Please begin a reference with the title of the book if there is no person or organization identified as the author and no editors or translators are given.

Example:

A guide for women with early breast cancer. Sydney: National Breast Cancer; 2003.

2.3. Chapter in a book

Author(s) of chapter - Family name and initials, Title of chapter. In: Editor(s) of book - Family name and initials, editors. Title of book. edition (if not first). Place of publication: Publisher name; Year of publication. p. [page numbers of chapter].

Example:

Rowlands TE, Haine LS. Acute limb ischaemia. In: Donnelly R, London NJM, editors. ABC of arterial and venous disease. 2nd ed. West Sussex: Blackwell Publishing; 2009. p. 123-140.

3. *Thesis/dissertation*

3.1. Thesis in print

Author - family name followed by initials. Thesis title [type of thesis]. Place of publication: Publisher; Year.

Example:

Kay JG. Intracellular cytokine trafficking and phagocytosis in macrophages [dissertation]. St Lucia, Qld: University of Queensland; 2007.

3.2. Thesis retrieved from full text database or internet

Author - family named followed by initials. Thesis title [type of thesis/dissertation on the Internet]. Place of publication: Publisher; Year [cited date – year month day]. Available from: URL

Example:

Pahl KM. Preventing anxiety and promoting social and emotional strength in early childhood: an investigation of risk factors [dissertation on the Internet]. St Lucia, Qld: University of Queensland; 2009 [cited 2017 Nov 22]. Available from: <https://espace.library.uq.edu.au/view/UQ:178027>

4. *Webpage*

4.1. Webpage with author

Author/organization's name. Title of the page [Internet]. Place of publication: Publisher's name; Publication date or year [updated date - year month day; cited date - year month day]. Available from: URL

Example:

American Dental Association. COVID-19 and Oral Health Conditions [Internet]. Chicago: American Dental Association; 2021 Feb 12 [updated 2021 Feb 12; cited 2021 Jun 24]. Available from: <https://www.ada.org/en/press-room/news-releases/2021-archives/february/covid-19-and-oral-health-conditions>

4.2. Webpage with no authors

Title [Internet]. Place of publication (if available): Publisher's name (if available); Publication date or year [updated date (if available); cited date]. Available from: URL

Example:

Dentistry and ADHD [Internet]. 2019 Jan 15 [updated 2019 Jan 15; cited 2020 Apr 8]. Available from: <https://snoozeden-tistry.net/blog/dentistry-and-adhd/>

4.3. Image on a webpage

Author/organization. Title [image on the Internet]. Place of publication: Publisher's name; Publication date or year [updated date; cited date]. Available from: URL

Note: If the image does not have a title - give the image a meaningful title in square brackets.

Example:

Poticny DJ. An Implant-Supported Denture Offers a Number of Advantages [image on the Internet]. Texas: Office of Dan Poticny; 2018 Nov 21 [updated 2018 Nov 21; cited 2019 Aug 30]. Available from: <https://www.dfwsimiledoc.com/blog/post/an-implant-supported-denture-offers-a-number-of-advantages.html>

5. *Government publications/reports*

5.1. Reports and other government publications

Author(s). Title of report. Place of publication: Publisher; Date of publication – year month (if applicable). Total number of pages (if applicable eg. 24 p.) Report No.: (if applicable)

Example:

Australian Institute of Health and Welfare. Oral health and dental care in Australia: key facts and figures trends 2014. Canberra: AIWH; 2014.

5.2. Government reports available online

Author(s). Title of report. Report No.: (if applicable). [Internet]. Place of publication: Publisher or Institution; Publication date or year [updated date - year month day; cited date - year month day]. Available from: URL

Example:

World Health Organization. WHO mortality database [Internet]. Geneva: World Health Organization; 2019 Dec 31 [updated 2019 Dec 31; cited 2021 Mar 29]. Available from: <https://www.who.int/data/mortality/country-profile>

6. *Tables/Figures/Appendices*

Follow the format of book, journal or website in which you found the table/figure/appendix followed by: table/figure/image/appendix number of original source, Title of table/figure/appendix from original source; p. Page number of table/figure/appendix from original source.

Note: each reference to a different table/figure within the same document requires a separate entry in the Reference list. Please provide permission documents from the original sources.

Example:

Smith J, Lipsitch M, Almond JW. Vaccine production, distribution, access, and uptake. Lancet 2011;378(9789):428-438. Table 1, Examples of vaccine classes and associated industrial challenges; p. 429.

7. *Journal abbreviation source*

Journal names should be abbreviated according to the Web of Science - Journal Title Abbreviations.

Peer-review Process

Oral Sciences Reports follows a double anonymized review process. Each manuscript will be assigned to at least three expertises for consideration. The identities of both reviewers and authors are concealed from each other throughout the review to limit reviewer bias. To facilitate this, please ensure that the manuscript keeps anonymity before submission such as affiliation, author's gender, country or city of origin, academic status, or previous publication history. Our peer review process is confidential and identities of reviewers are not released. Letters and technical comments are sent to the authors of the manuscript on which they comment for response or refutation, but otherwise are treated in the same way as other contributions with respect to confidentiality.

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Our online submission system guides you stepwise through the process of entering your article details and uploading your files. Please follow the submission process carefully. The system converts your article files to a single PDF file used in the peer-review process. Editable Microsoft word processing files are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent to your registered e-mail.

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Timing of Orthodontic Tooth Movement After Alveolar Bone Grafting in Patients with Alveolar Cleft: A Review Article

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Abstract

Alveolar bone grafting (ABG) is a cornerstone of the multidisciplinary management of cleft lip and palate (CLP), restoring alveolar continuity and enabling dental rehabilitation. Orthodontic tooth movement (OTM) into grafted sites promotes functional loading, enhances graft stability, and facilitates the eruption of cleft-adjacent teeth. However, the optimal timing for initiating OTM post-ABG remains a subject of clinical debate. While traditional approaches recommend longer healing periods, the earlier initiation of OTM is possible with individual assessment based on radiographic evidence of bone bridge formation and clinical consideration. This review synthesizes current evidence on graft biology, healing phases, orthodontic biomechanics, and timing strategies. It aims to guide clinicians in optimizing treatment protocols for improved outcomes in cleft rehabilitation.

Keywords: alveolar bone grafting, cleft lip and palate, functional loading, graft healing, orthodontic tooth movement

Introduction

Cleft lip and palate (CLP) affects approximately 1 in 700 live births globally^(1,2), with alveolar clefts present in up to 75% of cases.⁽³⁾ These defects disrupt maxillary continuity, impair tooth eruption, and compromise oral function and esthetics.⁽³⁾

Alveolar bone grafting (ABG) is a standard surgical intervention to repair the alveolar clefts and any associated oronasal fistula.⁽⁴⁾ The procedure's timing is critical and depends on the eruption of the adjacent permanent teeth, typically between 8 and 12 years of age.⁽⁴⁻¹²⁾ The timing is based on individual needs and clinical considerations, focusing on restoring structural integrity and supporting skeletal and dental development.^(8,10,13-15) This procedure also plays an important role in facilitating normal facial growth, enhancing dental rehabilitation, and promoting better oral hygiene.^(5,8,11,13) ABG was first reported by Boyne and Sand, who used the principle of autogenous marrow and cancellous bone grafting for the treatment of osseous clefts of the alveolar ridge and the anterior portion of the hard palate.⁽⁵⁾ The use of autogenous bone, commonly harvested from the anterior iliac crest, is widely acknowledged as the gold standard for its osteogenic, osteoinductive, and osteoconductive properties.^(5,8,11,16,17) The cancellous bone and marrow graft from this donor site has abundant cellular content and robust osteogenic potential, which enables predictable bone formation and incorporation for reconstructing bony defects associated with alveolar clefts.^(5,13,16,18)

Orthodontic treatment plays a vital role in aligning cleft-adjacent teeth, expanding the maxillary arch, and guiding eruption.⁽¹⁹⁾ Tooth movement into grafted bone stimulates osteogenesis and contributes to long-term graft stability.^(18,20-22) Despite its importance, the ideal timing for initiating orthodontic forces post-ABG remains controversial.⁽¹⁰⁾ This review explores biological principles, healing dynamics, and clinical timing strategies to inform evidence-based practice.

Materials and Methods

A literature review was performed by searching the PubMed, Scopus, and Embase databases to identify relevant and current information on the timing of orthodontic tooth movement (OTM) following ABG. The search included studies published in English from 1972, when alveolar bone grafting was first reported,

through 2025. The search strategy utilized keywords included “Cleft lip and palate”, “Alveolar bone graft”, “Orthodontic tooth movement and “Tooth movement timing”. Additional literatures were gathered via Google Scholar and manual searches. Study selection was defined by specific criteria. Inclusion was limited to human or animal studies involving tooth movement into cleft sites or alveolar bone defects, while exclusion criteria were applied to studies involving periodontal disease or those lacking follow-up. From the gathered results, The most significant article and supporting selected studies were included in the references.

Biological principles of bone grafting

Graft selection and properties

Autogenous cancellous bone is often harvested from the iliac crest and is the gold standard for ABG due to its:

Osteogenesis: Living osteoblast precursors contained within the graft promote new bone formation. These osteogenic cells, primarily osteoblast precursors, are found in bone, bone marrow, and the periosteum. Under appropriate host conditions, they can differentiate into mature osteoblasts and contribute to the formation of new bone.^(17,23)

Osteoconduction: The ability of the graft to serve as a structural scaffold for the ingrowth of new blood vessels, osteoblasts, and stem cells from the host tissue.⁽²³⁾ This framework is vital for the eventual integration of the graft with the host bone. Inadequate cellular and vascular ingrowth may compromise graft incorporation and mechanical stability.⁽¹⁷⁾

Osteoinduction: The process by which the graft recruits undifferentiated stem cells from the surrounding host tissue. These recruited cells are then signaled to differentiate into new osteoblasts.⁽²³⁾ This process is associated with specific bone growth factors, such as bone morphogenetic proteins (BMPs) and platelet-derived growth factors, which regulate cell differentiation and proliferation.^(17,23)

Healing phases

Graft incorporation proceeds through three overlapping stages⁽²³⁾:

Stage 1: Inflammation (0-4 weeks). In this phase, a cascade of inflammatory and reparative events occurs, including vascular invasion, osteoclast activation, and recruitment of mesenchymal stem cells (MSCs).⁽¹⁷⁾

Coagulated blood fills the graft bed, limiting blood loss, while vascular buds from the host tissue infiltrate the graft within the first day.⁽²⁴⁾ The inflammatory response is mainly composed of lymphocytes, plasma cells, mononuclear cells, and osteoclasts.^(23,25) Revascularization begins as early as 48 hours and rapidly progresses, repopulating marrow spaces with MSCs.⁽²⁴⁾ Surgical trauma and hypoxic conditions within the graft induce osteocytic autolysis, with necrosis marked by empty lacunae, while necrotic graft marrow is removed by macrophages.^(24,25) Despite ischemic injury, some osteogenic cells within the graft survive through diffusion of nutrients from surrounding soft tissues.⁽²⁴⁾ The associated metabolic byproducts, low oxygen tension, and reduced pH act as chemoattractants that recruit host-derived MSCs. Under the influence of osteoinductive factors, these MSCs differentiate into osteoblasts and contribute to the formation of new bone along necrotic trabeculae.⁽²⁵⁾ During the first 2 weeks, fibrous granulation tissue becomes predominant at the site, accompanied by increased osteoclastic activity while the number of inflammatory cells decreases.⁽²⁴⁾ The neovascularization may already be complete approximately 3 weeks post-grafting, with new bone deposited along trabecular surfaces, thereby increasing bone mass.⁽²⁶⁾ By the end of this phase, active bone resorption and new bone formation are established throughout the interior of the graft.⁽²⁵⁾

Stage 2: Repair (4-12 weeks). This stage is characterized by woven bone formation, osteoid deposition, and marrow repopulation. During this period, the woven bone forms around necrotic trabeculae and resorption of devitalized tissue begins. Histologically, osteoblasts line the dead bone cores and deposit osteoid around them, while osteoclasts resorb the necrotic parts.⁽²⁴⁾ Concurrently, new capillary ingrowth and hematopoietic marrow repopulation occur.^(23,25) There are two types of woven bone histologically. The dark and well-defined margin type of woven bone appears to rapidly remodel into mature bone, while another type, indistinct demarcation, may complete this process after 4 weeks; however, they serve the same function.⁽²⁶⁾ Autogenous graft remains clearly visible up to 4 weeks postoperatively but appear less distinct by 8 weeks, consistent with active remodeling and replacement by new bone.⁽²⁷⁾ By 8 weeks, cleft areas appear solid and histologically composed predominantly of viable bone,

while bone remodeling activity diminishes as osteoblasts and osteoclasts become less evident.⁽²⁰⁾

Stage 3: Remodeling (12+ weeks). The remodeling stage is characterized by replacement with mature lamellar bone and cortical consolidation. By approximately 6 months, substantial replacement of the cancellous autograft with host bone is achieved, and by 12 months, complete remodeling and cortical consolidation are complete.⁽²⁸⁾ This process restores skeletal strength and results in structural integration of the graft with the host skeleton.

The total resorption of the graft, accompanied by its replacement with living bone, is termed “creeping substitution,” and this process is most pronounced at the graft–host interface.⁽²⁵⁾

Autografts, both cancellous and cortical, undergo a similar process in the early stages of healing and incorporation.^(24,25) However, histologically, there are three notable differences. Cancellous autografts are revascularized more rapidly and completely, undergo creeping substitution, and generally achieve full repair over time.⁽²⁴⁾ In contrast, cortical autografts experience slower revascularization because of their dense, low porosity structure, which delays vascular ingrowth through Volkmann’s and Haversian canals until osteoclastic resorption has created pathways.^(8,24,26) Incorporation in cortical grafts begins with osteoclastic activity rather than osteoblastic deposition, and widespread resorption continues for several months⁽²⁶⁾, leading to transient mechanical weakness. Thus, cancellous grafts typically demonstrate greater strengthening compared to cortical grafts.^(23,24) Although new bone formation is detectable around the first several weeks, cortical grafts often remain a mixture of viable and necrotic bone for an extended period, with up to 40% of the original necrotic tissue persisting after 1 year.^(17,24)

Radiographic changes mirror histological progression, with increased radiodensity early due to osteoid deposition and a gradual decrease over months as resorption and remodeling progress.^(24,25,27) By 3 months, the margins between the graft and host bone gradually become indistinct as incorporation progresses.⁽²⁹⁾ At this time, the radiographic appearance shows little difference compared with findings at 6 months or 1 year.^(25,30) Moreover, autogenous cancellous bone grafting does not interfere with the development of teeth adjacent to the cleft.^(7,31)

Orthodontic tooth movement and graft interaction

Orthodontic treatment for patients with CLP aims to align teeth adjacent to the cleft site, reconstruct the collapsed alveolar arch by arch expansion, facilitate the eruption of permanent teeth, establish the proper space for dental replacement, and stabilize the maxillary segment.^(8,22,32)

Biological effects of orthodontic tooth movement

Orthodontic forces stimulate bone remodeling via two pathways. The first is the receptor activator of nuclear factor kappa-B (RANK) and receptor activator of nuclear factor kappa-B ligand (RANKL) pathway. RANKL, a membrane adhesion protein produced by osteoblasts and bone marrow stromal cells, binds to RANK receptors on osteoclast precursor cells or mature osteoclast membranes. This ligand–receptor interaction promotes osteoclast differentiation and maturation, while also suppressing apoptosis.^(33,34) Mechanical stress enhances RANKL expression via osteocytes, amplifying osteoclast-mediated resorption and strengthening the remodeling response.^(20,35) The second pathway involves Runt-related transcription factor 2 (RUNX2) expression. RUNX2, a member of the Runt-related transcription factor family, serves as a critical regulator of osteoblast differentiation, chondrocyte maturation, and bone matrix production.^(20,36) Increased RUNX2 expression during the late remodeling phase promotes osteogenesis and integration of the graft with the host bone.⁽²⁰⁾

Clinical goals

With a combined surgical–orthodontic approach, including alveolar bone grafting, cleft-adjacent teeth can erupt or be orthodontically guided into the grafted area, thereby improving tooth positioning and reducing the need for prosthodontic intervention.^(8,22,32)

Tooth eruption through the graft stimulates physiological osteogenesis⁽⁸⁾, while functional loading controlled by orthodontic forces can stimulate bone turnover, prevent graft resorption, provide root support, shape the dentoalveolar arch, and enhance the long-term stability of the alveolar support.^(6-8,10,18,21-23,27,37-39) Conversely, a lack of stress on the grafted bone may result in suboptimal volume maintenance and weaker support for adjacent teeth.^(22,23) Indistinct graft margins and cortical continuity indicate successful integration.^(29,40)

Orthodontic loading after grafting not only supports bone reconstruction and prevents postoperative bone

resorption but also facilitates proper teeth alignment, normal root development, and eruption of adjacent teeth, particularly the canines near the cleft site.^(6,7,19,21,38)

Timing strategies for orthodontic intervention

Traditional approach

Historically, orthodontic tooth movement (OTM) began 6 months post-ABG to allow for graft stabilization.^(41,42) However, this delay may lead to unnecessary resorption and reduced graft volume.^(39,43) Bone graft density was reported to markedly decrease at 1 month following grafting, followed by a gradual decline until stabilization was observed at 6 months postoperatively.⁽⁴¹⁾ Some studies resumed OTM once the cleft-adjacent tooth can be bonded, following either spontaneous eruption or surgical exposure.^(4,8,44)

Early intervention (3–6 months)

Some studies support initiating OTM as early as 3 months postoperatively, once the grafted bone has achieved initial osseointegration.^(4,10,45) Initiating tooth movement at approximately 3 months may not only facilitate closure of the gap in the maxillary arch but also provides functional stress that stimulates bone remodeling and prevents graft resorption.^(10,43,46)

Radiographically, little difference is observed in bone bridging between the 3-month follow-up and later follow-ups at 6 or 12 months, indicating that much of the remodeling occurs within the first 3 months.^(30,46) The residual cortical bone at the previous cleft site typically decreases during this period, reflecting the active turnover of transplanted bone; however, satisfactory outcomes can still be expected.⁽⁴⁰⁾

Long-term follow-up demonstrates that graft volume decreases significantly between 3 months and 1 year, despite maintenance of adequate bone bridging.⁽³⁹⁾ Therefore, to preserve graft stability, it is recommended that the site be placed under physiological stress through the eruption of adjacent teeth, orthodontic tooth movement, or dental implant placement once adequate bone formation is confirmed. This functional loading appears essential to minimizing progressive resorption and supporting long-term stability of the graft.^(39,46) However, some studies have reported significant graft resorption by 3 months, raising the question of whether earlier orthodontic intervention could reduce this loss.^(10,40)

Ultra-early loading (2-8 weeks)

Early initiation of OTM after alveolar bone grafting has been shown to promote favorable outcomes. It has been suggested that orthodontic intervention can begin as early as 2-3 weeks post-surgery, ideally with appliances already in place at the time of grafting to allow active movement soon after the surgical phase.^(9,27) Other reports recommend initiating treatment at around 4-6 weeks, when woven bone formation is already established, providing adequate stability for functional loading.^(14,47,48,49) Orthodontic treatment at this stage shows that satisfactory outcomes can be achieved when the marginal bone level is more than 50%-75% of the root length and the shortest vertical bone bridge length is ≥ 6.5 mm.⁽¹⁴⁾ By 6-8 weeks, the grafted bone typically shows more mature lamellar organization and stable vascular networks, supporting effective tooth movement.^(11,18,20,26)

Risks and considerations

External apical root resorption is a complication in orthodontic treatment for patients with clefts, particularly those with complete bilateral clefts, with the central incisors being the most affected.^(4,44) This risk may be related to the limited trabecular bone in the premaxilla, where tooth movement can cause root apices to press against the dense cortical layer.⁽⁴⁴⁾

Orthodontic tooth movement plays an important role in achieving satisfactory outcomes following alveolar bone grafting. Other factors, such as patient age, gender, type of cleft, surgical technique, the eruptive stage of the permanent canines, and oral hygiene, may also influence the success of the procedure.^(30,40,41,50)

Two-dimensional (2D) radiographs are routinely taken for orthodontic procedures and are often readily available^(12,39,51-53), and so they are the standard method for re-evaluating bone after ABG.⁽⁵⁴⁾ Although 2D radiographs involve less radiation exposure, they have several limitations, including image distortion, overlapping anatomical structures, and magnification errors.^(14,29,53,55) Moreover, 2D radiographs cannot represent the bone graft from all perspectives and may lead to an overestimation of the outcomes of secondary ABG.^(29,54,56-58)

To overcome these limitations, three-dimensional (3D) radiographs have been introduced for assessing alveolar bone grafting. This method provides accurate and reliable 3D information on the cleft defect and alveolar bone architecture, allowing evaluation of the cleft and

bone graft dimensions and assessment of the bone support for permanent teeth adjacent to the cleft.^(39,57) Studies have shown that 3D radiography is more efficient than 2D radiography for these purposes.^(53-55,58)

Clinical recommendations

Based on current evidence, early functional loading of the graft, achieved through spontaneous eruption or orthodontic movement of cleft-adjacent teeth, may promote graft stability by maintaining bone volume and reducing resorption.⁽⁴⁷⁾ Conversely, delaying treatment may lead to retard anteroposterior growth, which tends to produce premaxilla relapse, canine impaction, and lingual collapse of the incisors.^(43,59)

The optimal timing of tooth movement depends on the degree of graft remodeling and integration, as initiating too early may compromise root health.⁽¹⁸⁾ Some studies suggest that the timing of cleft-adjacent tooth movement after grafting is not directly associated with increased risk of external apical root resorption.⁽⁴⁶⁾

Following the healing phase, the woven bone starts to form within the first few weeks, transitions to lamellar bone from 4 weeks, and then undergoes remodeling through osteoclastic resorption and osteoblastic deposition.^(26,48) Importantly, cancellous autografts are incorporated by forming new bone on a necrotic scaffold, which initially strengthens the graft. As the necrotic bone gradually resorbs and is replaced, the mechanical strength of the graft-host junction is restored.^(24,25) Thus, applying orthodontic forces during the woven bone phase may be advantageous, as trabecular bone provides sufficient flexibility for controlled movement, while avoiding the higher resistance of fully mineralized bone.⁽⁴⁸⁾

Studies support that active OTM can begin between 1 and 3 months post-ABG, once radiographic evidence confirms adequate bone support before initiating OTM. Early initiation of OTM has been associated with more predictable tooth movement, improved periodontal support, and reduced graft resorption.^(9,11,14,18,37,39,47,48) Delays beyond 6 months should be avoided to ensure adequate graft stimulation and minimize the risk of graft resorption.^(43,59) The timing of OTM should be individualized, taking into account the patient's healing rate, cleft morphology, and specific orthodontic objectives. Throughout treatment, careful monitoring of root health and bone support is essential.^(19,46)

Table 1: Summary of studies on the timing of orthodontic tooth movement after alveolar bone grafting.

Author (Year)	Type of study	Type of sample	Sample size	Timing of tooth movement after ABG	Type of graft	Assessment method	Key findings
Yang <i>et al.</i> (2019) ⁽¹⁰⁾	Prospective	Human	20	3 months	Cancellous bone from anterior iliac crest	Periapical	Cleft-adjacent teeth could be bodily moved into the grafted bone with adequate alveolar bone support.
Datana <i>et al.</i> (2019) ⁽³⁰⁾	Prospective	Human	30	3 months	Particulate cancellous bone and marrow from anterior iliac crest	CBCT	Resorption of graft volume was determined after 3 months of grafting and related to the success of orthodontic treatment.
Maeda-lino <i>et al.</i> (2017) ⁽⁴⁶⁾	Retrospective	Human	30	3 months	Autogenous bone	Occlusal radiograph	Initiating orthodontic treatment within 3 months after alveolar bone graft minimizes resorption of the grafted bone.
de Ruiter <i>et al.</i> (2010) ⁽⁴⁵⁾	Retrospective	Human	75	12 weeks	Mandibular symphysis	Clinical visual assessment	The outcomes of postoperative orthodontic treatment showed excellent results.
Ahn <i>et al.</i> (2014) ⁽⁴⁸⁾	Prospective	Dogs	12	Immediately, 2 weeks and 12 weeks	Deproteinized bovine bone mineral and demineralized bone matrix	Micro-CT, histologic examination	Bone graft facilitates immediate orthodontic loading to promote OTM with favorable periodontal healing, concurrently lowering the risk of limited OTM in case of delayed postoperative force application.
Sun <i>et al.</i> (2018) ⁽²⁰⁾	Prospective	Rats	39	8 weeks	Cancellous bone from anterior iliac crest	Histological examination	OTM into the grafted area promoted bone remodeling, leading to bone resorption and followed by new bone deposition.
Ma <i>et al.</i> (2021) ⁽⁴⁹⁾	Prospective	Dogs	6	Immediately, 4 weeks and 8 weeks	Deproteinized bovine bone mineral	Histological examination, micro-CT	Orthodontic loading initiated at 4 weeks post-augmentation provided the most effective functional stimulation for alveolar bone graft.
Schultze-Mosgau <i>et al.</i> (2003) ⁽⁴⁷⁾	Retrospective	Human	68	4-6 weeks	Cancellous bone from anterior iliac crest	Panoramic radiograph	Gap closure provide more favorable results compared with gap opening.
Seike <i>et al.</i> (2012) ⁽¹⁴⁾	Retrospective	Human	49	1 month	Cancellous bone from anterior iliac crest	CT	Successful orthodontic outcomes were associated with a marginal bone level of ≥ 3 , the shortest vertical length of ≥ 6.5 mm, and the shortest anteroposterior bone width of ≥ 5 mm.
Hossain <i>et al.</i> (1996) ⁽²⁷⁾	Prospective	Dogs	9	2-4 weeks	Particulate cancellous bone and marrow from anterior iliac crest and beta-tricalcium phosphate	Histological and radiographic examination	By 4 weeks following graft placement, bone formation had occurred along the surface of the grafted material.
Turvey <i>et al.</i> (1984) ⁽⁹⁾	Retrospective	Human	33	2-3 weeks	Cancellous bone from anterior iliac crest	Periapical and panoramic radiograph	Tooth movement initiated within several weeks following ABG tended to exhibit more predictable outcomes.

Abbreviation: ABG: Alveolar bone grafting, CBCT: Cone beam computed tomography, CT: Computed tomography, OTM: Orthodontic tooth movement

A 3D radiograph should be considered before the initiation of OTM as it provides accurate and reliable information for the position and bone support of the developing cleft-adjacent tooth following ABG.^(39,57)

However, the strength of these clinical recommendations is limited by the current level of evidence available. The literature is characterized by a predominance of retrospective studies and animal models, which may not fully replicate human cleft biology. Furthermore, existing research often features small sample sizes and significant heterogeneity in graft materials and imaging methods. These limitations highlight the need for standardized, high-level prospective trials to definitively establish optimal OTM timing protocols.

Conclusions

Orthodontic tooth movement into grafted alveolar bone is a critical component of cleft rehabilitation. Based on graft healing and clinical evidence, active OTM can begin between 1-3 months post-ABG and should not be delayed beyond 6 months, as early functional loading enhances graft stability and dental outcomes. However, optimal timing is not universal, it may vary depending on patient-specific factors such as age, cleft morphology, graft type, and individual healing response. Therefore, 3D radiographic monitoring is essential to confirm bone support before initiating forces. While a personalized, interdisciplinary approach remains essential for optimizing care, it must be noted that high-level clinical evidence supporting these specific timelines remains limited.

Conflict of Interest

The authors declare no conflict of interest.

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Utilizing Laser Technology for Debonding of Orthodontic Ceramic Brackets: A Literature Review

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Abstract

Ceramic brackets have become increasingly popular and are now widely used in orthodontic treatment because of their less noticeable and aesthetically pleasing appearance. However, conventional debonding of ceramic brackets can result in enamel cracks, bracket breakage and discomfort to patients from shear and torsional forces. Laser-assisted debonding of ceramic brackets had been evidenced in several studies to search for the laser irradiation for bracket debonding which could reduce shear bond strength and debonding time without a significant increase in intra-pulpal temperature, bonding failure, or enamel damage. Consequently, laser-assisted debonding emerges as an efficient technique, reducing patient discomfort while maintaining safety by minimizing enamel surface impact and intra-pulpal temperature elevation. This review article aimed to compile and consider the types of lasers used in ceramic bracket debonding, including diode laser, Nd:YAG laser, Er,Cr:YSGG laser, Er:YAG laser, and CO₂ laser, along with their specific settings and various testing conditions. Additionally, the variables investigated, including adhesive remnant index, shear bond strength, intra-pulpal temperature, and enamel damage were described.

Keywords: ceramic bracket, debonding, laser in dentistry, orthodontic bracket

Introduction

Fixed orthodontic treatment using less visible material has seen a surge in demand across all age groups, which has driven the worldwide use of ceramic brackets because of their less noticeable and aesthetically pleasing appearance.⁽¹⁾ Ceramic brackets are composed of aluminum oxide, which offers an attractive visibility alternative to metallic brackets.⁽²⁾ However, they exhibit higher bond strength and lower fracture toughness, making them more prone to fracture compared to their metallic counterpart.⁽³⁾ Ceramic brackets could be classified into two types; polycrystalline alumina and single-crystal (monocrystalline) alumina, which are derived from variances in the fabrication processes employed in their manufacture.⁽¹⁾

In the midst of more attractiveness of ceramic brackets, the consideration of debonding procedure has to be mentioned. Conventional debonding of ceramic brackets typically used bracket-removing pliers, which apply shear and torsional forces, pose risks such as enamel cracks, bracket breakage and patient discomfort.⁽⁴⁾ Despite numerous attempts, no mechanical debonding method has been discovered that can remove brackets without causing any damage to the enamel surface or breakage of brackets.⁽⁵⁾ Consequently, alternative approaches for debonding have been explored, with laser-assisted techniques emerging as a promising option. The term “LASER” is an abbreviation for “Light Amplification by Stimulated Emission of Radiation”.⁽⁶⁾ Since the introduction of the Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) and Carbon Dioxide (CO₂) lasers in 1964, researchers have explored the application of laser technology in dentistry. This included the debonding of orthodontic brackets using laser. While early attempts with the ruby laser were limited due to its high energy requirement and risk of collateral damage, the Nd:YAG laser gained traction for dental applications. Subsequent advancements led to the approval of Erbium and diode lasers for dental procedures, thereby expanding the array of available laser technologies.⁽⁷⁾ The use of laser technology in bracket debonding offers several potential advantages, including reduced force application and softening of adhesive resin materials.⁽⁸⁾ However, concerns exist regarding heat diffusion to tooth structures, which could lead to intra-pulpal damage.⁽⁹⁾ Given that an increase in pulpal temperature of 5.5°C can trigger pulpal

necrosis, careful attention to safety measures is imperative when employing lasers for debonding.⁽¹⁰⁾

This article undertook a comprehensive review of the literature concerning the use of lasers in facilitating the debonding of ceramic brackets. Our focus was on examining key factors such as shear bond strength, intra-pulpal temperature, and enamel damage, taking into account variables such as bracket type, adhesive resin systems, laser types, lasing parameters, duration of lasing, and the time interval between lasing and debonding. Through this analysis, we sought to enhance understanding and inform decision-making in the utilization of laser-assisted debonding techniques.

The effects of laser-assisted debonding on shear bond strength

The effects of laser irradiation on orthodontic bracket removal have been the subject of extensive investigation in orthodontic research, primarily concerning its influence on shear bond strength (SBS), which refers to the maximum stress that a material can withstand before failure under shear loading.⁽¹¹⁾ Among these studies, various variables, including adhesive bonding systems, bracket types and laser parameter settings, were selected to demonstrate the efficacy of laser-assisted debonding (Table 1).

Currently, the bonding of dental substrates relies on three primary strategies: 1. etch-and-rinse, 2. self-etch and 3. the resin-modified glass-ionomer approach, which is recognized for its unique property of self-adherence to tooth tissue.⁽¹²⁾ Interestingly, Saito *et al.*, introduced a novel approach to debond a ceramic bracket by adding 30 and 40 wt% thermal expansion microcapsules to orthodontic adhesive in conjunction with using a CO₂ laser. The findings indicated a significant decrease in SBS after 5 and 6 seconds of irradiation, to approximately 0.40-0.48 times the strength observed without laser irradiation. As laser-assisted debonding appears to be beneficial in assisting bracket removal.⁽¹³⁾ Hayagawa *et al.*,⁽¹⁴⁾ revealed that different types of adhesive, including 4-META/MMA-based adhesive containing no fillers and a Bis-GMA-based photoactivated type containing fillers, yielded no significant effect on the reduction of SBS following Nd:YAG laser-assisted debonding. Similarly, Iijima *et al.*,⁽¹⁵⁾ consistently demonstrated that etch-and-rinse adhesive and self-etch adhesive also had no significant effect on the SBS of

debonding a ceramic bracket after irradiation with a CO₂ laser. Different adhesive types yield no significant effect on the reduction of SBS following laser-assisted debonding. Incorporating microcapsules into adhesive materials, effectively enhancing the debonding process for ceramic brackets. Despite advancements, both conventional and laser methods have shown to decrease SBS, with laser treatment exhibiting a greater efficacy in reducing SBS.⁽¹³⁾

Orthodontic bracket types used in laser-assisted debonding process apparently were related to a significant decrease in SBS outcomes after laser irradiation, particularly ceramic bracket. Investigations by Han *et al.*, revealed that ceramic bracket, which exhibited a higher SBS compared with metallic bracket in the experiment, demonstrated a significant decrease in SBS after Nd:YAG laser irradiation.⁽²⁾ Ceramic brackets primarily derive from aluminum oxide, existing in both polycrystalline and monocrystalline forms. Generally, the prevailing method for fabricating polycrystalline brackets is through ceramic injection molding, which entails amalgamating the aluminum oxide (Al₂O₃) particles with a binder, and subsequent injection into a bracket mold, facilitating their fluidity through the application of heat and pressure. Post-injection, the removal of the binder, or burnout, precedes sintering, a technique whereby a coherent mass forms through heating without melting. Conversely, the fabrication process for monocrystalline ceramic brackets, colloquially termed sapphire brackets, diverges significantly. The Al₂O₃ particles are melted, followed by a gradual cooling process conducive to controlled crystallization. This meticulous procedure results in the formation of a substantial, singular crystal, typically in rod or bar configurations. Consequently, the material undergoes shaping into brackets via precision techniques such as ultrasonic cutting or diamond cutting tools. Post-milling, the monocrystalline bracket undergoes a heat treatment regimen aimed at rectifying surface imperfections and mitigating stress induced by milling processes.⁽¹⁶⁾ Feldon *et al.*,⁽¹⁷⁾ stated that the application of the diode laser, both the 3 Watts and the 5 Watts per square centimeter laser protocols, proved highly effective in substantially reducing the force needed for debonding when using monocrystalline brackets compared to conventional debonding techniques. Similarly, Hayakawa *et al.*,⁽¹⁴⁾ found that using a 2 J power setting of Nd:YAG laser was more effective in reducing SBS in monocrystalline brackets compared to polycrystalline.

The notable distinctions observed between the monocrystalline and polycrystalline groups hinge on the bracket crystal's structure. Monocrystalline brackets feature a uniform crystal arrangement that enhances transmissibility, thereby minimizing laser energy loss. Consequently, the laser proves more effective on monocrystalline brackets compared to their polycrystalline counterparts.⁽¹⁴⁾ Furthermore, the retention system of brackets plays a crucial role, as highlighted by Matos *et al.*, who reported a significant decrease in bond strength in chemically retained brackets compared to mechanically retained ones.⁽¹⁸⁾ Therefore, bracket selection can significantly impact SBS during laser-assisted debonding procedures, particularly noteworthy with monocrystalline ceramic brackets due to their specific properties regarding laser transmission, and with chemically retained brackets due to the retention mechanism of the bracket system.

Beyond bracket selection, the influence of laser settings on SBS in laser-assisted debonding techniques has been recognized as a significant factor. Numerous studies have explored the effect of different energy levels of laser settings across various laser types on SBS. For instance, Hayakawa *et al.*, demonstrated a significant decrease in SBS when debonding ceramic brackets with a Nd:YAG laser at 2.0 and 3.0 J. However, exposure to 1.0 J of laser energy showed no significant decrease compared to non-lasing, likely due to inadequate energy levels.⁽¹⁴⁾ In a separate study, Nalbantgil *et al.*,⁽¹⁹⁾ also investigated the effect of Erbium-doped Yttrium Aluminum Garnet (Er:YAG) laser with different energy levels on debonding and concluded that all lasing groups significantly decreased SBS, particularly at power levels of 4W and 6W.⁽¹⁹⁾ Furthermore, Macri *et al.*, in an investigation of CO₂ laser settings, found that lasing for 3 seconds at 5 W with a pulse duration of 0.01 s resulted in the lowest SBS.⁽²⁰⁾ Meanwhile, Hoteit *et al.*,⁽²¹⁾ studied Er,Cr:YSGG and Er:YAG with different laser settings and found that Er,Cr:YSGG significantly reduced SBS across all settings, while Er:YAG showed no significant reduction, especially at power levels of 4W and 6W.

In addition to different energy levels of laser settings, factors such as lasing duration, time lag, and water-cooling play significant roles in affecting SBS. Studies by Nalbantgil *et al.*,⁽²²⁾ demonstrated that prolonged exposure time correlated with a greater decrease in SBS. Specifically, a 9-second lasing duration significantly reduced SBS

compared to a 3-second lasing duration. Following this, in 2011, Tozlu *et al.*,⁽²³⁾ demonstrated that an increase in time lag resulted in higher SBS. Furthermore, water-cooling during laser-assisted debonding has been shown to enhance SBS compared to procedures without cooling mechanisms, as indicated by Nalbantgil *et al.*⁽²⁴⁾ Recent advancements have expanded the scope of debonding techniques, with Khalil *et al.*'s comparative study of five methods demonstrating the efficacy of lasers in reducing SBS compared to conventional techniques.⁽²⁵⁾ In light of these findings, laser-assisted debonding techniques have shown promise in reducing SBS effectively. However, optimal parameters must be carefully considered to ensure both efficacy and safety in orthodontic practice.

The effects of laser-assisted debonding on intra-pulpal temperature

One of the primary concerns associated with using lasers for debonding ceramic brackets is the potential thermal impact in the pulp tissue due to laser irradiation. According to Zach and Cohen, an increase of 1.8°C in intra-pulpal temperature can result in minimal pulp damage, which is reversible within three months. Conversely, a temperature rise of 5.5°C raises the risk of pulp necrosis by 15%. Moreover, an increase of 11°C in temperature can substantially heighten the risk of pulp necrosis by as much as 60%.⁽²⁶⁾ Several research studies had shown that using different types of laser or laser settings was safe as long as the temperature increase remained below the threshold of 5.5°C (Table 2). Yassaei *et al.*,⁽²⁷⁾ reported that among different laser modes and energy levels, the 3 W group showed the highest temperature compared to other energy levels. Additionally, continuous wave mode resulted in a higher temperature than pulse mode. In 2010, Feldon *et al.*, compared different energy levels of a diode laser and different types of ceramic brackets. The results showed that the temperature increase did not exceed the threshold of 5.5°C significantly in all groups, except for the group that used an energy level of 5 W for debonding monocrySTALLINE ceramic brackets. In this group, the temperature increase was significantly greater than the standard of 1.8°C but was not significantly different from the threshold of 5.5°C.⁽¹⁷⁾

The studies conducted by Hayakawa *et al.*, Rao *et al.*, and Nalbantgil *et al.*, delved into the exploration of distinct laser settings employed for bracket debonding, utilizing

Nd:YAG, Erbium, Chromium:Yttrium Scandium Gallium Garnet (Er,Cr:YSGG), and Er:YAG lasers, respectively. Collectively, these investigations yielded congruent findings, revealing a consistent pattern of intra-pulpal temperature elevation subsequent to laser irradiation, all of which remained below the critical threshold of 5.5°C.^(14,19,28) Two studies investigated the use of CO₂ laser: Iijima *et al.*, and Macri *et al.* Iijima *et al.*,⁽¹⁵⁾ measured the intra-pulpal temperature using an infrared thermographic microscope system. After 5 seconds of lasing, the temperature of enamel cross-sections rose by approximately 200°C when exposed to 5 and 6 watts, and between 100°C and 150°C when exposed to 3 and 4 watts. After 30 seconds of lasing, all temperatures returned to the standard room level.⁽¹⁵⁾ Likewise, Macri *et al.*,⁽²⁰⁾ found that the temperature increase during lasing for 3 seconds with a pulse duration of 0.01 seconds at every energy level did not exceed the threshold of 5.5°C. These findings are consistent with those of Nalbantgil *et al.*, in 2011, who studied the duration of time using Er:YAG laser and found that an increase in duration led to a significant rise in intra-pulpal temperature in all groups.⁽²²⁾

In addition to different types of laser and laser settings, other factors including water-cooling, laser motion and types of brackets can be considered to affect intra-pulpal temperature in laser-assisted debonding. In 2014, Nalbantgil *et al.*, found that using a laser along with water cooling has the potential to decrease the intra-pulpal temperature and ensure safety for the pulp.⁽²⁴⁾ Grzech *et al.*, studied laser motion and found that scanning motion resulted in a significantly lower temperature increase compared to circular motion around ceramic brackets.⁽⁹⁾ Furthermore, they observed that scanning motion on ceramic brackets resulted in the lowest temperature increase.^(9,24) Both Grzech *et al.*,⁽⁹⁾ and Dostalova *et al.*,⁽²⁹⁾ investigated the comparison between the ceramic bracket and metallic bracket by using Er:YAG for debonding and found contradictory results. Grzech *et al.*,⁽⁹⁾ revealed that when comparing both bracket types with circular motion, ceramic brackets had higher temperatures than metal ones⁽⁹⁾, whereas Dostalova *et al.*,⁽²⁹⁾ reported the contrary result.

Hence, laser-assisted debonding of ceramic brackets is considered a safe method, as it results in an increase in intra-pulpal temperatures that increase below the critical threshold of 5.5°C. The duration of laser exposure and

the energy level applied are primary factors influencing temperature elevation. Furthermore, variables such as water cooling, bracket type, and laser motion can impact temperature fluctuations. However, current research findings do not indicate any substantial relationship between the adhesive bonding system utilized and alterations in intra-pulpal temperature.

The effects of laser-assisted debonding on enamel damage

The conventional method of debonding ceramic brackets typically involves applying sufficient force to break the bond, potentially leading to enamel damage through tearing. Concerns about enamel damage persist even with the use of lasers for ceramic bracket removal. Several studies have examined the effects of various laser types, including diode, Nd:YAG, Er,Cr:YSGG, Er:YAG, and CO₂ lasers, on enamel integrity during such procedures (Table 3).

Regarding the use of diode lasers, studies by Feldon *et al.*,⁽¹⁷⁾ Khalil *et al.*,⁽²⁵⁾ and Yassaei *et al.*,⁽²⁷⁾ found no significant difference in Adhesive Remnant Index (ARI) scores between using a diode laser for debonding and the conventional method. Most findings reported high ARI scores of 2 and 3. In contrast, Stein *et al.*, reported a significant difference in ARI scores between laser and conventional methods, predominantly observing ARI scores of 0. Additionally, they noted no discernible differences in enamel damage between lasing and conventional methods before debonding, as observed through Scanning Electron Microscopy (SEM). However, they did observe a significant number of enamel cracks when using the laser compared to the conventional method.⁽³⁾

In their investigation of Nd:YAG laser application, Han *et al.*,⁽²⁾ observed a significant decrease in ARI scores within the lasing group compared to conventional methods. Furthermore, SEM analysis revealed reduced enamel damage in the lasing group relative to the conventional technique, observed in both metallic and ceramic brackets. Similarly, Rao *et al.*,⁽²⁸⁾ reported a notable difference in ARI scores, with SEM analysis revealing the absence of enamel cracks when utilizing the Er,Cr:YSGG laser for debonding. Additionally, Hoteit *et al.*,⁽²¹⁾ found that the proportion of teeth with intact enamel topography was significantly smaller in the conventional group compared to the Er,Cr:YSGG lasing groups (4W/20 Hz and

5W/20Hz). Microcracks were only found in the 3W/20 Hz group, while statistically significant intact enamel was observed in the 4W/20 Hz and 5W/20 Hz groups, both displaying the most homogeneous topography. Furthermore, the enamel surface in the 4W/20 Hz group exhibited slightly more uniformity than in the 5W/20 Hz group.

In their investigation of Er:YAG lasers, Oztoprak *et al.*,⁽³⁰⁾ employed the laser at 4.2 W with a scanning motion for 9 seconds, revealing a significant difference in ARI scores between the lasing group, predominantly scoring 3, and the conventional method, consistent with the findings of Nalbantgil *et al.*,⁽²²⁾ Comparing time lag studied by Tozlu *et al.*,⁽²³⁾ found no significant difference in ARI scores between Er:YAG laser use and conventional methods for bracket removal. However, Nalbantgil *et al.*,⁽¹⁹⁾ examined various energy levels of the Er:YAG laser and identified significant ARI scores only at 6 W power, predominantly scoring 3. Furthermore, Dostalova *et al.*,⁽²⁹⁾ utilized SEM to examine adhesive remnants, noting a reduced presence when using the laser compared to conventional methods. Additionally, Hoteit *et al.*,⁽²¹⁾ analyzed enamel topography using SEM, reporting no significant differences between the conventional method and the use of the Er:YAG laser.

In a study conducted by Grzech *et al.*,⁽⁹⁾ Energy-Dispersive X-ray Spectroscopy (EDS) analysis, focusing on the calcium element, revealed higher percentages of calcium in all lasing groups compared to the conventional technique, suggesting enhanced enamel safety. They recommended further investigation into long-term effects, as well as hardness and Young's modulus testing. Reflecting on research from 2010, Iijima *et al.*,⁽¹⁵⁾ explored the effects of CO₂ laser-assisted debonding on hardness and Young's modulus. The results indicated a significant decrease in both parameters at a distance of 1 µm from the enamel surface across all samples, relative to other distances. Additionally, no significant differences were observed in ARI scores between lasing and conventional techniques.

In their investigation into the application of CO₂ lasers with different types of ceramic brackets, Ahrari *et al.*,⁽³¹⁾ discovered a significant difference in ARI scores between monocrystalline brackets treated with CO₂ laser and those treated with conventional methods, whereas no such difference was found with polycrystalline bracket. Conversely, Matos *et al.*, found that combining a CO₂

laser with Z250 composite resin and polycrystalline ceramic brackets resulted in the highest mean ARI score and reduced enamel damage, particularly with Fascination brackets, while the greatest damage was observed with Mystique brackets. Additionally, they examined the type of fracture after debonding, revealing that cohesive resin fractures resulted in minimal enamel damage, whereas cohesive enamel fractures caused more significant damage to the enamel surface.⁽¹⁸⁾

Therefore, laser debonding appears to be a promising alternative to conventional methods for ceramic brack-

et removal, showing potential benefits such as reduced enamel damage and improved adhesive remnant removal. However, further research is needed to fully understand the long-term effects, optimal parameters, and potential variations based on bracket type and laser settings. Nonetheless, the findings from these studies suggest that lasers can contribute to enhancing the safety and efficacy of orthodontic procedures, particularly in terms of preserving enamel integrity and minimizing post-debonding complications.

Table 1: Summary of studies investigating shear bond strength during laser-assisted ceramic bracket debonding.

Author/Year	Objective of study	Groups	Laser settings	Type of bracket/ Adhesive used	Results/Conclusions
Feldon <i>et al.</i> , 2010 ⁽¹⁷⁾	Comparative Mono-/ Poly-crystalline brackets, Laser/ No Laser	Bovine maxillary left central incisors (n=60, 5 groups) (1) No laser, Poly (2) No laser, Mono (3) Laser 2 W, Poly (4) Laser 2 W, Mono (5) Laser 5 W, Poly (6) Laser 5 W, Mono	diode WL: - P: 2 W CW T: 3 s	Ceramic (Inspire and Clarity) Transbond XT	The diode laser was ineffective with polycrystalline brackets and efficient with monocrystalline brackets in significantly decreasing the shear bond strength ($p<0.05$). Diode laser significantly decreased the force needed for removing monocrystalline brackets without causing a significant elevation in pulp temperature. However, the use of diode lasers did not result in a significant reduction in the debonding force required for polycrystalline brackets with stainless steel slots.
Hayakawa <i>et al.</i> , 2005 ⁽¹⁴⁾	Comparative different energy levels of Nd:YAG laser, Mono-/ Poly-crystalline brackets	Extract/ Intact bovine mandibular incisors (n=80, 16 groups) Monocrystalline (1) MMA, No laser (2) MMA, 1 J (3) MMA, 2 J (4) MMA, 3 J (5) Bis-GMA, No laser (6) Bis-GMA, 1 J (7) Bis-GMA, 2 J (8) Bis-GMA, 3 J Polycrystalline (9) MMA, No laser (10) MMA, 1 J (11) MMA, 2 J (12) MMA, 3 J (13) Bis-GMA, No laser (14) Bis-GMA, 1 J (15) Bis-GMA, 2 J (16) Bis-GMA, 3 J	Nd:YAG WL: 1060 nm E: 1, 2, 3 J PD: 1.2 ms 1 pulse per location	Ceramic (Inspire and Clarity) Super-Bond (4META/ MMA), Transbond (Bis-GMA)	All specimens in the 2.0 J and 3.0 J groups demonstrated a significant reduction in bonding strength compared to the non-lasing group. However, this difference was not observed in the 1.0 J group. At the 2.0 J energy level, there was a significant decrease in bond strength found in monocrystalline ceramic brackets compared to polycrystalline ceramic brackets. However, no significant differences were found among various types of adhesive resins.
Han <i>et al.</i> , 2008 ⁽²⁾	Comparative Laser/ No Laser, Metallic/ Ceramic brackets	Freshly extracted premolars (n=30, 3 groups) (1) Metallic, No laser (2) Ceramic, No laser (3) Ceramic, Laser	Nd:YAG WL: 1060 nm P: 3 W PD: 0.2 ms T: 2 s	Metallic (MBT), Ceramic (Clarity)	The lasing group significantly reduces shear bond strengths.

Oztoprak <i>et al.</i> , 2010 ⁽²⁶⁾	Comparative Laser/ No Laser	Bovine mandibular incisors (n=60, 2 groups) (1) No Laser (2) Laser	Er:YAG WL: 2940 nm P: 4.2 W PD: - T: 9 s Scanning motion	Ceramic (Transcend) Transbond XT	The lasing group significantly reduces shear bond strengths (9.52 MPa) compared to the non-lasing group (20.75 MPa).
Macri <i>et al.</i> , 2015 ⁽²⁰⁾	Comparative different laser settings	Human mandibular premolars (n=75, 5 groups) (1) Control (2) 5 W, PD=0.01, T=3 (3) 5 W, PD=0.03, T=3 (4) 8 W, PD=0.01, T=3 (5) 10 W, PD=0.01, T=3	CO ₂ WL: 10600 nm P: 5, 8, 10 W PD: 0.01, 0.03 s T: 3 s	Ceramic (Fascination) Transbond XT	Group 5 (10 W, 3 s, 0.01 s) showed the lowest shear bond strength.
Matos <i>et al.</i> , 2021 ⁽¹⁸⁾	Comparative Laser/ No Laser, different adhesive resins, different ceramic brackets	Human premolars (n=90, 6 groups) (1) TMC: Transbond+Mystique+Control (No laser) (2) TFC: Transbond+Fascination+Control (No laser) (3) TML: Transbond+Mystique+Laser (4) ZML: Z250+Mystique+Laser (5) TFL: Transbond+Fascination+Laser (6) ZFL: Z250+Fascination+Laser	CO ₂ WL: 10600 nm P: 10 W PD: 0.01 s T: 3 s	Ceramic (Mystique and Fascination) Transbond XT, Z250	Significantly lower shear bond strength was found in chemically retained Fascination brackets compared to mechanically retained Mystique brackets, as well as in all lasing groups compared to non-lasing groups. After lasing, the chemically retained Fascination brackets with Z250 showed the lowest shear bond strength.
Hoteit <i>et al.</i> , 2020 ⁽²¹⁾	Comparative between Er,Cr:YSGG and Er:YAG lasers settings	Bovine incisors (n=180, 15 groups) Er,Cr:YSGG (1) Laser 3 W/20 Hz (2) Laser 3 W/40 Hz (3) Laser 4 W/20 Hz (4) Laser 4 W/40 Hz (5) Laser 5 W/20 Hz (6) Laser 5 W/40 Hz Er:YAG (7) Laser 80 mJ/20 Hz (8) Laser 80 mJ/40 Hz (9) Laser 100 mJ/20 Hz (10) Laser 100 mJ/40 Hz (11) Laser 120 mJ/20 Hz (12) Laser 120 mJ/40 Hz (13) Laser 140 mJ/20 Hz (14) Laser 140 mJ/40 Hz (15) No laser	Er,Cr:YSGG WL: 2780 nm P: 3, 4, 5 W PD: 60 µs T: - Er:YAG WL: 2940 nm E: 80, 100, 120, 140 mJ PD: 50 µs T: -	Ceramic (Clarity)	In the lasing groups, there was a statistically significantly lower shear bond strength compared to the non-lasing groups, except in Er:YAG groups (80 mJ/20 Hz, 80 mJ/40 Hz, 100 mJ/20 Hz and 120 mJ/20 Hz).
Khalil <i>et al.</i> , 2021 ⁽²⁵⁾	Comparative effects of Chemical agent (peppermint oil), Ultrasonic, diode laser, and Er:YAG laser	Extracted human premolars (n=100, 5 groups) (1) No laser (2) Peppermint oil (3) Ultrasonic (4) diode laser (5) Er:YAG laser	diode WL: 980 nm P: 4 W CW T: 3 s on each side (Total 12 s) Er:YAG WL: 2940 nm P: 4 W PD: 100 µs T: 3 s on each side (Total 12s)	Ceramic (Perfect Clear) Transbond XT	A significantly lower shear bond strength was observed in group 3, group 4, and group 5 compared to the non-lasing group. Additionally, group 5 showed significantly lower SBS compared to group 2. However, using peppermint oil for debonding ceramic brackets had minimal impact on the shear bond strength.

Nalbantgil <i>et al.</i> , 2011 ⁽²²⁾	Comparative different time exposures to laser	Bovine mandibular incisors (n=80, 4 groups) (1) No laser (2) Laser, 3 s (3) Laser, 6 s (4) Laser, 9 s	Er:YAG WL: 2940 nm P: 4.2 W PD: - T: 3, 6, 9 s Scanning motion	Ceramic (Transcend) Transbond XT	The longer the duration of lasing, the lower the shear bond strength. This study found that a statistically significant difference exists between the groups with laser durations of 3 s and 9 s.
Tozlu <i>et al.</i> , 2011 ⁽²³⁾	Comparative different time lags	Non-carious human premolars (n=100, 5 groups) (1) No laser (2) Laser, 1 s (3) Laser, 18 s (4) Laser, 30 s (5) Laser, 60 s	Er:YAG WL: 2940 nm P: 5 W PD: - T: 6 s Scanning motion	Ceramic (Transcend) Transbond XT	The lasing group demonstrated a statistically significant decrease in shear bond strength compared to the non-lasing group ($p<0.001$). Moreover, there was a corresponding increase in shear bond strengths as the time lag between lasing and debonding increased.
Nalbantgil <i>et al.</i> , 2014 ⁽²⁴⁾	Comparative Waterless/ Water-cooling	Upper premolars (n=60, 3 groups) (1) No laser (2) Laser, Waterless (3) Laser, Water-cooling	Er:YAG WL: 2940 nm P: 5 W PD: - T: 9 s Scanning motion	Ceramic (Transcend) Transbond XT	Er:YAG laser-assisted debonding without water-cooling reduced shear bond strength in ceramic brackets compared to debonding with water-cooling.
Nalbantgil <i>et al.</i> , 2018 ⁽¹⁹⁾	Comparative different energy levels of Er:YAG laser	Bovine incisors (n=80, 4 groups) (1) No laser (2) Laser 2 W (3) Laser 4 W (4) Laser 6 W	Er:YAG WL: 2940 nm P: 2, 4, 6 W PD: 300 ms T: 6 s Scanning motion	Ceramic (Transcend) Transbond XT	Lower shear bond strengths were observed in the lasing groups compared to the non-lasing group. There was a statistically significant difference between all groups, except for the 4 W and 6 W groups.
Iijima <i>et al.</i> , 2010 ⁽¹⁵⁾	Comparative different laser settings, different adhesive bonding systems	Human premolars (n=50, 10 groups) (1) Etch & rinse, No laser (2) Etch & rinse, 3 W (3) Etch & rinse, 4 W (4) Etch & rinse, 5 W (5) Etch & rinse, 6 W (6) Self-etching, No laser (7) Self-etching, 3 W (8) Self-etching, 4 W (9) Self-etching, 5 W (10) Self-etching, 6 W	CO ₂ WL: 10600 nm P: 3, 4, 5, 6 W PD: - T: 5 s each spot	Ceramic bracket (Inspire ice) Transbond XT (Etch & rinse), Transbond Plus (Self-etching)	All lasing groups reduced shear bond strength compared to the non-lasing groups for both adhesive systems. Moreover, within the self-etching adhesive group, the 3 W showed higher shear bond strength than other laser settings.
Saito <i>et al.</i> , 2013 ⁽¹³⁾	Comparative different adhesive bonding systems	Freshly extracted bovine permanent mandibular incisors (n=96, 12 groups) No microcapsule content (1) No laser (2) Laser 4 s (3) Laser 5 s (4) Laser 6 s 30% microcapsule content (5) No laser (6) Laser 4 s (7) Laser 5 s (8) Laser 6 s 40% microcapsule content (9) No laser (10) Laser 4 s (11) Laser 5 s (12) Laser 6 s	CO ₂ WL: - P: 3 W PD: - T: 2-3 s	Ceramic Orthomite Super-Bond	In non-lasing groups, shear bond strength decreased to 0.75-fold and 0.63-fold with 30 wt% and 40 wt% microcapsules, respectively, compared to adhesive without microcapsules. Additionally, the bond strength of 30 wt% or 40 wt% microcapsules decreased significantly to 0.40- 0.48-fold after lasing for either 5 or 6 seconds compared to the non-lasing groups.

n: sample size; WL: wave length; P: power; PD: pulse duration; E: energy; T: time; CW: continuous wave; F: frequency.

Table 2: Summary of studies investigating intra-pulpal temperature during laser-assisted ceramic bracket debonding.

Author/ Year	Objective of study	Groups	Laser settings	Type of bracket/adhesive used	Results/Conclusions
Feldon <i>et al.</i> , 2010 ⁽¹⁷⁾	Comparative Mono-/Poly-crystalline brackets, Laser/ No Laser	Bovine maxillary left central incisors (n=60, 5 groups) (1) No laser, Poly (2) No laser, Mono (3) Laser 2 W, Poly (4) Laser 2 W, Mono (5) Laser 5 W, Poly (6) Laser 5 W, Mono	diode WL: - P: 2 W CW T: 3 s	Ceramic (Inspire and Clarity) Transbond XT	All mean increases in pulp chamber temperature for groups 3, 4, and 5 were significantly lower ($p<0.01$) than the threshold of 5.5°C and were not significantly different ($p<0.01$) from the standard of 1.8°C. The increase in pulp chamber temperature for Group 6 was significantly higher than the 1.8°C standard and not significantly different ($p<0.01$) from the 5.5°C threshold, based on statistical analysis.
Yassaei <i>et al.</i> , 2018 ⁽²⁸⁾	Comparative different modes of laser	Intact extracted premolars (n=90, 6 groups) Continuous wave (1) Laser 2 W (2) Laser 2.5 W (3) Laser 3 W Pulse mode (4) Laser 2 W (5) Laser 2.5 W (6) Laser 3 W	diode WL: 980 nm P: 2, 2.5, 3 W PD: 30 μ s T: 10 s (5 s from mesial and 5 s from distal)	Ceramic (Allure) Transbond XT	There were significant differences in temperature increase among all lasing groups. The highest increase in intra-pulpal temperature was observed in G3 (3.39 $\pm$ 0.76°C), followed by G6 (2.84 $\pm$ 0.40°C). However, this temperature increase remained below the 5.5°C threshold.
Hayakawa <i>et al.</i> , 2005 ⁽¹⁴⁾	Comparative different energy levels of Nd:YAG laser, Mono-/Poly-crystalline brackets	Extract/ Intact bovine mandibular incisors (n=80, 16 groups) Monocrystalline (1) MMA, No laser (2) MMA, 1 J (3) MMA, 2 J (4) MMA, 3 J (5) Bis-GMA, No laser (6) Bis-GMA, 1 J (7) Bis-GMA, 2 J (8) Bis-GMA, 3 J Polycrystalline (9) MMA, No laser (10) MMA, 1 J (11) MMA, 2 J (12) MMA, 3 J (13) Bis-GMA, No laser (14) Bis-GMA, 1 J (15) Bis-GMA, 2 J (16) Bis-GMA, 3 J	Nd:YAG WL: 1060 nm E: 1, 2, 3 J PD: 1.2 ms 1 pulse per location	Ceramic (Inspire, Clarity) Super-Bond (4META/ MMA), Transbond (Bis-GMA)	The increase in intra-pulpal temperature induced by lasing was extremely low, with the highest temperature increase of 5.1°C.
Rao <i>et al.</i> , 2023 ⁽²⁹⁾	Comparative different types of brackets, Laser/ No Laser	Extracted premolars (n=90, 6 groups) (A1) No laser (A2) Laser 4.5 W (A3) Laser 6 W (B1) No laser (B2) Laser 4.5 W (B3) Laser 6 W	Er,Cr:YSGG WL: 2780 nm P: 4.5, 6 W PD: - T: -	Group A: Metallic Group B: Ceramic Transbond XT	The pulp chamber temperature increased in all groups but were significantly lower than the 1.8°C standard and the 5.5°C threshold.
Nalbantgil <i>et al.</i> , 2011 ⁽²²⁾	Comparative different time exposures to laser	Human premolars (n=30, 3 groups) (1) Laser, 3 s (2) Laser, 6 s (3) Laser, 9 s	Er:YAG WL: 2940 nm P: 4.2 W PD: - T: 3, 6, 9 s Scanning motion	Ceramic (Transcend) Transbond XT	The longer the duration of lasing, the higher the intra-pulpal temperature increase. This study found that the 3 s group exhibited a statistically significantly lower temperature increase compared to the 6 s and 9 s groups, while the 6-second group also showed a significantly lower increase compared to the 9 s group.

Nalbantgil <i>et al.</i> , 2014 ⁽²⁴⁾	Comparative Waterless/ Water-cooling	Upper premolars (n=60, 3 groups) (1) No laser (2) Laser, Waterless (3) Laser, Water-cooling	Er:YAG WL: 2940 nm P: 5 W PD: - T: 9 s Scanning motion	Ceramic (Transcend) Transbond XT	Er-YAG laser-aided debonding with water-cooling reduced intra-pulpal temperature in ceramic brackets compared to debonding without water-cooling.
Dostalova <i>et al.</i> , 2016 ⁽³⁰⁾	Comparative different types of brackets	Caries-free human third molars (n=40, 4 groups) (1) Metallic+Transbond (Laser)=10 (2) Ceramic+Transbond (Laser)=10 (3) Ceramic+Variolink (Laser)=10 (4) Control=10 (No laser, 3 for each group, one for no bracket)	Er:YAG WL: 2940 nm E: 280 mJ F: 6 Hz T: -	Metallic (Victory Series), Ceramic (Clarity) Transbond XT, Variolink II	The temperature increased in both ceramic and metallic brackets, ranging from 2 to 3.2°C, which was considered safe as it remained lower than the 5.5°C threshold.
Grzech Lesniak <i>et al.</i> , 2018 ⁽⁹⁾	Comparative Scanning/ Circular motion technique, Metallic/ Ceramic brackets	Caries-free premolars (n=55, 4 groups) (1) Metallic, circular motion=15 (Laser) (2) Ceramic, circular motion=15 (Laser) (3) Ceramic, Scanning motion=15 (Laser) (4) Ceramic=5, Metallic=5 (No laser)	Er:YAG WL: 2940 nm P: 3.4 W PD: 300 µs T: 6 s Scanning motion	Metallic (Victory Series), Ceramic (Inspire) Transbond XT	A scanning motion resulted in a significantly lower temperature increase compared to a circular motion around ceramic brackets (1.78°C). After lasing in the circular motion, the temperature increase in ceramic brackets was significantly higher than in metallic brackets. Additionally, the lowest temperature increase was found in ceramic brackets using the scanning motion.
Nalbantgil <i>et al.</i> , 2018 ⁽¹⁹⁾	Comparative different energy levels of Er:YAG laser	Human premolars (n=60, 3 Groups) (1) Laser 2 W (2) Laser 4 W (3) Laser 6 W	Er:YAG WL: 2940 nm P: 2, 4, 6 W PD: 300 ms T: 6 s Scanning motion	Ceramic (Transcend) Transbond XT	As the laser power increases, so does the temperature; therefore, although the 6 W group showed the highest temperature increase, it still remained below the 5.5°C threshold.
Iijima <i>et al.</i> , 2010 ⁽¹⁵⁾	Comparative different laser settings	Human premolars (n=3) Different laser settings (3, 4, 5, and 6 W) were compared at 5 and 60 seconds after lasing.	CO ₂ WL: 10600 nm P: 3, 4, 5, 6 W PD: - T: 5 s each spot	Ceramic bracket (Inspire ice) Transbond XT (etch & rinse)	Measuring temperature using an infrared thermographic microscope system after 5 seconds of lasing, the temperature of enamel cross-sections rose to around 200°C when exposed to 5 or 6 watts, and between 100°C and 150°C when exposed to 3 and 4 watts. After 30 seconds of lasing, all temperatures returned to standard room levels.
Ahrari <i>et al.</i> , 2011 ⁽³¹⁾	Comparative Mono-/ Poly-crystalline brackets, Laser/ No Laser	Human maxillary and mandibular premolars (n=80, 4 groups) (1) CC: Fascination, No laser (2) MC: Inspire Ice, No laser (3) CL: Fascination, Laser (4) ML: Inspire Ice, Laser	CO ₂ WL: 10600 nm PP: 188 W F: 400 Hz PD: 0.0005 s T: 5 s Scanning motion	Ceramic (Fascination, Inspire Ice) Transbond XT	Intra-pulpal temperature in both ceramic bracket types remained below the threshold of 5.5°C.

Saito <i>et al.</i> , 2013 ⁽¹³⁾	Comparative different adhesive bonding systems	Freshly extracted bovine permanent mandibular incisors (n=96, 12 groups) No microcapsule content (1) No laser (2) Laser 4 s (3) Laser 5 s (4) Laser 6 s 30% Microcapsule content (5) No laser (6) Laser 4 s (7) Laser 5 s (8) Laser 6 s 40% Microcapsule content (9) No laser (10) Laser 4 s (11) Laser 5 s (12) Laser 6 s	CO ₂ WL: - P: 3 W PD: - T: 2-3 s	Ceramic Orthomite Super-Bond	The temperature of the bracket base increased above 80°C when exposed to the laser for more than 4 s. However, all mean temperature increases in the pulp chamber remained below 4.3°C.
Macri <i>et al.</i> , 2015 ⁽²⁰⁾	Comparative different laser settings	Human mandibular premolars (n=30, 12 groups) (1) 5 W, PD= 0.01, T=3 (2) 5 W, PD= 0.03, T=3 (3) 5 W, PD= 0.01, T=5 (4) 5 W, PD= 0.03, T=5 (5) 8 W, PD= 0.01, T=3 (6) 8 W, PD= 0.03, T=3 (7) 8 W, PD= 0.01, T=5 (8) 8 W, PD= 0.03, T=5 (9) 10 W, PD= 0.01, T=3 (10) 10 W, PD= 0.03, T=3 (11) 10 W, PD= 0.01, T=5 (12) 10 W, PD= 0.03, T=5	CO ₂ WL: 10600 nm P: 5, 8, 10 W PD: 0.01, 0.03 s T: 3, 5 s	Ceramic (Fascination) Transbond XT	The lasing duration of 3 seconds and pulse duration of 0.01 seconds, at power levels of 5, 8, and 10 W were considered safe as the temperature increases did not exceed the 5.5°C threshold.

n: sample size; WL: wave length; P: power; PD: pulse duration; E: energy; T: time; CW: continuous wave; F: frequency; PP: peak power.

Table 3: Summary of studies investigating the adhesive remnant index and enamel damage during laser-assisted ceramic bracket debonding.

Author/ Year	Objective of study	Groups	Laser settings	Type of bracket/ adhesive used	Results/Conclusions
Feldon <i>et al.</i> , 2010 ⁽¹⁷⁾	Comparative Mono-/ Poly-crystal-line brackets, Laser/ No Laser	Bovine maxillary left central incisors (n=60, 5 groups) (1) No laser, Poly (2) No laser, Mono (3) Laser 2 W, Poly (4) Laser 2 W, Mono (5) Laser 5 W, Poly (6) Laser 5 W, Mono	diode WL: - P: 2 W CW T: 3 s	Ceramic (Inspire and Clarity) Transbond XT	No significant differences were found in adhesive remnant index scores between groups. All groups had mean ARI scores of 3, indicating that most of the adhesive remained on tooth surfaces with bracket base imprints. The diode laser did not affect the amount of adhesive left after debonding.
Stein <i>et al.</i> , 2017 ⁽³⁾	Comparative Laser/ No Laser	Human third molar (n=30, 2 groups) (1) No laser (2) laser	diode WL: 445 nm P: 2 W CW T: 5 s on each side (Total 15s)	Ceramic (In-Ovation C, GAC) Transbond XT	In the lasing group, there was a significantly higher percentage of ARI scores of 0, whereas the non-lasing group showed a significantly higher percentage of ARI scores of 3. The result showed no difference in enamel damage in either the lasing or non-lasing groups before debonding; however, the lasing group showed less enamel damage compared to the non-lasing group after debonding.
Yassaei <i>et al.</i> , 2018 ⁽²⁸⁾	Comparative different modes of laser	Intact extracted premolars (n=90, 6 groups) Continuous wave (1) Laser 2 W (2) Laser 2.5 W (3) Laser 3 W Pulse mode (4) Laser 2 W (5) Laser 2.5 W (6) Laser 3 W	diode WL: 980 nm P: 2, 2.5, 3 W PD: 30 μ s T: 10 s (5 s from mesial and 5 s from distal)	Ceramic (Allure) Transbond XT	Comparing all laser settings, there were no differences in the ARI scores among all groups, as the ARI scores of all groups were mostly 2. There was a significant increase in the number of enamel cracks after bracket debonding. Additionally, all groups, except group 3 and group 6, also showed a significant increase in the length of enamel cracks.
Han <i>et al.</i> , 2008 ⁽²⁾	Comparative Laser/ No Laser, Metallic/ Ceramic bracket	Freshly extracted premolars (n=30, 3 groups) (1) Metallic, No laser (2) Ceramic, No laser (3) Ceramic, Laser	Nd:YAG WL: 1060 nm P: 3 W PD: 0.2 ms T: 2 s	Metallic (MBT), Ceramic (Clarity)	The ARI scores in the lasing group were significantly lower compared to the non-lasing group. Moreover, SEM analysis indicated less enamel damage in the lasing group compared in the non-lasing group for both metallic and ceramic brackets.
Rao <i>et al.</i> , 2023 ⁽²⁹⁾	Comparative different types of brackets, Laser/ No Laser	Extracted premolars (n=90, 6 groups) (A1) No laser (A2) Laser 4.5 W (A3) Laser 6 W (B1) No laser (B2) Laser 4.5 W (B3) Laser 6 W	Er,Cr:YSGG WL: 2780 nm P: 4.5, 6 W PD: - T: -	Group A: Metallic Group B: Ceramic Transbond XT	The ARI scores showed statistically significant differences ($p \leq 0.05$) between the control and study groups, particularly in metal brackets and were highly significant ($p \leq 0.001$) within the ceramic bracket group. SEM analysis of the laser debonding groups showed no cracks, whereas conventionally debonded metallic and ceramic brackets displayed pronounced fractures.
Nalbantgil <i>et al.</i> , 2011 ⁽²²⁾	Comparative different time exposures to laser	Bovine mandibular incisors (n=80, 4 groups) (1) No laser (2) Laser, 3 s (3) Laser, 6 s (4) Laser, 9 s	Er:YAG WL: 2940 nm P: 4.2 W PD: - T: 3, 6, 9 s Scanning motion	Ceramic (Transcend) Transbond XT	Statistically significant differences were observed in ARI scores between the 9 s group and non-lasing group, as well as 9 s and 6 s groups. Most ARI scores of the 9 s group were 3.

Oztoprak <i>et al.</i> , 2010 ⁽²⁶⁾	Comparative Laser/ No Laser	Bovine mandibular incisors (n=60, 2 groups) (1) No Laser (2) Laser	Er:YAG WL: 2940 nm P: 4.2 W PD: - T: 9 s Scanning motion	Ceramic (Transcend) Transbond XT	The adhesive remnant index scores showed a statistically significant difference ($p<0.001$) with the laser group having double the number of samples with adhesive scores of 2 or 3 on the index.
Tozlu <i>et al.</i> , 2011 ⁽²³⁾	Comparative different time lags	Non-carious human premolars (n=100, 5 groups) (1) No laser (2) Laser, 1 s (3) Laser, 18 s (4) Laser, 30 s (5) Laser, 60 s	Er:YAG WL: 2940 nm P: 5 W PD: - T: 6 s Scanning motion	Ceramic (Transcend) Transbond XT	Comparing the time lag, there was no difference in ARI scores. The ARI scores of all groups were mostly 2 and 3.
Dostalova <i>et al.</i> , 2016 ⁽³⁰⁾	Comparative different types of brackets	Caries-free human third molars (n=40, 4 groups) (1) Metallic+Transbond (Laser)=10 (2) Ceramic+Transbond (Laser)=10 (3) Ceramic+Variolink II (Laser)=10 (4) Control=10 (No laser, 3 for each group, 1 for no bracket)	Er:YAG WL: 2940 nm E: 280 mJ F: 6 Hz	Metallic (Victory Series), Ceramic (Clarity) Transbond XT, Variolink II	Er:YAG laser radiation effectively removed adhesive remnants in the ceramic (Clarity Advance) with resin adhesive system (Variolink II), leaving an almost pure layer of enamel. SEM analysis indicated a higher presence of adhesive material for metallic and ceramic brackets in the non-lasing group with ceramic remnants also observed in the case of ceramic brackets. Therefore, the lasing group was shown to protect the enamel surface.
Nalbantgil <i>et al.</i> , 2018 ⁽¹⁹⁾	Comparative different energy levels of Er:YAG laser	Bovine incisors (n=80, 4 groups) (1) No laser (2) Laser 2W (3) Laser 4W (4) Laser 6W	Er:YAG WL: 2940 nm P: 2,4,6 W PD: 300 ms T: 6 s Scanning motion	Ceramic (Transcend) Transbond XT	There was a significant difference in ARI scores between the non-lasing group and the lasing group with a 6 W laser, which showed a significantly higher percentage of ARI scores of 3 (70%).
Grzech Lesniak <i>et al.</i> , 2018 ⁽⁹⁾	Comparative Scanning/ Circular motion technique, Metallic/ Ceramic bracket	Caries-free premolars (n=55, 4 groups) (1) Metallic, circular motion=15 (Laser) (2) Ceramic, circular motion=15 (Laser) (3) Ceramic, Scanning motion=15 (Laser) (4) Ceramic=5, Metallic=5 (No laser)	Er:YAG WL: 2940 nm P: 3.4 W PD: 300 μ s T: 6 s Scanning motion	Metallic (Victory Series), Ceramic (Inspire) Transbond XT	Ceramic brackets debonded using the scanning method had the lowest average ARI score. The main finding was the absence of cracks or fractures in all lasing groups. In contrast, pronounced cracks in enamel were observed in the non-lasing group for both ceramic and metal brackets. EDS analysis indicated higher calcium element percentages in all lasing groups compared to the non-lasing group. Additionally, the calcium content was greater in metal brackets compared to ceramic brackets (higher calcium levels indicate safety).
Iijima <i>et al.</i> , 2010 ⁽¹⁵⁾	Comparative different laser settings, different adhesive bonding systems	Human premolars (n=50, 10 groups) (1) Etch & rinse, No laser (2) Etch & rinse, 3 W (3) Etch & rinse, 4 W (4) Etch & rinse, 5 W (5) Etch & rinse, 6 W (6) Self-etching, No laser (7) Self-etching, 3 W (8) Self-etching, 4 W (9) Self-etching, 5 W (10) Self-etching, 6 W	CO ₂ WL: 10600 nm P: 3, 4, 5, 6 W PD: - T: 5 s each spot	Ceramic bracket (Inspire ice) Transbond XT (Etch & rinse), Transbond Plus (Self-etching)	No significant differences were found in ARI scores among all 10 groups. Most ARI scores in all groups were 1. The hardness and elastic modulus are significantly lower at a 1 μ m distance from the enamel surface compared to other distances in all specimens.

Ahrari <i>et al.</i> , 2011 ⁽³¹⁾	Comparative Mono-/ Poly-crystalline bracket, Laser/ No Laser	Human maxillary and mandibular premolars (n=80, 4 groups) (1) CC: Fascination, No laser (2) MC: Inspire Ice, No laser (3) CL: Fascination, laser (4) ML: Inspire Ice, laser	CO ₂ WL: 10600 nm PP: 188 W F: 400 Hz PD: 0.0005 s T: 5 s Scanning motion	Ceramic (Fascination, Inspire Ice) Transbond XT	Both non-lasing groups had significantly more ARI scores of 0, while the lasing monocrystalline bracket group had significantly more ARI scores of 3 (70%). Laser debonding caused a significant decrease in the number of cracks for both ceramic bracket types, while resulting in an insignificant decrease in the length of cracks compared to the non-lasing group. Therefore, using laser debonding can reduce enamel damage.
Saito <i>et al.</i> , 2013 ⁽¹³⁾	Comparative different adhesive bonding systems	Freshly extracted bovine permanent mandibular incisors (n=96, 12 groups) No microcapsule content (1) No laser (2) Laser 4 s (3) Laser 5 s (4) Laser 6 s 30% microcapsule content (5) No laser (6) Laser 4 s (7) Laser 5 s (8) Laser 6 s 40% microcapsule content (9) No laser (10) Laser 4 s (11) Laser 5 s (12) Laser 6 s	CO ₂ WL: - P: 3 W PD: - T: 2-3 s	Ceramic Orthomite SuperBond	There was no significant difference in ARI scores after debonding in the lasing or non-lasing group. However, there were many scores of 0 and 1.
Matos <i>et al.</i> , 2021 ⁽¹⁸⁾	Comparative Laser/ No Laser, different adhesive resin, different ceramic brackets	Human premolars (n=90, 6 groups) (1) TMC: Transbond+Mystique+Control (No laser) (2) TFC: Transbond+Fascination+Control (No laser) (3) TML: Transbond+Mystique+Laser (4) ZML: Z250+Mystique+Laser (5) TFL: Transbond+Fascination+Laser (6) ZFL: Z250+Fascination+Laser	CO ₂ P: 10 W WL: 10600 nm PD: 0.01 s T: 3 s	Ceramic (Mystique and Fascination) Transbond XT, Z250	TMC had the lowest mean ARI score of 0. The best outcomes were found in the ZFL and ZML groups, which were bonded using Z250. The most common type of fracture observed was adhesive fracture, followed by cohesive resin fracture. The lowest enamel damage was found in ZFL (mostly cohesive resin fractures), while the greatest enamel damage was found in ZML (mostly cohesive enamel fractures).

Hoteit <i>et al.</i> , 2020 ⁽²¹⁾	Comparative between Er,Cr:YSGG and Er:YAG lasers settings	Bovine incisors (n=180, 15 groups) Er,Cr:YSGG (1) Laser 3 W/20 Hz (2) Laser 3 W/40 Hz (3) Laser 4 W/20 Hz (4) Laser 4 W/40 Hz (5) Laser 5 W/20 Hz (6) Laser 5 W/40 Hz Er:YAG (7) Laser 80 mJ/20 Hz (8) Laser 80 mJ/40 Hz (9) Laser 100 mJ/20 Hz (10) Laser 100 mJ/40 Hz (11) Laser 120 mJ/20 Hz (12) Laser 120 mJ/40 Hz (13) Laser 140 mJ/20 Hz (14) Laser 140 mJ/40 Hz (15) No laser	Er,Cr:YSGG WL: 2780 nm P: 3, 4, 5 W PD: 60 µs T: - Er:YAG WL: 2940 nm E: 80, 100, 120, 140 mJ PD: 50 µs T: -	Ceramic (Clarity)	The proportion of teeth with intact enamel topography was significantly smaller in the non-lasing group compared to the Er,Cr:YSGG groups (4 W/20 Hz and 5 W/20Hz). In contrast, there were no significant differences in the non-lasing group compared to any of the Er:YAG groups. In the Er,Cr:YSGG subgroups, micro-cracks were found only in the 3 W/20 Hz group. Statistically significant intact enamel was observed in the 4 W/20 Hz and 5 W/20 Hz groups, both displaying the most homogeneous topography compared to others. The enamel surface in the 4 W/20 Hz group was slightly more uniform than in the 5 W/20 Hz group. In the Er:YAG subgroups, all exhibited changes in enamel topography. Er:YAG lasing at both 100 mJ/40 Hz and 120 mJ/40 Hz resulted in reduced enamel micro-cracks compared to the non-lasing group. However, these lasing groups did not significantly differ in the proportion of teeth with normal enamel topography compared to the non-lasing group. SEM analysis revealed rough and amorphous enamel topography in the 100 mJ/40 Hz subgroup, while the 120 mJ/40 Hz subgroup exhibited stripped and shiny changes.
Khalil <i>et al.</i> , 2021 ⁽²⁵⁾	Comparative effects of Chemical agent (peppermint oil), Ultrasonic, diode laser, and Er:YAG laser	Extracted human premolars (n=100, 5 groups) (1) No laser (2) Peppermint oil (3) Ultrasonic (4) diode laser (5) Er:YAG laser	diode WL: 980 nm P: 4 W CW T: 3 s on each side (Total 12 s) Er:YAG WL: 2940 nm P: 4 W PD: 100 µs T: 3 s on each side (Total 12s)	Ceramic (Perfect Clear) Transbond XT	Statistically significantly higher ARI scores were found in group 5 (Er:YAG) compared to the other groups, and no other significant differences were found between the groups with regard to ARI. SEM analysis showed cracks and erosion in groups 1 and 2, while groups 3 and 4 showed various degrees of voids. In contrast, group 5 showed an intact enamel microstructure with minimal alterations.

n: sample size; WL: wave length; P: power; PD: pulse duration; E: energy; T: time; CW: continuous wave; F: frequency; PP: peak power; EDS: energy-dispersive X-ray spectroscopy.

Conclusions

Based on the available evidences, laser-assisted debonding of ceramic orthodontic brackets appears to be an effective method for reducing shear bond strength and facilitating bracket removal. Most studies indicate that appropriate laser use can lower the force required for debonding while maintaining enamel integrity and keeping intra-pulpal temperature within safe limits. However, the current evidence is mainly derived from studies with varied methodologies, laser parameters, and outcome measures. This variability limits the overall strength of the conclusions and makes direct clinical translation challenging. As a result, the effectiveness of laser-assisted debonding is likely influenced by proper case selection and careful adjustment of laser settings.

Therefore, laser-assisted debonding should be considered an adjunctive technique rather than a routine replacement for conventional mechanical debonding. Further well-designed clinical studies with standardized protocols and long-term follow-up are needed before clear clinical recommendations can be established.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Oral-Systemic Mechanisms in Diagnostic Medicine: A Syndromic and Translational Review

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Abstract

The oral cavity's diagnostic potential remains underutilized in mainstream medicine, despite being a dynamic interface between systemic physiology and environmental exposure. This review proposes a mechanism-based framework that repositions oral structures and secretions as bio-reflective zones, thereby mirroring pathophysiological processes across endocrine, cardiovascular, renal, neurological, and genetic domains. By integrating evidence from salivary biomarkers, mucosal alterations, craniofacial anomalies, and radiographic features, we demonstrate how oral diagnostics can serve as early indicators of systemic dysfunction. Mechanistic clues to multisystem disorders are provided by oral phenotypes, with a particular emphasis on syndromic convergence. The manuscript also underscores the potential for implementation in the fields of interdisciplinary screening protocols, AI-assisted oral imaging, and salivary biosensing. It is imperative to take diagnostic equity into account when examining the potential of oral evaluations to address disparities in underserved populations, particularly in situations where systemic testing is unavailable. By integrating clinical, molecular, and imaging-based insights, this review enhances oral diagnostics from adjunctive observations to actionable tools in the detection and monitoring of systemic diseases, thereby promoting a paradigm.

Keywords: diagnosis, oral cavity, oral manifestations, saliva, systemic diseases

Introduction

The oral cavity has traditionally been viewed as the site of local pathologies such as caries and periodontal disease, yet growing evidence points to its broader role as a diagnostic interface for systemic health. Changes in oral tissues and, more recently, in the molecular composition of saliva, provide valuable insights into physiological disturbances that extend beyond the mouth. Because saliva contains a diverse spectrum of proteins, nucleic acids, metabolites, and microbial signatures, it has emerged as a particularly attractive medium for detecting disease-related alterations in a non-invasive manner.^(1,2)

Despite this potential, the healthcare landscape often remains divided, with dentistry and medicine functioning as largely independent disciplines. Such compartmentalization limits opportunities for early recognition of systemic diseases and diminishes the impact of preventive care. Oral manifestations that might otherwise serve as early diagnostic signals are frequently overlooked or managed in isolation, delaying comprehensive treatment and contributing to higher disease burden.

The review employs a mechanism-based framework to address challenges. Rather than classifying oral manifestations by broad disease categories, the review redefines the oral cavity as a bio-reflective zone, where systemic dysfunctions display through commonly shared biological pathways (allostatic load), such as chronic inflammation, oxidative stress, immune dysregulation, and metabolic deregulation. Through the lens of translational research, the review bridges the connections made in previous reviews by revealing the mechanistic links of oral and saliva findings in a clearly defined structure and emphasising how clinicians can put together the clinically actionable information about systemic health. We highlight translational research—specifically, salivary diagnostics—as a non-invasive diagnostic method that can reveal early indicators of health decline by reviewing more recent clinical, biological, and translational studies.

Oral clues to systemic illness—a mechanism-based framework

Different biological routes enable systemic abnormalities to manifest through the oral cavity's dynamic interface.⁽³⁾ In contrast to disease-based catalogues, a mechanism-oriented approach facilitates the comprehension of the way in which various conditions result in com-

parable oral outcomes.⁽⁴⁾ This method helps clarify the impact of systemic disorders on oral health by examining the dissemination of microbes, inflammatory reactions, immune system changes, and molecular signalling. It provides a comprehensive understanding of the interconnections between oral and systemic health.

The subsequent subsections focus on a specific pathway, illustrating how systemic dysfunction leads to oral and sublingual alterations that have diagnostic potential.

Inflammatory and immune-mediated disorders

Linking systemic disease to oral disease involves fundamental processes such as chronic inflammation and immunological dysregulation. Pro-inflammatory cytokines, altered immune cell profiles, and dysregulated host-microbe interactions form oral symptoms that may precede or follow systemic illness.^(5,6)

- Diabetes mellitus: Persistent hyperglycemia promotes low-grade systemic inflammation and impaired neutrophil function, contributing to increased periodontal susceptibility and delayed wound healing.⁽⁷⁾ Elevated salivary levels of advanced glycation end products (AGEs) and inflammatory mediators further reflect disease activity.⁽⁸⁾

- Rheumatoid arthritis (RA): Shared pathways of joint and periodontal destruction, including TNF- α and IL-6 signaling, underscore the bidirectional relationship between RA and periodontitis. Oral clinical signs may correlate with systemic disease severity.^(9,10)

- Systemic lupus erythematosus (SLE): Immune complex deposition and mucosal vasculitis lead to oral ulcers, lichenoid lesions, and salivary gland dysfunction. Salivary anti-dsDNA antibodies and cytokine profiles have been investigated as non-invasive disease markers.⁽¹¹⁻¹³⁾

- Inflammatory bowel disease (IBD): Aberrant mucosal immunity manifests orally as aphthous-like ulcers, mucosal cobble stoning, or pyostomatitis vegetans.^(14,15) Salivary calprotectin and altered microbiome signatures have been proposed as adjunctive diagnostic tools.^(16,17)

Salivary gland dysfunction and secretory imbalance

Alterations in salivary gland structure or function compromise the oral cavity's protective environment, leading to xerostomia, opportunistic infections, and

impaired mucosal healing.⁽¹⁸⁾

- Sjögren's syndrome: Autoimmune destruction of salivary acini reduces flow and alters glandular proteins, producing dryness, rampant caries, and mucosal discomfort. Salivary anti-Ro/SSA antibodies serve as promising non-invasive markers.⁽¹⁹⁻²¹⁾
- HIV infection: Salivary gland disease may manifest as diffuse infiltrative lymphocytosis, parotid swelling, and xerostomia, reflecting immune dysregulation.⁽²²⁾
- Drug-induced xerostomia: Anticholinergics, antihypertensives, and antidepressants can diminish secretion, mimicking glandular disease and complicating oral management.^(23,24)

Recognition of these changes highlights saliva as both a diagnostic fluid and a therapeutic target.

Mucosal and gingival alterations

Systemic hematologic and infectious disorders frequently manifest as mucosal or gingival lesions due to impaired hemostasis, vascular fragility, or viral-mediated inflammation.⁽²⁵⁾

- Leukemia: Gingival hypertrophy, spontaneous bleeding, and petechiae reflect infiltration and thrombocytopenia.^(26,27)
- Thrombocytopenia: Low platelet counts produce ecchymoses and mucosal haemorrhage.⁽²⁸⁾
- COVID-19: Viral tropism for ACE2-expressing oral tissues can result in dysgeusia, mucositis, and ulceration.^(29,30)

These mucosal findings often precede systemic diagnosis, underscoring their clinical value.

Bone metabolism disorders

Oral bone is highly sensitive to systemic disturbances in mineral metabolism, presenting with changes in alveolar bone density and architecture.⁽³¹⁾

- Osteoporosis: Reduced bone mass predisposes to tooth loss and compromised implant stability; salivary calcium and collagen breakdown products have been explored as biomarkers.^(32,33)
- Renal osteodystrophy: Secondary hyperparathyroidism leads to jawbone changes, loss of lamina dura, and brown tumors.^(34,35)

Oral radiography can provide adjunctive insights into skeletal health.

Oral-origin bacteremia and cardiovascular risk

The oral cavity serves as a reservoir for pathogenic bacteria capable of translocating into the bloodstream, contributing to cardiovascular morbidity.⁽³⁶⁾

- Infective endocarditis: Poor oral hygiene and invasive dental procedures can introduce *viridans streptococci* and *Enterococcus* into circulation.^(37,38)
- Periodontitis–cardiac links: Systemic inflammation driven by periodontal pathogens such as *Porphyromonas gingivalis* is implicated in atherogenesis.^(39,40)

Routine periodontal care represents a preventive measure with systemic benefit.

Neurological and sensory manifestations

Neurological disease often alters oral sensation, motor control, and salivary function, reflecting broader neurodegenerative processes.⁽⁴¹⁾

- Parkinson's disease: Impaired motor control leads to drooling and swallowing dysfunction; reduced salivary dopamine metabolites may have biomarker relevance.^(42,43)
 - In Multiple sclerosis, demyelination may result in dysgeusia and trigeminal neuralgia.^(44,45)
 - Zinc deficiency disrupts the function of taste receptors, resulting in hypogeusia or dysgeusia.⁽⁴⁶⁾
- These modifications highlight the diagnostic interaction between neurology and oral medicine.

Gastrointestinal and acid-related damage

Digestive tract disorders frequently present as erosive or pigmentary alterations in oral tissues, showing signs of acid exposure or mucosal pathology.⁽⁴⁷⁾

- Gastroesophageal reflux disease (GERD): prolonged acid exposure erodes enamel and irritates the mucosa.^(48,49)
- Eating disorders: Xerostomia, parotid enlargement, and palatal erosion are caused by episodes of vomiting.⁽⁵⁰⁾
- Before intestinal polyps are found, mucocutaneous pigmentation of the lips and buccal mucosa can serve as a diagnostic hint in Peutz-Jeghers syndrome.⁽⁵¹⁾

Consequently, oral evaluation provides a perspective on gastrointestinal pathology.

Nutrient-linked mucosal and structural alterations

Oral tissues experience rapid nutrient deficiencies as

a result of their high metabolic demands and rapid cellular turnover.

- Iron deficiency causes angular cheilitis and atrophic glossitis; Plummer-Vinson syndrome causes dysphagia and pallor in the oral mucosa.^(52,53)
- B-complex deficiency: Glossitis, cheilitis, and burning mouth are all typical indicators.⁽⁵¹⁾
- Vitamin C deficiency: Leads to gingival bleeding and poor wound healing.⁽⁵⁴⁾
- Vitamin D deficiency: Impairs mineralization, affecting alveolar bone.^(55,56)
- Protein–energy malnutrition: Causes mucosal atrophy and delayed eruption in children.⁽⁵⁷⁾

The oral cavity's susceptibility to systemic nutrition is underscored by these manifestations.

Genetic disorders and syndromic oral features

Early diagnostic markers may be the distinctive oral and craniofacial manifestations of several hereditary and syndromic disorders. The timely genetic assessment and multidisciplinary care can be significantly influenced by a precise oral examination.

- Down syndrome (Trisomy 21): Common oral symptoms include delayed eruption, hypodontia, macroglossia, fissured tongue, and a much higher risk of periodontal disease since the immune system is dysfunctional.⁽⁵⁸⁻⁶⁰⁾
- Major functional and aesthetic implications are associated with ectodermal dysplasia, which is characterised by hypodontia or anodontia, peg-shaped or conical teeth, impaired salivary flow, and xerostomia.⁽⁶¹⁻⁶³⁾
- Cleidocranial dysplasia is characterised by multiple impacted and extra teeth, delayed eruption, and a high-arched mouth. Oral x-rays are often used to help make the diagnosis.^(64,65)
- In Marfan syndrome, defects in the connective tissues cause the jaw joints to be hypermobile, the palate to be high-arched, and crowding to be present.⁽⁶⁶⁾
- Neurofibromatosis type 1: Oral neurofibromas, enlargement of fungiform papillae, and mandibular radiolucencies may be observed.^(67,68)
- Apert syndrome: Midface hypoplasia, high-arched palate, crowding, and delayed eruption result from craniosynostosis and altered jaw development.^(69,70)
- Treacher Collins syndrome: Hypoplastic zygoma and mandible, cleft palate, and dental anomalies such as

enamel hypoplasia are common.^(71,72)

- Turner syndrome: Associated with high-arched palate, micrognathia, and increased risk of malocclusion.^(73,74)
- Williams syndrome: Often presents with small, widely spaced teeth, malocclusion, and increased prevalence of dental caries.⁽⁷⁵⁻⁷⁷⁾
- Osteogenesis imperfecta: Often associated with Dentinogenesis imperfecta in which teeth are translucent, opalescent with rapid wear is a defining oral feature.⁽⁷⁸⁻⁸⁰⁾

Uremic and dialysis associated oral changes

Uremia and dialysis alter the oral environment through metabolic toxins and fluid imbalance.

- Uremic stomatitis, which manifests in advanced renal failure, has an odour similar to ammonia, ulcerations on the mucosal surface, and pseudomembranes.⁽⁸¹⁾
- Dialysis patients often have xerostomia as a result of fluid restriction and the side effects of their medications.^(82,83)
- Changes associated with dialysis: These include petechiae, delayed healing, and an increase in calculus formation.⁽⁸⁴⁻⁸⁶⁾

Clinical and translational implications

Reconceptualising the oral cavity as a bio-reflective zone enables new approaches for the diagnosis, monitoring, and risk stratification of systemic diseases. Early indicators of renal, cardiovascular, neurodegenerative and endocrine diseases can be detected by the changes in the oral cavity, such as craniofacial anomalies, mucosal changes, and salivary biomarkers. As an advantage, the oral evaluations could be incorporated for standard systemic assessment to enhance diagnostic sensitivity and early detection.

Salivary biomarkers: evidence, advantages, and challenges

Saliva is considered a reflection of blood, and its popularity in the field of diagnostics is accelerating, especially as it is a non-invasive and patient-friendly mode of collection.^(87,88) It contains a wide array of biologically relevant constituents like proteins, nucleic acids, antibodies, cytokines, metabolites and microbial components that reveal the immune, inflammatory, endocrine and metabolic states.^(87,89,90) There have been

several correlations that demonstrate the link between serum and salivary biomarkers, such as the inflammatory and cardiac markers, including C-reactive protein and troponins in cardiovascular diseases^(91,92), proteomic signatures and autoantibodies in autoimmune disorders like Sjogren's syndrome^(93,94), salivary glucose levels in diabetes^(95,96), proteomic, microRNA, and spectroscopic signatures in oral and systemic malignancies, including breast, lung and pancreas.⁽⁹⁷⁻¹⁰¹⁾ The salivary biomarkers are also associated with neurodegenerative diseases, including Alzheimer's and Parkinson's.^(102,103) The translational relevance and diagnostic sensitivity are further enhanced using advances in analytical techniques like enzyme-linked immunosorbent assays, quantitative mass spectrometry, Raman spectroscopy and saliva-omics platforms.^(89,104,105) The salivary-based tests offer an upper hand by reducing patient discomfort, being non-invasive and easy to collect, and potentially applicable in large-scale populations.^(106,107) However, the clinical translation remains challenged by biological variability, circadian rhythm, lower biomarker concentrations, salivary flow rate fluctuations, lack of standardised reference ranges and limited large-scale validation across diverse populations. These limitations are to be addressed before relying completely on salivary biomarker-based diagnostics in routine clinical practice.

Artificial intelligence (AI) -assisted oral imaging: clinical relevance, advantages and limitations

Another powerful tool for early detection, monitoring and diagnosis is artificial intelligence (AI) assisted oral imaging. The AI-based algorithms are applied to intraoral photographs, radiographs and cone-beam computed tomography (CBCT), and optical imaging modalities have high sensitivity in identifying dental caries, periapical pathologies, periodontal bone loss, oral potentially malignant disorders and even malignancies like oral squamous cell carcinoma.^(108,109) A lot of things can be carried out using AI-assisted imaging, such as predicting the disease, assessing its severity, and monitoring the progression of the disease, which in turn reduces the inter-observer variability and enhances the diagnostic consistency.^(110,111) This integration of chairside imaging, along with deep learning models, could improve the detection of even subtle oral or radiographic alterations, which could be accidentally missed or over-

looked during routine clinical examination.

AI-assisted oral imaging offers several advantages in a translational perspective, such as rapid analysis of the images, easier when assessing larger patient populations and the possibility of integration into tele-dentistry and remote screening workflows.⁽¹¹²⁾ AI-based imaging systems support a multi-modal diagnostic framework when combined with clinical examination and other diagnostic modalities, which could align the precision and preventive approach.⁽¹¹³⁾ However, there could be several challenges that could be faced, such as varying image quality, lack of standardised imaging protocols, algorithm bias due to non-representative training datasets, data privacy-related concerns, regulatory oversight and the most importantly, widespread clinical adoption of the technique.^(114,115) It is essential to address these limitations through multi-centre validation studies, and standardised reporting guidelines are essential to ensure safe, ethical, and effective integration of AI-assisted oral imaging to routine clinical practice.^(108,114)

Strengths

The clinical value of liquid biopsy has expanded beyond its value for disease assessment.^(116,117) Information at the molecular level will reflect systemic physiological changes at an earlier stage, even before clinical symptoms begin to appear, making salivary biomarker research even more reliable.⁽¹¹⁸⁾ This ability to identify even the slightest biological shift supports earlier clinical risk assessment and long-term monitoring, especially for chronic diseases.^(118,119) Along with the advances in salivary diagnostics integration with AI-assisted analysis of oral images, it helps to identify the changes that could not be detected from visual examination alone, allowing for precise diagnostics.⁽¹²⁰⁾ When considered together, these approaches help to a more integrated understanding of patient health, which is especially relevant for screening and preventive care.

Limitations

Although there are several advantages, these tools face some important challenges that could hinder their application in routine clinical use.⁽¹²¹⁾ The oral conditions and biological variation among individuals influence the salivary biomarkers, which might cause difficulties in interpretation and reduce the specificity. The training data

quality and its diversity play a major role in the performance of AI-assisted imaging, and models developed in controlled environments may not perform consistently across different populations or clinical situations.⁽¹²²⁾ Both approaches also lack widespread longitudinal validation and standardised implementation pathways, making integration into existing clinical workflows uneven. Addressing these limitations will be essential to help oral diagnostic innovations move beyond experimental settings and achieve clinically reliable everyday application.⁽⁸⁹⁾

Future directions

To fully utilise the diagnostic capabilities of the oral cavity, subsequent research should progress from initial discoveries to mechanistic validation and clinical integration. The chairside use with a focus on population-level specificity and sensitivity, which could detect inflammatory, metabolic and neuroendocrine markers using salivary biosensing platforms. AI-assisted oral imaging appears to be promising for early detection of systemic disease when trained on a variety of datasets through pattern identification of disease progression. Syndromic mapping of oral phenotypes should be broadened to encompass underrepresented disorders and populations, thereby facilitating the development of more broad-based diagnostic algorithms. As systemic testing is unavailable in underserved communities, oral diagnostics have the potential to address this. It requires support at the policy level, ethical management of data, and culturally aware implementation. Integrating oral diagnostics into systemic care pathways, refining AI models, and advancing biosensor technology can transform the mouth from a passive site of observation to an active sentinel of whole-body health.

Conclusions

The oral cavity serves as a bio-reflective zone, reflecting systemic health via structural, microbial, and molecular indicators. This review presents oral diagnostics as a mechanism-driven approach for the early detection and monitoring of systemic diseases. Oral features, ranging from salivary biomarkers to craniofacial anomalies, provide insights that extend beyond disciplinary boundaries. To realise this potential, oral diagnostics require validation across diverse populations, integration into screening protocols, and support through interdis-

iplinary collaboration. Recent developments in biosensing, AI-assisted imaging, and syndromic mapping present significant translational opportunities, particularly in underserved areas. We propose a paradigm shift that transforms oral evaluations from supplementary observations into effective instruments for systemic care. Oral diagnostics can integrate clinical silos, fostering an understanding of the mouth not merely as a site of disease, but as an indicator of overall health. Advances in salivary biosensing and AI-assisted oral imaging further support the role of the oral cavity as a scalable, non-invasive diagnostic interface for systemic disease.

Conflict of Interest

The authors declare no conflict of interest.

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Comparative Effectiveness of Vertical Ridge Augmentation Techniques for Dental Implant Treatment: A Systematic Review

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Abstract

Background: Dental implants placement in long-standing edentulous areas often encounter the problem of alveolar height deficiency from gradual bone resorption over time. Therefore, vertical bone augmentation prior to implant placement would be much needed.

Objectives: To compare the effectiveness of various vertical ridge augmentation techniques.

Methods: This review followed the PRISMA guideline. Electronic and manual searches of randomized controlled trials (RCTs) were conducted through the MEDLINE, CENTRAL, Embase, and Scopus databases. The primary outcome was vertical bone gain. Secondary outcomes were bone resorption, complications, implant survival, and success rates. The Cochrane risk-of-bias assessment tool version 2 was used for quality assessment.

Results: Data analyses of the 29 included studies indicated that distraction osteogenesis (DO) provided the highest final vertical bone gain (8.38 ± 1.74 mm.) followed by inlay bone grafting (2.69 ± 0.37 to 7.00 ± 1.76 mm) and guided bone regeneration (GBR) (1.50 ± 1.60 to 6.86 ± 0.94 mm). The highest degree of bone resorption was observed with onlay bone grafting (0.60 ± 0.70 to 4.77 ± 1.67 mm). The DO and GBR techniques demonstrated 20-60% and 0-47% complication rates, respectively. Implant survival and success rates for all ridge augmentation techniques were over 90% and 60%, respectively.

Conclusions: From this study, all vertical bone augmentation techniques can effectively increase the alveolar ridge height. While DO provides the greatest vertical bone gain, the GBR techniques might be a more clinically practical option. However, future well-planned RCTs to identify effective vertical bone augmentation techniques are still warranted.

Keywords: distraction osteogenesis, guided bone regeneration, inlay graft, onlay graft, systematic review

Introduction

Tooth loss is one of the problems that negatively impacts the patients' oral health-related quality of life by lowering self-confidence and impairing the biting or chewing functions, which may consequently weaken the patients' overall health.^(1,2) To date, dental implant treatment has been increasingly selected from its reliable outcome and long-term success. The dimensions of alveolar ridge would normally be maintained by the presence of healthy and functional teeth. However, when there is tooth loss, bone resorption and subsequent loss of the alveolar ridge dimensions could occur, which, over time could result in anatomical limitations for dental implant placement.^(3,4)

Vertical alveolar ridge augmentation techniques are considered sensitive procedures due to the frequent complications associated with them. However, the success of vertical bone augmentation is influenced by many factors, including variability in clinical settings and operator experience.⁽⁴⁾ The main surgical procedures for increasing vertical bone height included distraction osteogenesis (DO), inlay bone graft, onlay bone graft, and guided bone regeneration (GBR).^(5,6) DO is a technique involving the gradual, controlled separation of surgically created bone fragments, which induces new bone formation within the gap.⁽⁷⁾ Inlay bone graft is a procedure that the bone grafting material is placed between bone segments at the recipient site. Onlay bone graft is a technique that places bone grafting material on the alveolar bone defect, and fixed with either screw, plate, or implant. Guided bone regeneration is a technique that fills the defective bone area with bone grafting material and covers with barrier membrane.^(6,8) Ongoing researches are being conducted to develop proper vertical ridge augmentation methods, that are simple, and could provide predictable outcomes, with less complications. Besides exploring different vertical bone augmentation techniques, the use of autogenous bone graft, bone substitutes, and diverse types and forms of barrier membranes are also being investigated. However, the efficiencies of the reported methods still varied among different studies.^(8,9)

This study aims to compare the effectiveness of various vertical ridge augmentation techniques, by evaluating vertical bone gain, resorption levels of the alveolar ridge after complete healing, the occurrence of postoperative complications, the survival and success rates of dental

implants placed in those areas.

Materials and Methods

Protocol development and research question

This systematic review used the updated PRIS-MA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as the reporting guideline.⁽¹⁰⁾ The study protocol was developed and registered with the International Prospective Register of Systematic Reviews (PROSPERO), with the registration number of CRD42024508826. The research question was "In patients with vertical alveolar ridge deficiency, what is the effectiveness of various vertical ridge augmentation techniques on vertical bone gain?" It could be written in PICO format, as follows: participant (P), patients with vertical alveolar ridge deficiency; intervention (I), any ridge augmentation techniques used as intervention; comparator (C), any ridge augmentation techniques used as control; and outcome (O), vertical bone gain as the primary outcome while the resorption level after complete healing, postoperative complications, the survival and success rates of implants placed at the augmentation sites were considered as secondary outcomes. In this study, only the randomized clinical controlled trials (RCTs) were included for the review.

Search strategy

An electronic search for relevant studies was performed in MEDLINE, EMBASE, Scopus, and CENTRAL databases from their inception date to August 22, 2025. The search strategy included only terms or keywords related to the review question, and only studies published in English language were recruited. The authors also reviewed the reference lists from previously published systematic review and/or meta-analysis on the same topic. All eligible studies from electronic databases and the reference lists will be included at this stage.

The following combination of keywords were used as search strategies which were adapted to each database: (((alveolar ridge OR alveolar bone OR alveolar crest) AND (defect* OR deficien* OR loss* OR atroph*)) OR ((Alveolar Ridge OR Alveolar bone OR Alveolar crest) AND (gain* OR augment*)) OR (Bone graft* OR Bone substitut* OR Alveolar graft*)) AND ((block graft* OR onlay graft*) OR (alveolar OR distraction osteogenes*) OR (guided bone regeneration* OR (particulat* AND

graft*)) OR (sandwich* AND techni*) OR (tent* OR pole* OR screw*)) AND (((Bone OR alveolar OR alveolar bone) AND (gain* OR height*))).

Inclusion criteria

1. Randomized controlled clinical trials in which participants were patients with vertical alveolar ridge deficiency who needed dental implant treatment.
2. Intervention treatments with DO, inlay bone graft, onlay bone graft, or guided bone regeneration
3. Comparator treatment with DO, inlay bone graft, onlay bone graft, or guided bone regeneration
4. Outcome showed vertical bone gain

Exclusion criteria

1. Case report, case series, clinical controlled trial, systematic review, or meta-analysis.
2. Vertical bone augmentation at posterior maxilla with osteotome sinus floor elevation or lateral window approach
3. Vertical bone evaluation after socket preservation

Literature screening and data extraction

Relevant studies retrieved from the databases and the manual search were imported to the Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia (available at www.covidence.org), where the duplicates were removed. The remaining studies were screened through their titles and abstracts by 2 reviewers (C.K. and P.T.) and selected according to the inclusion and exclusion criteria. Full text articles of potentially eligible studies were retrieved and independently assessed by the two reviewers (C.K. and P.T.). When disagreements or uncertainties regarding the eligibility of a study occurred, they were resolved by discussions with a third reviewer (M.S.). Reasons for the exclusion of any study were recorded.

The authors used a prepared form to record the required data from the included studies. Data extraction was done by the two reviewers (C.K. and P.T.), who independently read the full-text articles of the studies included. If there is any disagreement, the third reviewer (M.S.) will be consulted. The extracted data included the following: first author's name, publication year, mean age $\pm$ standard deviation (or median age and range), gender, type of study design, sample size (classified by number of surgical sites and implants), surgical technique defined as intervention, surgical technique defined as control, bone grafting mate-

rials, source of bone graft, barrier membranes, special procedures (such as simultaneous implant placement, using tenting screw), follow-up time (healing period), primary outcome (vertical bone gain), secondary outcomes (bone resorption, complications, implant survival and success rate), measurement methods, statistical value, and information for assessment of the risk of bias.

Qualitative assessment (risk of bias)

The quality of the included RCTs, or risk of bias, was independently assessed by 2 reviewers (C.K. and P.T.) and any disagreement will be resolved by discussing with the third reviewer (M.S.). The Cochrane risk-of-bias assessment tool version 2 (RoB 2) was used for quality assessment of each randomized controlled trial.⁽¹¹⁾ The tools evaluated five aspects as follows: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each randomized controlled study was rated as low risk, some concerns, or high risk of bias. The RoB 2 assessment of all included studies will be visualized using robvis, a tool that generates risk-of-bias plots.⁽¹²⁾

Outcome parameters

This study collected vertical bone gain (mm) at complete healing period as the primary outcome. If the included studies reported the level of bone resorption, the presence of postoperative complications, or the implant survival or success rates, these outcomes were recorded as secondary outcomes. Vertical bone gain and bone resorption were compared according to types of surgical techniques.

Results

Initial literature search via electronic databases and the manual search revealed 5,000 relevant studies which were retrieved as follows: 1,772 studies from CENTRAL, 1,081 studies from PubMed, 1,148 studies from Embase, 999 studies from Scopus, and 43 studies from the manual search. After removal of 1,613 duplicate studies, 3,430 studies were screened from their titles and abstracts which resulted in exclusion of 3,356 studies. The full-text articles of the 74 relevant studies were retrieved, and extensively assessed for their eligibility, mainly in their Material and Methods and Results sections. Consequently, 45 studies

were excluded with the reasons shown in Figure 1, and finally 29 RCT studies were eligible to be included in this review. The extracted data of baseline characteristics (augmentation technique, bone grafting material, source of bone, type of membrane, special procedure) of the included studies⁽¹³⁻⁴¹⁾, were shown in Table 1. Vertical bone gain and bone resorption according to the types of surgical techniques were shown in Tables 2-5. The complications, implant survival and success rates from the included studies were summarized in Table 6.

Risk of bias assessment

Qualitative assessment of the included studies was performed by using RoB 2 tool, which categorized the studies as having low (1 study), some concerns (16 studies) and high (12 studies) risk of bias as shown in Figure 2. The overall risk of bias, in percentages, were depicted as low in 3.45%, some concern in 55.17%, and high in 41.38% of the studies included (Figure 3).

Data analysis

All included studies compared either two or three surgical techniques in each study. The surgical techniques of vertical bone augmentations studied include distraction osteogenesis (DO), the inlay or onlay bone graft, and the guided bone regeneration (GBR) techniques. From the 29 included studies, there were 3 studies of DO, 8 studies of onlay (bone block) graft, 7 studies of inlay bone graft (sandwich technique), and 19 studies of GBR technique. The details of the surgical techniques, their group assignments, bone grafting materials, membranes use, and any additional procedures performed in each study were shown in Table 1.

From the 3 studies that used DO to increase alveolar bone height, the vertical bone gain, at completion of distraction period, ranged from 5.33 ± 1.58 mm to 10.36 ± 2.96 mm. However, only one study showed final vertical bone gain of 8.38 ± 1.74 mm after 3 to 4 months of healing period (Table 2). By using the inlay bone grafting technique,

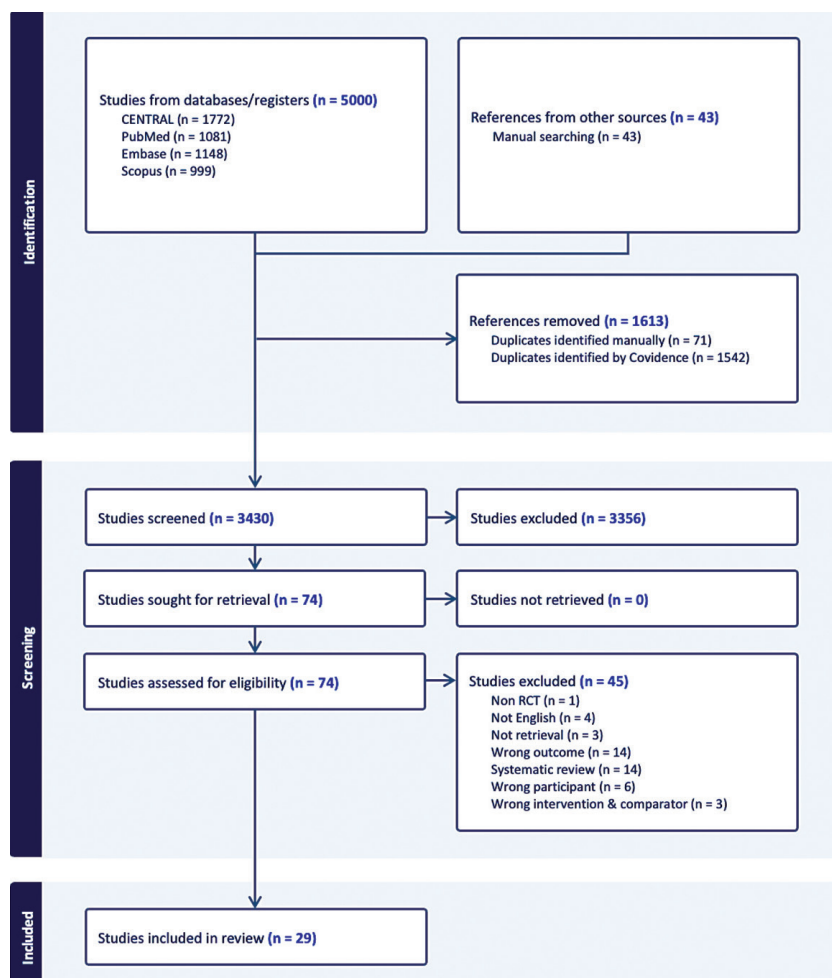


Figure 1: PRISMA flow diagram of included studies.

immediate vertical bone gain ranged from 5.10 ± 1.10 mm to 6.20 ± 2.20 mm. This technique showed final vertical bone gain from 2.69 ± 0.37 mm to 7.00 ± 1.76 mm after the healing period of 3 to 6 months (Table 3). With the onlay bone grafting technique, immediate vertical bone gain ranged from 2.90 ± 0.90 mm to 6.52 ± 1.11 mm, while the final bone gains were from -0.02 ± 1.86 mm to 4.80 ± 1.50 mm, which demonstrated bone height decrease overtime. Interestingly, El Zhawy and colleagues⁽²³⁾ reported the highest level of bone graft resorption at 4.77 ± 1.67 mm, (Table 4).

The GBR technique showed immediate vertical bone gain ranged from 2.73 ± 0.79 mm to 6.37 ± 0.71 mm, and final vertical bone gain ranged from 1.50 ± 1.60 mm to 6.86 ± 0.94 mm (Table 5). From the GBR studies, most of them demonstrated some degree of bone resorption at the complete healing period, which then resulted in the lower level of final vertical bone gain (VBG) when compared with the immediate post-op VBG. However, some studies showed no bone resorption at the complete healing period, which led to a somewhat higher final VBG relative to the immediate post-op VBG. These outcomes may be influenced by the differences in the GBR techniques used in those studies.

Data extraction of the complications, implant survival, and success rates from the vertical augmentation techniques, from all the included studies were shown in Table 6. The complications associated with the DO technique mainly included lingual inclination of the distracted bone, incomplete distraction, and infection. Whereas wound dehiscence, infection, neurosensory disturbance, and graft loss were the complications observed from the other techniques. Complication rates varied substantially by technique: DO ranged from 20% to 60%, while the ranges for inlay bone graft, onlay bone graft, and GBR were 0% to 100%, 0% to 88.89%, and 0% to 46.67%, respectively (Table 7). Survival and success rates of the implants placed in the vertically augmented bone were reported in 17.24% (5 out of 29 studies) and 13.79% (4 out of 29 studies) of the included studies, respectively. Implant placements after DO, inlay, and onlay grafting techniques had 100% implant survival rate. However, one study reported 94% to 97% of implant survival rates from the GBR technique. The success rate, at one year, of implants placed in the bone which had undergone DO ranged from 93.7% to 100%. From the inlay technique, the implant success rates were shown to be at 95.2% (at 1 year) and went down to 90% (at 17 to 22 months). Implants placed following onlay bone augmentation demonstrated success rates ranging from 86.9% to 89.5% (at 1 to 2 years). For GBR technique, there was one included study demonstrated success and survival rates.⁽¹⁸⁾ The survival rate of GBR was 100%. The success rate of GBR technique with simultaneous implant placement was 61.5% at 2 to 3 years, while GBR technique alone was 75% at 2 to 3 years.

The summary of outcomes for each vertical bone augmentation technique was presented in Table 7. DO



Figure 2: Risk of bias of each study.

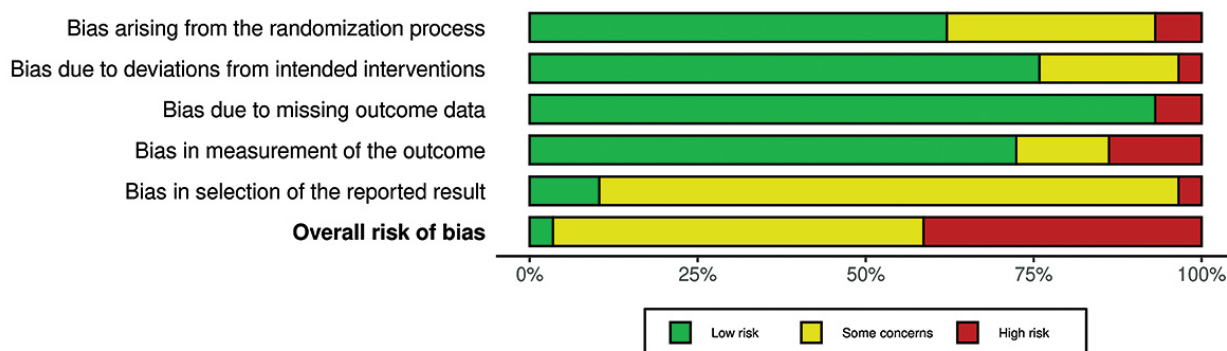


Figure 3: Risk of bias domains in percentage.

provided the most final vertical bone gain, while onlay bone graft resulted in the lowest. In terms of bone resorption, onlay bone graft also demonstrated the highest range, while inlay bone graft showed the lowest. The highest range of complication rate was associated with inlay bone graft, while GBR showed the lowest range. Although implant survival rates were generally high across all techniques, implant success rates showed notable variability, ranging from 61.5% to 94.7% depending on the specific technique and follow-up duration.

Discussions

The objective of the study was to compare the effectiveness of various surgical vertical augmentation techniques by looking at the outcomes of vertical bone gain, resorption of the alveolar ridge after bone remodeling, complications from the treatments, as well as the success and survival rates of implants placed in the areas where the alveolar ridge height has been surgically increased.

Distraction osteogenesis

Distraction osteogenesis resulted in the highest final vertical bone gain (8.38 ± 1.74 mm) compared to the other techniques, despite the occurrence of some bone resorption during the healing process. From the review of our included studies, final vertical bone gain from the DO technique was comparable to that reported in other non-RCT studies. Marianetti and colleagues⁽⁴²⁾ reported mean vertical bone gain after distraction osteogenesis of 10.5 mm (range 7-17 mm). Sezer and colleagues⁽⁴³⁾ reported mean vertical bone gain of 7.2 ± 0.8 mm. Mohanty and colleagues⁽⁴⁴⁾ claimed that their results of vertical bone gains ranged from 6 to 11 mm. Distraction osteogenesis

seem to provide large amount of bone gain. Most likely, it could be that the distracted bones are autogenous bones, and they are attached to soft tissues which provide sufficient blood supply to the bone segment. At the same time, during the distraction phase, new soft tissue is created along the tension direction from the distraction device (distraction histogenesis) and receives blood supply from the new bone formation process between the bone segment and the bone base.⁽⁴⁵⁾ Although DO showed good results in vertical bone gain, bone resorption still occurred. Mean bone resorption of the included studies ranged from 0.3 ± 0.3 to 1.98 ± 1.34 mm. The results were in accordance with previous retrospective studies.^(46,47) Reininger and colleagues⁽⁴⁶⁾ has shown that average bone resorption was 1.4 ± 0.5 mm, and the rate of resorption ranged from 7% to 25%. From the study of Ettl and colleagues⁽⁴⁷⁾, it was shown that mean bone resorption was 1.8 mm with the resorption rate of 21.1%. From the reported rates of resorption, overcorrection of the distraction length at least 20% would be recommended. Complications can be found at all stages of the procedure. From our review, lingual inclination of the distracted segments was observed in all the 3 DO RCT studies, with some reports of infection and incomplete distraction.^(15,18,19) Previous studies have reported other complications from the DO technique such as basal bone fracture, inadequate vestibular depth after complete distraction, and device failure.⁽⁴⁷⁻⁵¹⁾ As for the success rates of dental implants placed in the vertically increased bone height by DO technique, the 3 included RCTs demonstrated 94.1% to 94.7% success, at 2 to 3 years, which was lower than the reported 100% success rate from the retrospective study of Sezer and colleagues.⁽⁴³⁾ However, since the number of RCTs for vertical bone

augmentation by DO is still low, it might be difficult to conclude the implant success rate in distracted alveolar bone.

Inlay technique

The inlay bone grafting or sandwich technique demonstrated high amounts of final vertical bone gain in the included studies, with the highest bone gain of 7.00 ± 1.76 mm (Table 3). Bone resorption from the inlay technique ranged from 0.60 ± 0.40 mm to 1.65 ± 0.94 mm, which was relatively lower than those from the other vertical augmentation techniques. The bone resorption level was comparable to that from the previous meta-analysis study which showed bone resorption ranging from 0.50 to 2.3 mm.⁽⁵²⁾ The main benefit of the inlay technique is that blood supply to the osteotomized segments could be maintained⁽⁵³⁾, which could be a possible reason for the lesser bone resorption when compared to other techniques. Moreover, the types of bone grafting materials used e.g. bone block, or particulate bone may influence the healing potential within the inlay grafting area. The particulate bone could be more closely adapted to the recipient site when compared to the bone block, therefore, grafting with the mix of bone substitutes could be beneficial for the bone regeneration in the grafting area.⁽⁵⁴⁾ From the reviewed studies, the most reported complication associated with the inlay bone grafting technique was temporary neurosensory disturbance of inferior alveolar nerve, which is in agreement with previous studies.⁽⁵⁵⁻⁵⁹⁾ In addition, wound dehiscence and fracture of bone fragment have been reported in the included studies, which were consistently shown in previous studies.⁽⁶⁰⁻⁶⁵⁾ The implant survival rates of included studies were 100% and the success rates were 95.2% (at 1 year) and 90% (at 17 to 22 years) (Table 6). The results were comparable to the previous meta-analysis study which reported the survival rate ranging from 92% to 100% and the success rate ranging from 87.2% to 96.8%.⁽⁵²⁾

Onlay technique

By using the onlay bone grafting technique, final vertical bone gain from the included studies ranged from -0.02 ± 1.86 mm to 4.80 ± 1.50 mm. However, this bone grafting technique showed higher degrees of bone resorption (0.60 ± 0.70 mm to 4.77 ± 1.67 mm) (Table 4) when compared to the other bone grafting techniques. In the

8 included studies, the edentulous ridges were vertically augmented with autogenous bone blocks, the remaining gaps were filled with particulate bone autograft and the block grafts were fixed with titanium screws in 7 studies or dental implants in 1 study. From these studies, it is apparent that onlay bone grafting with simultaneous implant placement for fixation resulted in high degree of bone resorption than the bone blocks fixed with titanium screws. The staged onlay graft could provide sufficient vertical bone volume before implant placement, then primary stability of implant could be achieved.⁽⁶⁶⁾ The primary challenge with the onlay bone augmentation technique is soft tissue management to ensure complete wound closure. Due to high resorption rate during the first year, the grafts should be harvested in larger sizes to account for volume loss during the initial resorption phase.⁽⁸⁾ The complications associated with onlay bone grafting consisted of wound dehiscence, graft loss, graft mobility, paresthesia, infection, and crack of bone block. Only 2 of the studies reported the implant survival rate of 100%, while the implant success rates were lower than 90%. The implant survival and success rates from our study were consistent to a previous systematic review which reported implant survival rate ranged from 72.8% to 100%, and implant success rate ranged from 86.9% to 100%.⁽⁸⁾

Guided bone regeneration

The GBR technique was the preferred technique for vertical bone augmentation as seen from the largest number of treatment arms in all included studies. It is a versatile procedure which could be adapted and modified in many alveolar bone grafting conditions. The GBR techniques may vary in terms of surgical process, the types of bone substitutes, types of membrane used, and with or without simultaneous implant placement. However, there were complications from this procedure especially wound dehiscence.^(67,68)

The use of GBR technique resulted in final vertical bone gain ranging from 1.50 ± 1.60 mm to 6.86 ± 0.94 mm (Table 5). The large gap between the lower and upper range of bone gains might be due to the use of varying surgical techniques, bone grafting materials and barrier membranes in each study. Bone resorption at the complete healing period ranged from -0.81 ± 0.74 mm to 2.32 ± 1.09 mm. Interestingly, negative values of bone resorption

were shown in 3 studies^(20,32,38), which represented some bone gain rather than resorption. These negative values of bone resorption were presented in the studies that used GBR techniques with simultaneous implant placement and therefore resulted in the higher final bone gain when compared to the immediate post-operative vertical bone gain. This might be the result of a process where, after implant placement and the addition of bone grafting materials, the barrier membranes were adapted to cover above the shoulder of the implants. The barrier membranes used in these three studies^(20,32,38) were non-resorbable membranes (PTFE or titanium mesh), which might create a space-maintaining effect allowing for more bone growth.⁽⁶⁹⁾ In addition, the bone grafting materials used in these studies were either combinations of autograft and allograft or xenograft, which promote bone growth with the biological mechanisms of osteogenesis, osteoinduction and osteoconduction.⁽⁷⁰⁾ However, other studies that used non-resorbable membranes and the combinations of bone grafting materials did not provide the same results. The frequently occurred complications associated with GBR techniques included wound dehiscence, paresthesia, infection, and membrane exposure. The implant survival rates were higher than 90%. The implant success rates following one year in the group using GBR technique were higher than 80%. However, they ranged from 61.5% (at 2 to 3 years) to 75% (at 2 to 3 years). The lowest success rate (61.5%) was noticeable in the study of Chiapasco and colleagues⁽¹⁸⁾, that utilized the GBR technique with simultaneous implant placement.

From all vertical ridge augmentation techniques reviewed in this study, DO yielded the greatest final vertical bone gain, followed by inlay bone grafting, GBR, and onlay bone grafting. Regarding bone resorption and complications, onlay bone grafting demonstrated the highest degree of bone resorption. Inlay bone grafting had the highest complication rate, whereas GBR showed the lowest complication rate. Despite the limited number of studies that reported on implant survival and success rates, all vertical augmentation techniques demonstrated high implant survival rates. However, implant success rates were notably different in two augmentation techniques i.e. highest implant success rate was achieved with DO, while the lowest success rate was shown in the GBR technique. It is important to note that these reported success rates were assessed at varying follow-up periods (Table 7).

Limitation

This study is a systematic review which aims to collect and analyze only randomized clinical controlled studies. However, the number of randomized clinical controlled studies of vertical ridge augmentation was rather minimal and varied in terms of the parameter studied which, in turn, affected the data gathering of each surgical technique, number of participants, and lack of secondary outcomes in some studies. In addition, the restriction of included studies to only English-language publications is another limitation of this study. Moreover, the clinical heterogeneity between the studies was high; as a result, it was not suitable for performing the meta-analysis. Therefore, future studies should be properly designed and conducted.

Table 1: Characteristics of included studies.

Author (year)	Type of RCT	Mean age ± SD or median age (Min to Max) (years)	Male/female	Treatment arm	Technique	Bone grafting material	Source of bone	Membrane	Special procedure	p value between groups of final VBG
Abrahamsson <i>et al.</i> 2012 ⁽¹³⁾	Parallel	20 (18 to 49)	6/4	Control	Onlay	Block autograft	Lateral border of mandible using Piezosurgery	Not used	Titanium screw fixation	N/A
		22 (18 to 55)	8/2	Test	GBR	Particulate autograft	Lateral border of mandible using bone scraper	Titanium mesh, collagen membrane	Soft tissue expansion before GBR	
Al-Dubai <i>et al.</i> 2023 ⁽¹⁴⁾	Parallel	N/A	5/11	Control	Inlay	Particulate xenograft	Bovine xenograft	Not used	Microplate and microscrew fixation	0.518
				Test	Inlay	Particulate xenograft	Bovine xenograft	Not used	Simultaneous implant placement for fixation	
Bianchi <i>et al.</i> 2008 ⁽¹⁵⁾	Parallel	42 (25 to 55)	3/2	Control	DO	N/A	N/A	N/A	N/A	0.003
		47 (30 to 55)	3/3	Test	Inlay	Block autograft	Medial surface of iliac crest	Not used	Miniplate and miniscrew fixation	
Byun <i>et al.</i> 2020a ⁽¹⁶⁾	Parallel	57.86±13.22	14/7	Control	GBR	Particulate xenograft	Bovine xenograft	Titanium-reinforced d-PTFE	N/A	N/A
		54.35±13.99	10/7	Test (TEG)	GBR	Particulate xenograft	Bovine xenograft	Titanium-reinforced d-PTFE	Soft tissue expansion before GBR (TEG)	
		57.63±10.38	6/13	Test (TET)	GBR	Particulate xenograft	Bovine xenograft	Collagen membrane	Soft tissue expansion before GBR with tunneling technique (TET)	
Byun <i>et al.</i> 2020b ⁽¹⁷⁾	Parallel	61.13±11.13	15/8	Control	GBR	Particulate xenograft	Bovine xenograft	Titanium-reinforced d-PTFE	No soft tissue expansion. Tenting screws were used in some cases.	N/A
		54.13±12.66	9/14	Test (TET)	GBR	Particulate xenograft	Bovine xenograft	Collagen membrane	Soft tissue expansion before GBR with tunneling technique (TET)	
Chiapasco <i>et al.</i> 2004 ⁽¹⁸⁾	Parallel	35 (18 to 55)	N/A	Control	DO	N/A	N/A	N/A	N/A	N/A
		48 (31 to 57)	N/A	Test (A)	GBR	Particulate autograft	Chin and/or ramus of mandible	Titanium-reinforced e-PTFE	Simultaneous implant placement for supporting membrane	
		39 (28 to 59)	N/A	Test (B)	GBR	Particulate autograft	Chin and/or ramus of mandible	Titanium-reinforced e-PTFE	Titanium screws for supporting membrane	
Chiapasco <i>et al.</i> 2007 ⁽¹⁹⁾	Parallel	42 (18 to 55)	6/3	Control	DO	N/A	N/A	N/A	N/A	N/A
		46 (30 to 57)	2/6	Test	Onlay	Block autograft, filled gap with cancellous bone or milled cortical bone remnant	Ramus of mandible using fissure bur and chisels	Not used	Titanium miniscrew fixation	
Cucchi <i>et al.</i> 2017 ⁽²⁰⁾	Parallel	52	13/27	Control	GBR	50% particulate autograft, 50% particulate allograft	External oblique ridge of mandible using bone scraper, allograft	Titanium mesh, cross-linked collagen membrane	Simultaneous implant placement	0.58
				Test	GBR	50% particulate autograft, 50% particulate allograft	External oblique ridge of mandible using bone scraper, allograft	Titanium-reinforced d-PTFE	Simultaneous implant placement	

GBR: Guided bone regeneration; DO: Distraction osteogenesis; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; d-PTFE: dense polytetrafluoroethylene; e-PTFE: expanded polytetrafluoroethylene; N/A: Not applicable

Table 1: Characteristics of included studies (continue 1).

Author (year)	Type of RCT	Mean age ± SD or median age (Min to Max) (years)	Male/female	Treatment arm	Technique	Bone grafting material	Source of bone	Membrane	Special procedure	p value between groups of final YBG
Cucchi <i>et al.</i> 2021 ⁽²¹⁾	Parallel	N/A	7/8	Control	GBR	50% particulate autograft, 50% particulate xenograft	Posterior mandible using bone scraper, porcine xenograft	Custom made titanium mesh	N/A	0.11
			8/7	Test	GBR	50% particulate autograft, 50% particulate xenograft	Posterior mandible using bone scraper, porcine xenograft	Custom made titanium mesh, cross-linked collagen membrane	N/A	
Cucchi <i>et al.</i> 2024 ⁽²²⁾	Parallel	59 (30 to 70)	9/16	Control	GBR	50% particulate autograft, 50% particulate xenograft	Autograft source N/A but using bone scraper, bovine xenograft	Titanium-reinforced d-PTFE, collagen membrane	Titanium-reinforced d-PTFE was adapted to augmented 3D model before applied to surgical site	0.233
			5/20	Test	GBR	50% particulate autograft, 50% particulate xenograft	Autograft source N/A but using bone scraper, bovine xenograft	Custom made titanium mesh, collagen membrane	N/A	
El Zahwy <i>et al.</i> 2019 ⁽²³⁾	Parallel	38 (24 to 47) 39 (31 to 48)	6/2	Control	Onlay	Block autograft, filled gap with milled cancellous bone	Chin	Not used	Block graft fixed with implants	N/A
			4/4	Test	Inlay	Block autograft, filled gap with milled cancellous bone	Chin	Not used	Block graft fixed with implants	
Felice <i>et al.</i> 2008 ⁽²⁴⁾	Split-mouth	54 (32 to 73)	4/6	Control	Inlay	Block autograft, filled gap with particulate iliac bone	Iliac crest	Collagen membrane	Miniplate and miniscrew fixation	N/A
				Test	Inlay	Block xenograft, filled gap with particulate xenograft from block	Bovine xenograft	Collagen membrane	Miniplate and miniscrew fixation	
Felice <i>et al.</i> 2009 ⁽²⁵⁾	Parallel	54.5 (39 to 63) 55.5 (30 to 75)	2/8	Control	Onlay	Block autograft, filled gap with particulate iliac bone	Iliac crest	Collagen membrane	Titanium miniscrew fixation	0.19
			4/6	Test	Inlay	Block autograft, filled gap with particulate iliac bone	Iliac crest	Collagen membrane	Miniplate and miniscrew fixation	
Felice <i>et al.</i> 2024 ⁽²⁶⁾	Parallel	56.37±10.14	12/15	Control	GBR	80% particulate autograft, 20% particulate xenograft	Ramus of mandible using bone scraper, porcine xenograft	Titanium-reinforced PTFE	N/A	0.867
				Test (Mesh)	GBR	80% particulate autograft, 20% particulate xenograft	Ramus of mandible using bone scraper, porcine xenograft	Custom made titanium mesh	N/A	
				Test (Foil)	GBR	80% particulate autograft, 20% particulate xenograft	Ramus of mandible using bone scraper, porcine xenograft	Custom made titanium foil	N/A	
Fontana <i>et al.</i> 2008 ⁽²⁷⁾	Split-mouth	55 (47 to 66)	0/5	Control	GBR	Particulate autograft	Retromolar region	Titanium-reinforced e-PTFE	Tenting screw and mini-implant support membrane	N/A
				Test	GBR	Particulate allograft	Allogenic bone matrix	Titanium-reinforced e-PTFE	Tenting screw and mini-implant support membrane	

GBR: Guided bone regeneration; DO: Distraction osteogenesis; d-PTFE: dense polytetrafluoroethylene; e-PTFE: expanded polytetrafluoroethylene; N/A: Not applicable

Table 1: Characteristics of included studies (continue 2).

Author (year)	Type of RCT	Mean age ± SD or median age (Min to Max) (years)	Male/female	Treatment arm	Technique	Bone grafting material	Source of bone	Membrane	Special procedure	p value between groups of final VBG
Giragosyan <i>et al.</i> 2024 ⁽²⁸⁾	Parallel	N/A	N/A	Control	GBR	50% particulate autograft, 50% particulate xenograft	Oblique line of mandible using bone scraper, xenograft	Titanium-reinforced d-PTFE	N/A	0.4
				Test	GBR	50% particulate autograft, 50% particulate xenograft	Oblique line of mandible using bone scraper, xenograft	Custom made titanium mesh	N/A	
Helal <i>et al.</i> 2025 ⁽²⁹⁾	Split-mouth	47 (36 to 56)	4/6	Control	Onlay	CAD/CAM allograft block	Allograft bone block	Nonporous d-PTFE	Bone block hydrated with saline, titanium screw fixation	0.0001
				Test	Onlay	CAD/CAM allograft block	Allograft bone block	Nonporous d-PTFE	Bone block hydrated with hyaluronic acid, titanium screw fixation	
Kawakami <i>et al.</i> 2013 ⁽³⁰⁾	Split-mouth	52.1	3/9	Control	Inlay	Block autograft, filled gap with particulate autograft	Intraoral bone	Not used	Titanium osteosynthesis miniplates and miniscrews fixation	>0.05
				Test	Inlay	Mix of alloplast powder and pellet	resorbable non-ceramic hydroxylapatite (nHA)	Not used	Titanium osteosynthesis miniplates and miniscrews fixation	
Leong <i>et al.</i> 2015 ⁽³¹⁾	Parallel	59.4 ± 7.5	10/6	Control	GBR	Particulate cancellous allograft (on ridge), particulate cortical allograft (second layer)	Cancellous allograft, cortical allograft	Collagen membrane	Tenting screws for supporting membrane	0.305 (Clinical)
				Test	Onlay	Block allograft	Block allograft	Collagen membrane	Titanium screw fixation (2 or more)	0.321 (CBCT)
Maiorana <i>et al.</i> 2021 ⁽³²⁾	Split-mouth	54.2 ± 12.5	1/4	Control	GBR	50% particulate autograft, 50% particulate xenograft	Retromolar region using bone scraper, bovine xenograft	Titanium mesh	Tenting screw and mini-implant support membrane	0.1
				Test	GBR	50% particulate autograft, 50% particulate xenograft	Retromolar region using bone scraper, bovine xenograft	Titanium-reinforced d-PTFE	Tenting screw and mini-implant support membrane	
Merli <i>et al.</i> 2007 ⁽³³⁾	Parallel	49.9 (36 to 69)	1/10	Control	GBR	Particulate autograft	Various intraoral bone	Titanium-reinforced e-PTFE	Simultaneous implant placement	0.58
		44.6 (29 to 59)	3/8	Test	GBR	Particulate autograft	Various intraoral bone	Collagen membrane	Simultaneous implant placement, osteosynthesis plates and screws for supporting membrane	
Morad <i>et al.</i> 2013 ⁽³⁴⁾	Split-mouth	55.8 (49 to 62)	2/4	Control	Onlay	Block autograft (double layer), covered with particulate xenograft	Ramus of mandible using fissure bur, bovine xenograft	Not used	Screws fixation	0.051
				Test	GBR	Block autograft as cortical tenting, filled internal space with 50% particulate autograft and 50% xenograft	Ramus of mandible using fissure bur (for block), particulate autograft harvested from area of harvested block, bovine xenograft	Not used	Screws fixation	

GBR: Guided bone regeneration; DO: Distraction osteogenesis; d-PTFE: dense polytetrafluoroethylene; e-PTFE: expanded polytetrafluoroethylene; N/A: Not applicable

Table 1: Characteristics of included studies (continue 3).

Author(year)	Type of RCT	Mean age ± SD or median age (Min to Max) (years)	Male/female	Treatment arm	Technique	Bone grafting material	Source of bone	Membrane	Special procedure	p value between groups of final VBG
Moussa <i>et al.</i> 2024 ⁽³⁵⁾	Split-mouth	44.7±7.35	4/6	Control	Inlay	Particulate xenograft	Bovine xenograft	Not used	Conventional technique	0.001
				Test	Inlay	Particulate xenograft	Bovine xenograft	Not used	Two patient-specific guides for osteotomy and fixation	
Moustafa <i>et al.</i> 2025 ⁽³⁶⁾	Split-mouth	38.2±2.39	6/4	Control	GBR	50% particulate autograft, 50% particulate xenograft	Symphysis of mandible using Auto Chip Maker bur, bovine xenograft	Titanium mesh	N/A	0.095
				Test	GBR	Particulate xenograft	Bovine xenograft	Titanium mesh	Particulate xenograft mixed with bone marrow aspirate concentrate (BM/MAC)	
Rocuzzo <i>et al.</i> 2007 ⁽³⁷⁾	Parallel	49 (20 to 60) 50.5 (34 to 68)	3/9 4/8	Control	Onlay	Block autograft, filled gap with particulate autograft	Ramus and angle of mandible	Not used	Titanium screw fixation	N/A
				Test	Onlay	Block autograft, filled gap with particulate autograft	Ramus and angle of mandible	Titanium mesh	Titanium screw fixation	
Ronda <i>et al.</i> 2014 ⁽³⁸⁾	Parallel	49.6±11.6	1/22	Control	GBR	50% particulate autograft, 50% particulate allograft	Autograft source N/A but collected using bone scraper, allograft	Titanium-reinforced e-PTFE	Simultaneous implant placement	N/A
				Test	GBR	50% particulate autograft, 50% particulate allograft	Autograft source N/A but collected using bone scraper, allograft	Titanium-reinforced d-PTFE	Simultaneous implant placement	
Shaker <i>et al.</i> 2024 ⁽³⁹⁾	Parallel	N/A	8/8	Control	GBR	50% particulate autograft, 50% particulate xenograft	Autograft source N/A but collected using bone scraper, bovine xenograft	Titanium-reinforced PTFE	N/A	0.569
				Test	GBR	Autogenous cortical bone shell, 50% particulate autograft, 50% particulate xenograft	External oblique ridge using piezo/surgical disc and bone scraper, bovine xenograft	Not used	Khouri's bone shell technique	
Shomurov <i>et al.</i> 2023 ⁽⁴⁰⁾	Parallel	44.5±3.6 45.3±3.8	12/8 9/9	Control	GBR	50% particulate autograft, 50% particulate xenograft	Retromolar region, porcine xenograft	N/A	N/A	<0.05
				Test	GBR	50% particulate autograft, 50% particulate xenograft	Retromolar region, porcine xenograft	N/A	Soft tissue expansion before GBR	
Urban <i>et al.</i> 2025 ⁽⁴¹⁾	Parallel	51.2±10.6	5/10 4/11	Control	GBR	50% particulate autograft, 50% particulate xenograft	Autograft from adjacent grafting area using bone scraper, bovine xenograft	Titanium-reinforced d-PTFE	N/A	0.68
				Test	GBR	50% particulate autograft, 50% particulate xenograft	Autograft from adjacent grafting area using bone scraper, bovine xenograft	Titanium-reinforced d-PTFE, collagen membrane	N/A	

GBR: Guided bone regeneration; DO: Distraction osteogenesis; d-PTFE: dense polytetrafluoroethylene; e-PTFE: expanded polytetrafluoroethylene; N/A: Not applicable

Table 2: Alveolar ridge measurements following vertical bone augmentation with distraction osteogenesis.

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMD)	Number of implants (AMX/PMX/AMD/PMD)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Bianchi <i>et al.</i> 2008 ⁽¹⁵⁾	Control	5 (0/0/0/5)	16 (0/0/0/16)	10.36±2.96	3 to 4	1.98±1.34	8.38±1.74	CBCT
Chiapasco <i>et al.</i> 2004 ⁽¹⁸⁾	Control	10 (Maxilla/Mandible=1/9)	34 (1/3/12/18)	6.58±1.38	2 to 3	0.37±0.40	N/A	Periapical film
Chiapasco <i>et al.</i> 2007 ⁽¹⁹⁾	Control	9 (0/0/0/9)	21 (0/0/7/14)	5.33±1.58	2 to 3	0.30±0.30	N/A	Periapical film

VBG: Vertical bone gain; AMX: Anterior maxilla; PMX: Posterior maxilla; AMD: Anterior mandible; PMD: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 3: Alveolar ridge measurements following vertical bone augmentation with inlay bone grafting.

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMD)	Number of implants (AMX/PMX/AMD/PMD)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Al-Dubai <i>et al.</i> 2023 ⁽¹⁴⁾	Control	8 (8/0/0/0) 8 (8/0/0/0)	18 (18/0/0/0) 17 (17/0/0/0)	N/A N/A	4 4	N/A N/A	3.86±0.52 4.04±0.59	CBCT
Bianchi <i>et al.</i> 2008 ⁽¹⁵⁾	Test	7 (0/0/0/7)	21 (0/0/0/21)	5.91±0.76	3 to 4	0.89±0.27	5.03±0.58	CBCT
El Zahwy <i>et al.</i> 2019 ⁽²³⁾	Test	8 (8/0/0/0)	20 (20/0/0/0)	N/A	6	1.65±0.94	3.34±1.20	CBCT
Felice <i>et al.</i> 2008 ⁽²⁴⁾	Control Test	10 (0/0/0/10) 10 (0/0/0/10)	Total 38 both control and test	5.10±1.10 6.20±2.20	4 4	1.10±1.80 0.60±0.40	N/A N/A	CBCT
Felice <i>et al.</i> 2009 ⁽²⁵⁾	Test	10 (0/0/0/10)	20 (0/0/0/20)	5.24±1.11	3 to 4	0.72±0.80	4.52±1.19	CBCT
Kawakami <i>et al.</i> 2013 ⁽³⁰⁾	Control Test	11 (0/0/0/11) 11 (0/0/0/11)	22 (0/0/0/22) 22 (0/0/0/22)	N/A N/A	6 6	N/A N/A	6.50±2.40 7.00±1.76	CBCT
Moussa <i>et al.</i> 2024 ⁽³⁵⁾	Control Test	10 (0/0/0/10) 10 (0/0/0/10)	Total 40 both control and test	N/A N/A	4 4	N/A N/A	2.69±0.37 3.76±0.72	CBCT

VBG: Vertical bone gain; AMX: Anterior maxilla; PMX: Posterior maxilla; AMD: Anterior mandible; PMD: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 4: Alveolar ridge measurements following vertical bone augmentation with onlay bone grafting.

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMID)	Number of implants (AMX/PMX/AMD/PMID)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Abrahamsson <i>et al.</i> 2012 ⁽¹³⁾	Control	10 (10/0/0/0)	13 (13/0/0/0)	2.90±0.90	6	1.30±1.16	1.60±0.80	Clinical
Chiapasco <i>et al.</i> 2007 ⁽¹⁹⁾	Test	8 (0/0/0/8)	19 (0/0/0/19)	5.00±1.07	4 to 5	0.60±0.70	N/A	Periapical film
El Zahwy <i>et al.</i> 2019 ⁽²³⁾	Control	8 (8/0/0/0)	20 (20/0/0/0)	N/A	6	4.77±1.67	-0.02±1.86	CBCT
Felice <i>et al.</i> 2009 ⁽²⁵⁾	Control	10 (0/0/0/10)	23 (0/0/0/23)	6.52±1.11	3 to 4	2.88±1.13	3.64±1.05	CBCT
Helal <i>et al.</i> 2025 ⁽²⁹⁾	Control	10 (0/0/0/10) 10 (0/0/0/10)	N/A N/A	N/A N/A	6 6	N/A N/A	2.497±0.66 3.947±0.31	CBCT
Leong <i>et al.</i> 2015 ⁽³¹⁾	Test	9 (0/0/0/9)	N/A	N/A	6	N/A	Clinical 1.78 (range 0 to 5) CBCT 1.96 (range 0 to 5.19)	Clinical and CBCT
Morad <i>et al.</i> 2013 ⁽³⁴⁾	Control	6 (0/0/0/6)	N/A	6.07±1.20	4	1.58±1.11	4.48±0.52	Panoramic film
Rocuzzo <i>et al.</i> 2007 ⁽³⁷⁾	Control Test	12 (2/0/1/9) 12 (2/6/0/4)	25 (5/0/2/18) 28 (3/15/0/10)	5.50±1.20 5.70±1.50	4 to 6 4 to 6	1.90±1.10 0.90±0.80	3.60±1.40 4.80±1.50	Clinical

VBG: Vertical bone gain; AMX: Anterior maxilla; PMX: Posterior maxilla; AMD: Anterior mandible; PMID: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 5: Alveolar ridge measurements following vertical bone augmentation with guided bone regeneration.

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMD)	Number of implants (AMX/PMX/AMD/PMD)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Abrahamsson <i>et al.</i> 2012 ⁽¹³⁾	Test	10 (9/0/0/1)	10 (9/0/0/1)	4.10±1.70	6	1.10±1.60	3.00±1.40	Clinical
Byun <i>et al.</i> 2020a ⁽¹⁶⁾	Control	21 (Maxilla/Mandible=12/9)	N/A	4.32±0.97	6	2.06±1.00	N/A	CBCT
	Test (TEG)	17 (Maxilla/Mandible=5/12)	N/A	5.71±1.99	6	1.16±0.62	N/A	
	Test (TET)	19 (Maxilla/Mandible=13/6)	N/A	5.13±1.32	6	1.54±0.12	N/A	
Byun <i>et al.</i> 2020b ⁽¹⁷⁾	Control	23 (Maxilla/Mandible=13/10)	N/A	4.22±1.15	6	2.32±1.09	N/A	CBCT
	Test	23 (Maxilla/Mandible=13/10)	N/A	5.12±1.25	6	1.57±1.03	N/A	
Chiapasco <i>et al.</i> 2004 ⁽¹⁸⁾	Test (A)	6 (Maxilla/Mandible=1/5)	13 (1/0/3/9)	4.50±1.38	6 to 7	1.27±0.80	N/A	Periapical film
	Test (B)	5 (Maxilla/Mandible=4/1)	12 (5/4/0/3)	5.08±1.06	6 to 7	1.35±0.90	N/A	
Cucchi <i>et al.</i> 2017 ⁽²⁰⁾	Control	19 (0/0/0/19)	Total 108 both control and test	4.00±0.08	9	-0.20±0.70	4.10±1.00	Clinical
	Test	20 (0/0/0/20)		3.80±0.70	9	-0.50±0.60	4.20±1.00	
Cucchi <i>et al.</i> 2021 ⁽²¹⁾	Control	15 (Maxilla/Mandible=5/10)	34 (N/A)	N/A	6	N/A	4.74±2.56	CBCT
	Test	15 (Maxilla/Mandible=9/6)	37 (N/A)	N/A	6	N/A	6.36±2.31	
Cucchi <i>et al.</i> 2024 ⁽²²⁾	Control	24 (Maxilla/Mandible=10/14)	55 (N/A)	6.08±1.77	6 (Mandible)	N/A	5.79±1.71	CBCT
	Test	24 (Maxilla/Mandible=12/12)	60 (N/A)	5.59±1.68	9 (Maxilla)	N/A	5.18±1.61	
					9 (Mandible)			

VBG: Vertical bone gain; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; AMX: Anterior maxilla; PMX: Posterior maxilla; AMD: Anterior mandible; PMD: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 5: Alveolar ridge measurements following vertical bone augmentation with guided bone regeneration (continue 1).

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMD)	Number of implants (AMX/PMX/AMD/PMD)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Felice <i>et al.</i> 2024 ⁽²⁶⁾	Control	9 (N/A)	19 (N/A)	N/A	8	N/A	6.53±0.73	CBCT
	Test (Mesh)	9 (N/A)	20 (N/A)	N/A	8	N/A	6.86±0.94	
	Test (Foil)	9 (N/A)	21 (N/A)	N/A	8	N/A	6.81±2.13	
Fontana <i>et al.</i> 2008 ⁽²⁷⁾	Control	5 (0/0/0/5)	12 (0/0/0/12)	4.90±0.93	6	0.80±1.08	4.10±0.88	Clinical
	Test	5 (0/0/0/5)	13 (0/0/0/13)	5.15±0.34	6	0.45±0.37	4.70±0.48	
Giragosyan <i>et al.</i> 2024 ⁽²⁸⁾	Control	20 (N/A)	N/A	N/A	6	N/A	4.24±2.19	CBCT
	Test	20 (N/A)	N/A	N/A	6	N/A	3.65±1.73	
Leong <i>et al.</i> 2015 ⁽³¹⁾	Control	10 (0/0/0/10)	N/A	N/A	6	N/A	Clinical 1 (range -1 to 3) CBCT 0.96 (range -2 to 5.14)	Clinical and CBCT
Maiorana <i>et al.</i> 2021 ⁽³²⁾	Control	5 (0/0/0/5)	10 (0/0/0/10)	3.40±1.00	8	1.90±1.50	1.50±1.60	Clinical
	Test	5 (0/0/0/5)	11 (0/0/0/11)	4.20±1.70	8	-0.05±0.60	4.20±2.20	
Merli <i>et al.</i> 2007 ⁽³³⁾	Control	11 (Maxilla/Mandible=0/11)	55 (N/A)	2.73±0.79	4.6	0.25±0.62	2.48±1.13	Clinical
	Test	11 (Maxilla/Mandible=1/10)	42 (N/A)	2.93±0.86	4.6	0.77±1.25	2.16±1.51	
Morad <i>et al.</i> 2013 ⁽³⁴⁾	Test	6 (0/0/0/6)	N/A	6.37±0.71	4	1.17±0.41	5.20±0.76	Panoramic film

VBG: Vertical bone gain; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; AMX: Anterior maxilla; AMD: Anterior mandible; PMD: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 5: Alveolar ridge measurements following vertical bone augmentation with guided bone regeneration (continue 2).

Author (year)	Treatment arm	Number of surgical sites (AMX/PMX/AMD/PMD)	Number of implants (AMX/PMX/AMD/PMD)	VBG (immediate post-op) (mm)	Healing period (months)	Resorption (complete healing period) (mm)	Final VBG (complete healing period) (mm)	Measurement method
Moustafa <i>et al.</i> 2025 ⁽³⁶⁾	Control Test	10 (Maxilla/ Mandible=10/0) 10 (Maxilla/ Mandible=10/0)	Total 60 both control and test N/A	N/A N/A	6 6	N/A N/A	4.10±0.67 3.47±0.87	CBCT
Ronda <i>et al.</i> 2014 ⁽³⁸⁾	Control Test	13 (0/0/0/13) 13 (0/0/0/13)	40 (0/0/0/40) 38 (0/0/0/38)	4.10±1.86 4.70±1.69	6 to 7 6 to 7	-0.81±0.74 -0.80±0.76	4.91±1.78 5.49±1.58	Clinical
Shaker <i>et al.</i> 2024 ⁽³⁹⁾	Control Test	8 (0/0/0/8) 8 (0/0/0/8)	N/A N/A	N/A N/A	6 6	N/A N/A	3.56±1.12 4.20±0.46	CBCT
Shomurodov <i>et al.</i> 2023 ⁽⁴⁰⁾	Control Test	20 (Maxilla/ Mandible=8/12) 18 (Maxilla/ Mandible=6/12)	Total 96 both control and test	4.75±0.16 5.85±0.42	6 6	2.01±0.15 1.78±0.12	2.70±0.14 4.07±0.30	CBCT
Urban <i>et al.</i> 2025 ⁽⁴¹⁾	Control Test	15 (Maxilla/ Mandible=5/10) 15 (Maxilla/ Mandible=8/7)	N/A N/A	N/A N/A	9 9	N/A N/A	4.47±2.05 4.11±2.69	CBCT

VBG: Vertical bone gain; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; AMX: Anterior maxilla; AMD: Anterior mandible; PMD: Posterior mandible; CBCT: Cone beam computed tomography; N/A: Not applicable.

Table 6: Complications and implant success and survival rates.

Author (year)	Control (Number of sites, implants)	Test (Number of sites, implants)	Complications Control	Complications Test	Implant survival Control (%)	Implant survival Test (%)	Implant success Control (%)	Implant success Test (%)
Abrahamsson <i>et al.</i> 2012 ⁽¹³⁾	Onlay (10,13)	GBR (10,10)	None	Minor perforation during soft tissue expansion = 2 Titanium mesh exposure after GBR = 2 (Overall rate = 40%)	N/A	N/A	N/A	N/A
Al-Dubai <i>et al.</i> 2023 ⁽¹⁴⁾	Inlay (8,18)	Inlay (8,17)	Crack of bone fragment during screw fixation = 1 (Overall rate = 12.5%)	None	N/A	N/A	N/A	N/A
Bianchi <i>et al.</i> 2008 ⁽¹⁵⁾	DO (5,16)	Inlay (7,21)	Minor local infection = 1 Progressive lingual proclination = 2 (Overall rate = 60%)	Post-surgical dehiscence = 1 (Overall rate = 14.29%)	100	100	93.7 (at 1 year)	95.2 (at 1 year)
Byun <i>et al.</i> 2020a ⁽¹⁶⁾	GBR (21,N/A)	GBR (TEG) (17,N/A)	None	Over soft tissue expansion (silicone envelope tearing) = 1 (Overall rate = 5.88%)	N/A	N/A	N/A	N/A
		GBR (TET) (19,N/A)	Mucosal perforation during soft tissue expansion = 1 Over soft tissue expansion (silicone envelop tearing) = 2 (Overall rate = 15.79%)			N/A		N/A
Byun <i>et al.</i> 2020b ⁽¹⁷⁾	GBR (23,N/A)	GBR (TET) (23,N/A)	Early wound dehiscence after bone grafting = 2 (Overall rate = 8.7%)	Over soft tissue expansion (silicone envelope tearing) = 2 Mucosal perforation during soft tissue expansion = 1 (Overall rate = 13.04%)	N/A	N/A	N/A	N/A
Chiapasco <i>et al.</i> 2004 ⁽¹⁸⁾	DO (10,34)	GBR (A) (6,13)	Lingual inclination bone fragment = 2 (Overall rate = 20%)	Membrane exposure without infection = 1 Membrane exposure with infection = 1 (Overall rate = 33.33%)	100	100	100 (at 1 year) 100 (at 1-2 year) 94.1 (at 2-3 year)	84.6 (at 1 year) 76.9 (at 1-2 year) 61.5 (at 2-3 year)
		GBR (B) (5,12)		Paresthesia at chin = 1 Paresthesia at chin and membrane exposure = 1 (Overall rate = 40%)		100		83.3 (at 1 year) 83.3 (at 1-2 year) 75 (at 2-3 year)
Chiapasco <i>et al.</i> 2007 ⁽¹⁹⁾	DO (9,21)	Onlay (8,19)	Lingual inclination distracted bone fragment = 2 Incomplete distraction = 1 (Overall rate = 33.33%)	Partial graft loss due to graft exposure = 1 Transient paresthesia = 2 Permanent paresthesia = 1 (Overall rate = 50%)	100	100	100 (at 1 year) 94.7 (at 1-2 year) 94.7 (at 2-3 year) 94.7 (at 3-4 year) 94.7 (at 4-5 year)	89.5 (at 1 year) 89.5 (at 1-2 year) 89.5 (at 2-3 year) 89.5 (at 3-4 year) 89.5 (at 4-5 year)
Cucchi <i>et al.</i> 2017 ⁽²⁰⁾	GBR (19,N/A)	GBR (20,N/A)	Temporary paresthesia = 3 Abscess without exposure = 1 Early exposure with infection = 1 Late exposure without infection = 1 (Overall rate = 36.84%)	Temporary paresthesia = 1 Abscess without exposure = 1 Early exposure with infection = 1 Late exposure without infection = 1 (Overall rate = 20%)	N/A	N/A	N/A	N/A
Cucchi <i>et al.</i> 2021 ⁽²¹⁾	GBR (15,34)	GBR (15,37)	Surgical/technical complications = 2 Healing complications = 5 (Overall rate = 46.67%)	Surgical/technical complications = 4 Healing complications = 2 (Overall rate = 40%)	94	97	N/A	N/A

GBR: Guided bone regeneration; DO: Distraction osteogenesis; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; N/A: Not applicable

Table 6: Complications and implant success and survival rates (continue 1).

Author (year)	Control (Number of sites, implants)	Test (Number of sites, implants)	Complications Control	Complications Test	Implant survival Control (%)	Implant survival Test (%)	Implant success Control (%)	Implant success Test (%)
Cucchi <i>et al.</i> 2024 ⁽²²⁾	GBR (24,55)	GBR (24,60)	Flap perforation = 1 Early exposure without infection = 1 Late exposure without infection = 1 Abscess without exposure = 1 Complete graft loss = 1 Partial graft loss = 2 (Overall rate = 29.17%)	Flap perforation = 1 Transient paresthesia = 2 Early exposure with infection = 1 Abscess without exposure = 1 Complete graft loss = 1 Partial graft loss = 1 (Overall rate = 29.17%)	N/A	N/A	N/A	N/A
El Zahwy <i>et al.</i> 2019 ⁽²³⁾	Onlay (8,20)	Inlay (8,20)	Crack of block autograft during implant placement = 1 Mobility of graft and loss of implant = 3 Complete loss of autograft = 2 Implant thread exposure = 1 (Overall rate = 87.5%)	None	N/A	N/A	N/A	N/A
Felice <i>et al.</i> 2008 ⁽²⁴⁾	Inlay (10,N/A)	Inlay (10,N/A)	Buccal dehiscence = 1 Bone graft fracture and wound dehiscence = 1 (Overall rate = 20%)	Lingual dehiscence = 1 (lingual soft tissue perforation from piezo-electric instrument) (Overall rate = 10%)	N/A	N/A	N/A	N/A
Felice <i>et al.</i> 2009 ⁽²⁵⁾	Onlay (10,23)	Inlay (10,20)	Dehiscence = 2 Infection = 1 Temporary hypoesthesia = 2 (Overall rate = 50%)	Dehiscence = 3 Temporary hypoesthesia = 4 (Overall rate = 70%)	100	100	86.9 (13-22 months)	90 (17-22 months)
Felice <i>et al.</i> 2024 ⁽²⁶⁾	GBR (9,19)	GBR (Mesh) (9,20) GBR (Foil) (9,21)	Transient paresthesia = 1 Pari-implant mucositis = 1 (Overall rate = 22.22%)	Transient paresthesia = 1 Device exposure = 1 Implant lack of integration = 1 (Overall rate = 33.33%) Device exposure = 1 Deficient of regenerated bone = 1 (Overall rate = 22.22%)	N/A	N/A	N/A	N/A
Fontana <i>et al.</i> 2008 ⁽²⁷⁾	GBR (5,12)	GBR (5,13)	Paresthesia = 1 Infection without dehiscence = 1 (Overall rate = 40%)	Temporary paresthesia = 1 Buccal bone dehiscence = 1 (Overall rate = 40%)	N/A	N/A	N/A	N/A
Giragosyan <i>et al.</i> 2024 ⁽²⁸⁾	GBR (20,N/A)	GBR (20,N/A)	Overall rate = 38.9%	Overall rate = 33.3%	N/A	N/A	N/A	N/A
Helal <i>et al.</i> 2025 ⁽²⁹⁾	Onlay (10,N/A)	Onlay (10,N/A)	Transient paresthesia = 1 Dehiscence without infection = 2 (Overall rate = 30%)	Transient paresthesia = 1 Minor gingival edema and erythema = 1 (Overall rate = 20%)	N/A	N/A	N/A	N/A
Kawakami <i>et al.</i> 2013 ⁽³⁰⁾	Inlay (11,22)	Inlay (11,22)	Titanium miniplate exposure = 1 Temporary neurosensory disturbance = 6 (Overall rate = 63.64%)	Titanium miniplate exposure = 1 Temporary neurosensory disturbance = 6 (Overall rate = 63.64%)	N/A	N/A	N/A	N/A
Leong <i>et al.</i> 2015 ⁽³¹⁾	GBR (10,N/A)	Onlay (9,N/A)	Wound dehiscence = 3 (Overall rate = 30%)	Wound dehiscence = 7 Graft failure = 1 (Overall rate = 88.89%)	N/A	N/A	N/A	N/A

GBR : Guided bone regeneration; DO : Distraction osteogenesis; TEG : Tissue expansion before GBR; TET : Tissue expansion before GBR with tunneling technique; N/A: Not applicable

Table 6: Complications and implant success and survival rates (continue 2).

Author (year)	Control (Number of sites, implants)	Test (Number of sites, implants)	Complications Control	Complications Test	Implant survival Control (%)	Implant survival Test (%)	Implant success Control (%)	Implant success Test (%)
Maiorana <i>et al.</i> 2021 ⁽³²⁾	GBR (5,10)	GBR (5,11)	Titanium mesh exposure = 2 (Overall rate = 40%)	None	N/A	N/A	N/A	N/A
Merli <i>et al.</i> 2007 ⁽³³⁾	GBR (11,55)	GBR (11,42)	Fistula (abutment connection) = 1 Fistula (2 weeks post surgery) = 1 Fistula (2 months post surgery) = 1 Lymph node swelling (1 month post surgery) = 1 Dehiscence with infection and graft failure = 1 (Overall rate = 45.45%)	Dehiscence without pus = 1 Swelling and infection = 1 Abscess and graft failure = 2 (Overall rate = 36.36%)	N/A	N/A	N/A	N/A
Morad <i>et al.</i> 2013 ⁽³⁴⁾	Onlay (6,N/A)	GBR (6,N/A)	None	None	N/A	N/A	N/A	N/A
Moussa <i>et al.</i> 2024 ⁽³⁵⁾	Inlay (10,N/A)	Inlay (10,N/A)	Transient paresthesia = 10 (Overall rate = 100%)	Soft tissue dehiscence and transient paresthesia = 1 Transient paresthesia = 9 (Overall rate = 100%)	N/A	N/A	N/A	N/A
Moustafa <i>et al.</i> 2025 ⁽³⁶⁾	GBR (10,N/A)	GBR (10,N/A)	Soft tissue dehiscence = 1 (Overall rate = 10%)	None	N/A	N/A	N/A	N/A
Roccuzzo <i>et al.</i> 2007 ⁽³⁷⁾	Onlay (12,25)	Onlay (12,28)	Incomplete integration of graft = 3 Graft mobility during implant placement = 1 Temporary paresthesia = 1 Significant graft resorption = 2 (Overall rate = 58.33%)	Titanium mesh exposure = 4 (Overall rate = 33.33%)	N/A	N/A	N/A	N/A
Ronda <i>et al.</i> 2014 ⁽³⁸⁾	GBR (13,40)	GBR (13,38)	None	None	N/A	N/A	N/A	N/A
Shaker <i>et al.</i> 2024 ⁽³⁹⁾	GBR (8,N/A)	GBR (8,N/A)	None	Wound dehiscence = 1 (Overall rate = 12.5%)	N/A	N/A	N/A	N/A
Shomurodov <i>et al.</i> 2023 ⁽⁴⁰⁾	GBR (20,N/A)	GBR (18,N/A)	Early wound dehiscence = 2 Temporary hypoesthesia = 4 (Overall rate = 30%)	Temporary hypoesthesia = 1 (Overall rate = 5.56%)	N/A	N/A	N/A	N/A
Urban <i>et al.</i> 2025 ⁽⁴¹⁾	GBR (15,N/A)	GBR (15,N/A)	Membrane exposure = 1 (Overall rate = 6.67%)	Abscess without exposure = 1 (Overall rate = 6.67%)	N/A	N/A	N/A	N/A

GBR: Guided bone regeneration; DO: Distraction osteogenesis; TEG: Tissue expansion before GBR; TET: Tissue expansion before GBR with tunneling technique; N/A: Not applicable

Table 7: Summary of outcomes for vertical ridge augmentation techniques.

Augmentation technique	Final vertical bone gain (mm)	Bone resorption (mm)	Complication rate	Key complications	Implant survival rate	Implant success rate (at the longest follow-up time)
Distraction osteogenesis	8.38±1.74	0.30±0.30 to 1.98±1.34	20% to 60%	-Lingual inclination of distracted fragment -Infection -Incomplete distraction	100%	94.7% (at 4-5 years)
Inlay	2.69±0.37 to 7.00±1.76	0.60±0.40 to 1.65±0.94	0% to 100%	-Transient hypoesthesia -Wound dehiscence -Crack of bone fragment -Miniplate exposure	100%	90% (at 17-22 months)
Onlay	1.60±0.80 to 4.80±1.50	0.60±0.70 to 4.77±1.67	0% to 88.89%	-Wound dehiscence -Transient paresthesia -Partial graft loss -Complete graft loss	100%	89.5% (at 4-5 year)
Guided bone regeneration	1.50±1.60 to 6.86±0.94	0.25±0.62 to 2.32±1.09	0% to 46.67%	-Transient paresthesia -Wound dehiscence -Membrane exposure -Infection	94% to 100%	61.5% to 75% (at 2-3 year)

Conclusions

Based on the findings of this study, all vertical bone augmentation techniques can effectively increase the height of the augmented areas. While DO provides the greatest vertical bone gain, it requires a highly experienced surgeon, specialized instruments and complex treatment planning. The more practical technique would be GBR, since it provides high final vertical bone gain, low bone resorption, and the lowest complication rate. In addition, it can be easily modified to use barrier membranes and bone grafting materials to suit individual patients.

Conflict of Interest

The authors declare there is no conflict of interest regarding the publication of this article. The funder did not have any influence on this study.

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Foreign Object Entrapment in Pulp Space of Primary and Permanent Teeth: A Systematic Review and A Series of Three Cases

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Abstract

Objectives: To systematically review paediatric case reports documenting foreign body entrapment within the pulp space of primary and permanent teeth in children under 16 years of age and to supplement the review with three additional clinical cases.

Methods: A comprehensive search was performed in PubMed, Cochrane Library, and Google Scholar from database inception to April 2025. The review followed PRISMA 2020 guidelines and was registered in PROSPERO (CRD42024594531). Case reports and case series in English describing foreign objects lodged within the pulp chamber or root canal in children under 16 years were included. Data extraction and quality appraisal were conducted independently using the JBI and CARE guidelines.

Results: Thirty-one studies reporting 37 cases were included. Most patients were males (81%), and the mean age was 10.9 years. A total of 41 teeth were affected, including 14 primary (34.15%) and 27 permanent teeth (65.85%). Twenty different foreign objects were identified, with stapler pins being the most common. Management varied by dentition: extraction was more frequently performed in primary teeth, whereas conservative retrieval using endodontic files and tweezers was preferred in permanent teeth when feasible.

Conclusions: Foreign body entrapment in the pulp space is often associated with untreated caries and self-inserted objects for pain relief. Prompt clinical and radiographic assessment can facilitate early detection and prevent complications. Increased parental awareness and timely dental care are essential to prevent such behaviours.

Keywords: foreign object, foreign object retrieval, permanent tooth, primary tooth, pulp chamber

Introduction

Dental caries is among the most prevalent diseases globally, affecting nearly 50% of children worldwide. It begins with minor surface roughness or subsurface demineralisation and gradually progresses to cavitation.⁽¹⁾ These open carious lesions can serve as sites for the insertion of various foreign objects like stapler pins⁽²⁾, pencil leads⁽³⁾, darning needles⁽⁴⁾, metal screws⁽⁵⁾, nails⁽⁶⁾, etc., potentially becoming focal points for infection and pain. Retrieving foreign objects from within the pulp chamber or root canal can be clinically challenging, yet it remains essential for successful treatment. The success of their removal is often influenced by the operator's expertise, patience, and experience, along with anatomical factors, and the accessibility of the root canal, as well as the foreign object's shape, size, and position.⁽⁷⁾ Despite numerous reports, the overall understanding of the clinical presentations, diagnostic approaches, and treatment modalities associated with such cases remains fragmented. Therefore, this paper aims to systematically review paediatric cases reporting the entrapment of unusual foreign objects within the pulp space of primary and permanent teeth in children under 16 years of age, supplemented by three illustrative clinical case reports.

Materials and Methods

Research question (DDO framework)

Among paediatric patients with foreign objects inserted into the pulp space of primary or permanent teeth (Domain), how do variations in the type and location of the foreign object (Determinant) influence the clinical presentation, diagnostic approach, and treatment outcomes (Outcome).

Protocol and registration

This review followed the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to ensure a structured and transparent methodology. The review protocol was registered at PROSPERO under the unique number CRD42024594531. This review was conducted and reported in accordance with the PRISMA 2020 guidelines.

Eligibility criteria

The review included full-text case reports and case series published in English that documented the pres-

ence of foreign bodies within the pulp space of children below 16 years of age. Studies were excluded if they were abstracts, duplicates, editorials, commentaries, retrospective, or comparative in nature, or if they described foreign objects located in the peri-radicular or peri-apical regions.

Information sources and search strategy

The databases searched included MEDLINE via PubMed, Cochrane, and Google Scholar. The electronic search strategy was developed using a combination of Medical Subject Headings (MeSH) terms and relevant keywords from seminal publications. The search terms included: "foreign object", "foreign body", "pulp space", "pulp chamber", "root canal space", "masochistic habit", "self-injurious habit", "self-inflicting habit", "children", and "child". Boolean operators (AND, OR) were applied to combine these terms appropriately. The search was limited to studies published in English, involving human subjects, and restricted to case reports and case series.

Selection process

All records retrieved through the search strategy were imported into the Rayyan software for reference management and removal of duplicates. Title and abstract screening, as well as full-text eligibility assessment, were conducted independently and in duplicate by two reviewers (DS and AG). Any disagreements at either stage were resolved through discussion and consensus, and when necessary, by consulting a third reviewer (NS). Data extraction from the included studies was also performed independently by the two reviewers using a standardised, pre-piloted data extraction form, and consistency was verified through cross-checking and consensus before synthesis.

Data items

Type of study, country, demographic data, clinical characteristics; type of foreign object, dentition involved and management were collected.

Risk of bias assessment

The methodological quality of the included case reports and case series was evaluated using the Joanna Briggs Institute (JBI) critical appraisal checklists for Case Reports and Case Series and the CARE (CAse REport) guidelines. Two reviewers (DS and AG) independently

assessed each study across the respective checklist items, focusing on the clarity of patient demographics, intervention details, clinical outcomes, and follow-up data. Any discrepancies in scoring were resolved through discussion and consensus, and where required, by the third reviewer (NS). The overall risk of bias for each study was cate-

gorised as low, moderate, or high based on the proportion of criteria fulfilled. This approach ensured consistency and transparency in the evaluation of the included literature. The detailed results of this quality appraisal are presented in Table 1.^(2,5-34)

Table 1: Risk of bias assessment of included studies (Based on JBI Critical Appraisal Checklist for Case Reports and Case Series).

Author (Year)	Type of Study	Clear Patient Description	Diagnostic Methods Clearly Reported	Intervention/Treatment Clearly Described	Outcome Adequately Reported	Follow-up Adequate	Overall Risk of Bias
Holla G, <i>et al.</i> , ⁽⁸⁾ (2010)	Case report	Yes	Yes	Yes	Yes	No	Low
Lehl G, <i>et al.</i> , ⁽⁹⁾ (2010)	Case report	Yes	Yes	Yes	Yes	No	Low
Nagaveni N, <i>et al.</i> , ⁽¹⁰⁾ (2012)	Case series	Yes	Yes	Yes	Yes	No	Low
Dhull K, <i>et al.</i> , ⁽¹¹⁾ (2013)	Case report	Yes	Yes	Yes	Yes	No	Low
Pereira T, <i>et al.</i> , ⁽¹²⁾ (2013)	Case report	Yes	Yes	Yes	Yes	No	Low
Mahesh R, <i>et al.</i> , ⁽¹³⁾ (2014)	Case report	Yes	Yes	Yes	Yes	No	Low
Kanumuri P, <i>et al.</i> , ⁽¹⁴⁾ (2016)	Case report	Yes	Yes	Yes	Yes	No	Low
Sharmin DD, <i>et al.</i> , ⁽¹⁵⁾ (2017)	Case report	Yes	Yes	Yes	Yes	No	Low
Lakhani B, <i>et al.</i> , ⁽¹⁶⁾ (2019)	Case report	Yes	Yes	Yes	Yes	No	Low
Chandran N, <i>et al.</i> , ⁽¹⁷⁾ (2020)	Case report	Yes	Yes	Yes	Yes	No	Low
Subbareddy V, <i>et al.</i> , ⁽¹⁸⁾ (1990)	Case report	Yes	Yes	Yes	Yes	No	Low
Prabhakar A, <i>et al.</i> , ⁽⁵⁾ (1998)	Case report	Yes	Yes	Yes	Yes	No	Low
Rao A, <i>et al.</i> , ⁽¹⁹⁾ (1999)	Case report	Yes	Yes	Yes	Yes	No	Low
Nadkarni U, <i>et al.</i> , ⁽²⁰⁾ (2002)	Case report	Yes	Yes	Yes	Yes	No	Low
McAuliffe N, <i>et al.</i> , ⁽²⁾ (2005)	Case report	Yes	Yes	Yes	Yes	No	Low
Ozsezer E, <i>et al.</i> , ⁽²¹⁾ (2006)	Case report	Yes	Yes	Yes	Yes	No	Low
Prabhakar A, <i>et al.</i> , ⁽²²⁾ (2008)	Case report	Yes	Yes	Yes	Yes	No	Low
Aduri R, <i>et al.</i> , ⁽²³⁾ (2009)	Case report	Yes	Yes	Yes	Yes	No	Low
Gadgil R, <i>et al.</i> , ⁽²⁴⁾ (2009)	Case report	Yes	Yes	Yes	Yes	No	Low
Kataoka S, <i>et al.</i> , ⁽²⁵⁾ (2010)	Case report	Yes	Yes	Yes	Yes	No	Low
Pinky C, <i>et al.</i> , ⁽⁶⁾ (2011)	Case report	Yes	Yes	Yes	Yes	No	Low
Khan S, <i>et al.</i> , ⁽⁷⁾ (2011)	Case report	Yes	Yes	Yes	Yes	No	Low
Rangeeth B, <i>et al.</i> , ⁽²⁶⁾ (2011)	Case report	Yes	Yes	Yes	Yes	No	Low
Chand K, <i>et al.</i> , ⁽²⁷⁾ (2013)	Case report	Yes	Yes	Yes	Yes	No	Low
Ramugade M, <i>et al.</i> , ⁽²⁸⁾ (2014)	Case report	Yes	Yes	Yes	Yes	No	Low
Kumar D, <i>et al.</i> , ⁽²⁹⁾ (2016)	Case series	Yes	Yes	Yes	Yes	No	Low
Rathore K, <i>et al.</i> , ⁽³⁰⁾ (2017)	Case report	Yes	Yes	Yes	Yes	No	Low
Ashqar N, <i>et al.</i> , ⁽³¹⁾ (2019)	Case report	Yes	Yes	Yes	Yes	No	Low
Rawat G, <i>et al.</i> , ⁽³²⁾ (2023)	Case report	Yes	Yes	Yes	Yes	No	Low
Chourasia HR, <i>et al.</i> , ⁽³³⁾ (2023)	Case report	Yes	Yes	Yes	Yes	No	Low
Ahemd M, <i>et al.</i> , ⁽³⁴⁾ (2025)	Case report	Yes	Yes	Yes	Yes	No	Low

Summary: All included case reports and case series adequately described the patient demographics, clinical presentation, diagnostic approach, intervention, and outcomes. However, follow-up data were inconsistently reported. According to the JBI criteria, the overall risk of bias across studies was low.

Literature search

Electronic searches identified a total of 1,603 records across the databases (PubMed=1,573, Google Scholar=30, Cochrane=0). After removing 175 duplicate records, 1,428 records remained. Of these, 1,189 were automatically excluded by database filters and automation tools, and 60 were removed for other reasons (e.g., non-relevant document type). The remaining 179 records were screened by title and abstract, after which 43 were excluded. A total of 134 full-text articles were assessed for eligibility. Following the exclusion of studies conducted in adults (n=97), animal studies (n=4), and reports describing foreign objects in peri-radicular or periapical regions (n=2), 31 studies met the inclusion criteria and were included in the qualitative synthesis (Figure 1).

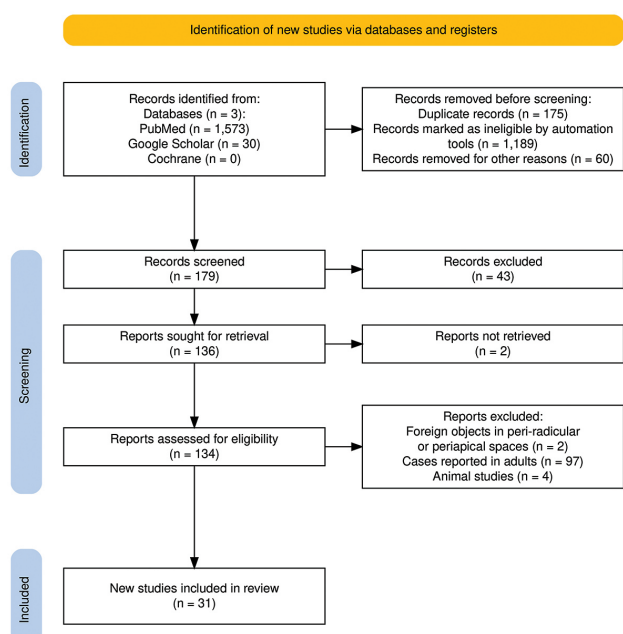


Figure 1: Literature search Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

Study characteristics

A total of 31 studies met the inclusion criteria, comprising individual case reports and a few case series describing foreign body lodgement within the pulp space of primary and permanent teeth. The studies were published between 1990 and 2025, reflecting more than three decades of clinical documentation. Overall, 37 cases were identified, with a marked male predominance (30 males, 81%; 7 females, 19%). The age of the affected children ranged from 5 to 16 years, with a mean age of

approximately 10.9 years, indicating a higher incidence among older school-age children. A total of 41 teeth were involved across the 37 cases, including 14 primary teeth (34.15%) and 27 permanent teeth (65.85%).

Foreign body insertion was more frequently reported in permanent teeth (n=27, 65.85%) than in primary teeth (n=14, 34.15%), most often involving the maxillary central incisors, consistent with their anterior location and accessibility. Across the reports, a total of 20 distinct types of foreign objects were identified, with stapler pins, metal wires, sewing needles, and ball-pen refills being the most frequently encountered (Graph 1). Most of these objects were self-inserted, typically driven by curiosity or self-inflicting oral habits.

Regarding management, nonsurgical retrieval methods were predominantly employed, including the use of H-files, K-files, barbed broaches, and tweezers under radiographic guidance. In cases where the object could not be dislodged or where associated pathology was present, tooth extraction was performed. The various retrieval methods employed are illustrated in Graph 2. The detailed assessment of methodological quality is summarised in Table 2.^(2,5-34)

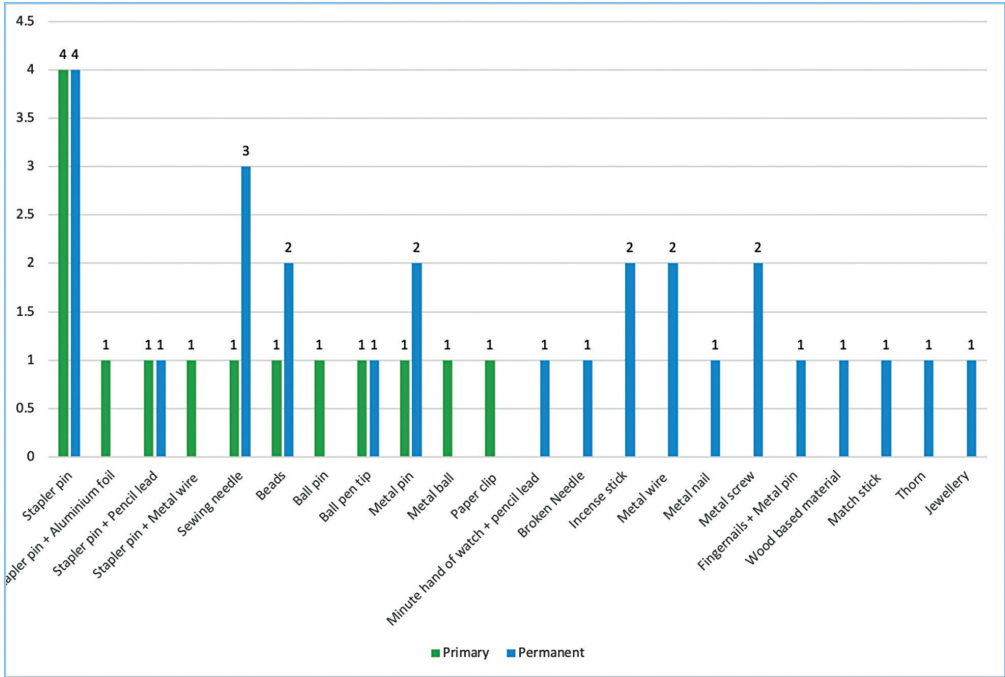
Case series

The cases were reported to the Department of Paediatric and Preventive Dentistry, SRM Dental College, Ramapuram, Chennai, between June 2024 and September 2024.

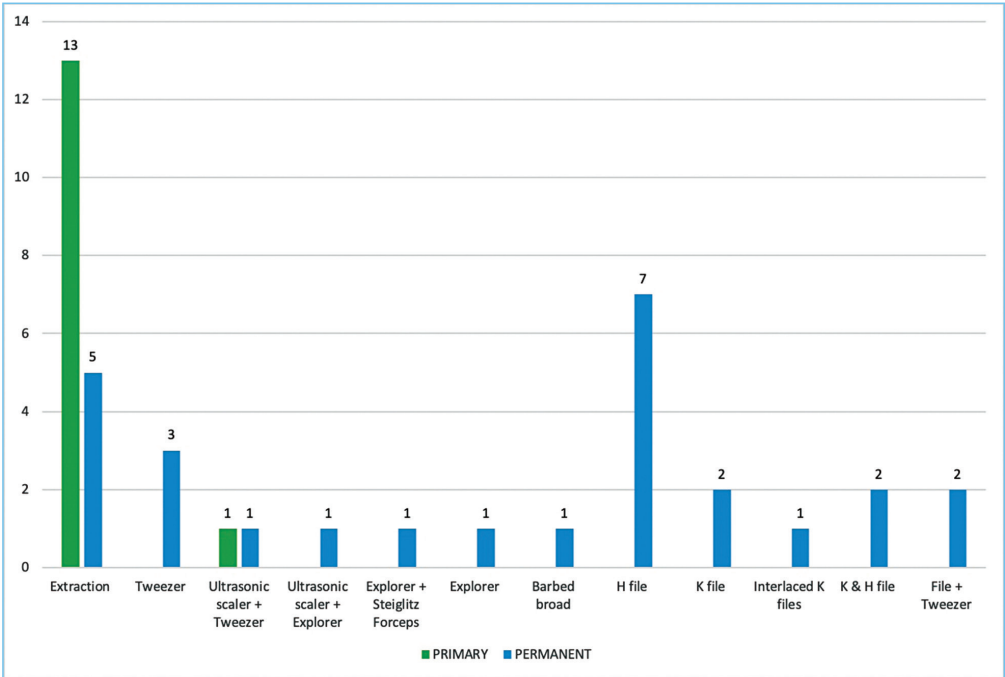
Case report 1

A 7-year-old boy reported with a chief complaint of pain in the upper right front tooth for the past 2 weeks. The pain was spontaneous in onset, continuous, sharp, aggravated on mastication and had no relieving factor. The child was medically healthy, with no pre-existing systemic conditions or special healthcare needs.

On clinical examination, dental caries in 53, 51 and 61 was elicited (Figure 2a). An intraoral periapical radiograph (IOPA) in #53 revealed a round radio-opacity measuring about 1mm in diameter in the coronal third of the root canal (Figure 2b). To confirm its position, another radiograph was taken using the SLOB technique (Figure 2c). On further examination, the child gave a history of inserting a pencil and a safety pin into the carious lesion to remove food particles and relieve pain. The treatment



Graph 1: Different types of foreign objects found in the pulp space of primary and permanent dentition.



Graph 2: Retrieval methods used to remove the foreign object from pulp space.

Table 2: Summary of reported foreign objects in the tooth and their management.

Authors	Year	Journal	Indexing	Type of study	Foreign Object	Age	Sex	Clinical characteristics	Treatment
Foreign object in primary teeth									
Holla G <i>et al.</i> , ⁽⁸⁾	2010	Journal of Contemporary Clinical Dentistry	PubMed	Case report	Stapler pins and aluminum foil	10y	Female	#53	Extraction
				Case report	Sewing needles	5y	Male	#51	Extraction
Lehl G <i>et al.</i> , ⁽⁹⁾	2010	Journal of Indian Society of Pedodontics and Preventive Dentistry	PubMed	Case report	Paper clip	6y	Male	#55 ,within the canal	Extraction
Nagaveni N. <i>et al.</i> , ⁽¹⁰⁾	2012	Journal of Cranio-Maxillary Diseases	Google Scholar	Case series	Stapler pin	6y	Male	#85pulp chamber and root canal	Extraction
					Glass bead	12y	Female	#84 ;pulp chamber	Extraction
					Stapler pin	9y	Male	#64 pulp chamber	Extraction
Dhull K <i>et al.</i> , ⁽¹¹⁾	2013	International Journal of Clinical Pediatric Dentistry	PubMed	Case report	Ball pin	8y	Female	#85	Ultrasonic scaler tip and tweezer
Pereira T <i>et al.</i> , ⁽¹²⁾	2013	International Journal of Pediatric Dentistry	PubMed	Case report	Ball pen refill tip	7y	Male	#54 pulp chamber and root canal	Extraction
Mahesh R. <i>et al.</i> , ⁽¹³⁾	2014	Ethiopian Journal of Health Sciences	PubMed	Case report	Stapler pin	5y	Male	#51 within the root canal	Extraction
Kanumuri P <i>et al.</i> , ⁽¹⁴⁾	2016	British Medical Journal	PubMed	Case report	Metal wires and stapler pins	10y	Male	#75	Extraction
Sharmin DD <i>et al.</i> , ⁽¹⁵⁾	2017	Symbiosis	Google Scholar	Case report	Stapler pins, Microtip pencil lead	12y	Female	#54 and #55	Extraction
Lakhani B <i>et al.</i> , ⁽¹⁶⁾	2019	International Journal of Clinical Pediatric Dentistry	Google Scholar	Case report	Metal ball	8y	Male	#75	Extraction
Chandran N <i>et al.</i> , ⁽¹⁷⁾	2020	Indian Journal of Medical Research	Google Scholar	Case report	Stapler pin	6y	Male	#64	Extraction
Foreign object in permanent teeth									
Subbareddy V <i>et al.</i> , ⁽¹⁸⁾	1990	Oral surgery, Oral Medicine, Oral Pathology, Oral Radiology Journal	PubMed	Case report	Beads	12y	Female	#11 and #21, within the root canal	Tweezer
Prabhakar A <i>et al.</i> , ⁽⁵⁾	1998	Journal of Indian Society of Pedodontics and Preventive Dentistry	PubMed	Case report	Metal screw	13y	Male	#36, pulp chamber	Extraction
Rao A <i>et al.</i> , ⁽¹⁹⁾	1999	Indian Journal of Dental Research	PubMed	Case report	Stapler pin	13y	Male	#21, apical extrusion	Extraction
Nadkarni U <i>et al.</i> , ⁽²⁰⁾	2002	Quintessence International	PubMed	Case report	Sewing needle	12y	Male	#16, palatal canal	File and tweezer
McAuliffe N <i>et al.</i> , ⁽²⁾	2005	International Journal of Pediatric Dentistry	PubMed	Case report	Stapler pin	11y	Male	#21, within the root canal	Barbed broach
Ozsezer E <i>et al.</i> , ⁽²¹⁾	2006	Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology Journal	PubMed	Case report	Minute hand of a watch and pencil lead	14y	Female	#11, within apical third of the root canal	H-file
Prabhakar A <i>et al.</i> , ⁽²²⁾	2008	International Endodontic Journal	PubMed	Case report	Piece of ornament	12y	Male	#11, within the apical third of root canal	File and tweezer

Aduri R <i>et al.</i> , ⁽²³⁾	2009	Journal of Indian Society of Pedodontics and Preventive Dentistry	PubMed	Case report	Stapler pin	12y	Female	#26, palatal root	Ultrasonic scaler used to loosen and removed with explorer
Gadgil R <i>et al.</i> , ⁽²⁴⁾	2009	British Dental Journal	PubMed	Case report	Bunch of incense sticks	13y	Male	#21, apical extrusion	Extraction
Kataoka S <i>et al.</i> , ⁽²⁵⁾	2010	Journal of Health Sciences	Google Scholar	Case report	Metal Nail	12y	Male	#11, within the root canal	Three K-files interlaced for removal
Pinky C <i>et al.</i> , ⁽⁶⁾	2011	Journal of Clinical and Experimental Dentistry	Google Scholar	Case report	Fingernails& metal pin	11y	Male	#21 within the root canal	k-file
Khan S <i>et al.</i> , ⁽⁷⁾	2011	Asian Journal of Oral Health and Allied Sciences	Google Scholar	Case report	Thorn	14y	Male	#12 within the root canal	K & H-file
Rangeeth B <i>et al.</i> , ⁽²⁶⁾	2011	Journal of the Indian Society of Pedodontics and Preventive Dentistry	PubMed	Case report	Wood based material	13y	Male	#32 within the root canal	K-file
Chand K <i>et al.</i> , ⁽²⁷⁾	2013	Journal of Conservative Dentistry	PubMed	Case report	Stapler pin	14y	Male	#11 pulp chamber & root canal	H-file
Ramugade M <i>et al.</i> , ⁽²⁸⁾	2014	Singapore Dental Journal	PubMed	Case report	Sewing needle	13y	Male	#21 within the root canal	K & H -files
Mahesh R <i>et al.</i> , ⁽¹³⁾	2014	Ethiopian Journal of Health sciences	PubMed	Case report	Metal pin	11y	Male	#21 within root canal	H-file
Kumar D <i>et al.</i> , ⁽²⁹⁾	2016	Endodontology	Google Scholar	Case series	Broken needle Stapler pin and pencil tip	10y 14y	Male Male	#21 and #22 #21	H-file H-file
Rathore K <i>et al.</i> , ⁽³⁰⁾	2017	Saudi Journal of Oral and Dental Research	Google Scholar	Case report	Metal wire	10y	Male	#21 within the root canal	Extraction
Lakhani B <i>et al.</i> , ⁽¹⁶⁾	2019	International Journal of Clinical Pediatric Dentistry	Google Scholar	Case report	Match sticks	13y	Male	#21	H-file
Ashqar N <i>et al.</i> , ⁽³¹⁾	2019	Journal of Clinics and Practice	PubMed	case report and literature review	Metal screw	11y	Male	#26 pulp chamber	H-file
Rawat G <i>et al.</i> , ⁽³²⁾	2023	National Research Denticon	Google Scholar	Case report	Incense stick	16y	Male	#11 pulp chamber	Extraction
Chourasia H <i>et al.</i> , ⁽³³⁾	2023	European Journal of General Dentistry	Google Scholar	Case report	Sewing needle	13y	Male	#11& #21	Shepherd's Hook and Steiglitz Forceps
Ahemd M, <i>et al.</i> , ⁽³⁴⁾	2025	University Journal of Dental Sciences	Google Scholar	Case report	Ballpoint pen nib	14y	Male	#16	Explorer

plan included the retrieval of the foreign object from the canal. Infiltration anaesthesia was administered using 2% lignocaine with adrenaline (1:200000). While probing the caries to remove the food debris, resistance was encountered. An attempt was made to clear the debris and open the access using a small round diamond bur (BR-45). During this process, black debris emerged from the pulp chamber upon excavation. Once the access was gained, the canal was instrumented using Kerr files ranging from size 15k-25k (21mm) with copious saline irrigation until no further resistance was felt. Multiple small black flecks were retrieved from the canal, and necrosed discoloured pulp tissue was extirpated (Figure 2d). The working length was determined (Figure 2e). Cleaning and shaping were done using rotary files (Super Endo-21mm) in the order Sx, S2, F1, with thorough saline irrigation. Canal was obturated using calcium hydroxide and iodoform paste (Metapex-MetaBiomed) (Figure 2f). The access was then sealed with Type II glass ionomer cement (Shofu-Japan) (Figure 2g).

Case report 2

A 9-year-old girl presented with the main complaint of pain in the upper right posterior tooth area, which had persisted for the past two months. The pain was continuous, dull aching, aggravated at night and relieved with medications. The patient was otherwise medically normal, with no systemic illnesses or special needs.

On clinical examination, intraoral swelling and sinus tract opening in relation to #55 with no exudate and an extraoral swelling that was diffuse, soft, tender and had ill-defined borders was seen. The patient had undergone pulpectomy and a stainless steel crown 3 years ago, and the crown was dislodged within 6 months. The patient was apparently healthy.

On further examination, the patient gave a history of inserting the wooden part of a Q-tip into the pulp space after crown dislodgment. Radiographic examination revealed radiolucency in enamel, dentin and pulp and radiopacity in the middle third of the mesiobuccal root, suggestive of obturation material. Radiolucency in the furcation area extending till the coronal 1/3rd of the root of underlying #15 (Nolla's stage 7) mesially. (Figure 3a)

The patient was advised to take antibiotics and analgesics for 5 days, after which the tooth was planned for extraction. The mucobuccal fold was dried with cotton, and

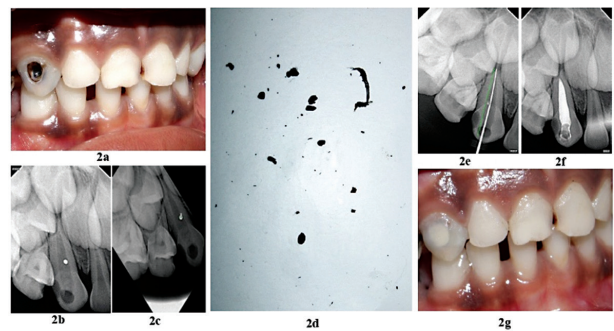


Figure 2: (2a) Pre-operative Clinical image showing #53; (2b) Pre-operative IOPA of #53; (2c) Pre-operative IOPA of #53 using SLOB rule to confirm the position of the radiopacity; (2d) Retrieved pencil graphite fragments, eraser particles and extirpated pulp; (2e) Working length determination; (2f) Obturation with calcium hydroxide and iodoform paste; (2g) Post-operative clinical image showing #53.

benzocaine gel 20% (Septodont Pro-Gel B) was applied for topical anaesthesia. Field block and palatal infiltration were administered in relation to #55 using 2% lignocaine hydrochloride with adrenaline (1:200000). After achieving anaesthesia, the tooth was extracted, which revealed a wooden stick that was inserted distobuccally into the pulp space. (Figure 3b & 3c) The abscess was drained, the socket was irrigated with normal saline, and haemostasis was achieved. Post-extraction instructions were given. The patient was reviewed after 1 week.

Case report 3

A 13-year-old boy reported with a chief complaint of pain in the lower left back tooth region for the past 4 days. The pain was continuous, dull aching, aggravated on mastication and at night, and relieved under medication. The patient was medically fit and healthy, without any pre-existing conditions or special healthcare requirements.

On clinical examination, dental caries in #36 was seen. (Figure 4a) An intraoral periapical radiograph was then taken for assessment, which revealed a radio-opaque object measuring about 8 mm in length in the pulp chamber and distal root canal. (Figure 4b) On further examination, the patient revealed a habit of inserting a stapler pin, finger nail and pencil tip into the open carious lesion to relieve pain.

The treatment plan was the retrieval of foreign objects from the root canal spaces. An inferior alveolar nerve block was administered using 2% lignocaine with adrenaline to achieve adequate anaesthesia. While

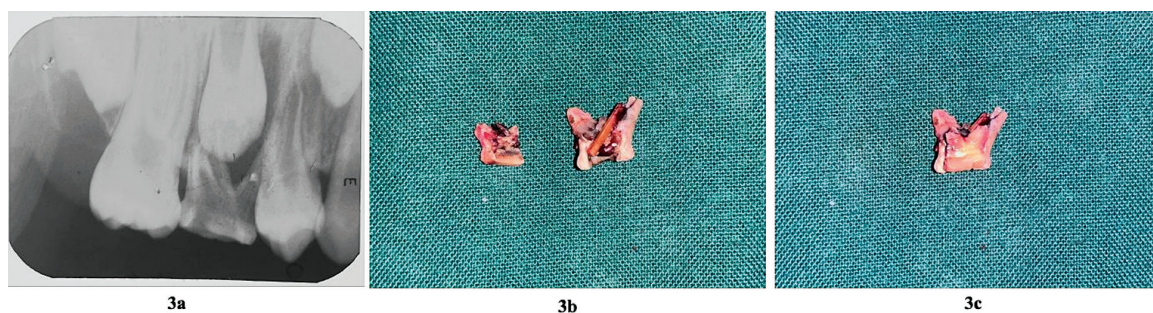


Figure 3: (3a) Pre-operative IOPA of #55; (3b) Extracted #55 showing wooden fragment of Q-tip; (3c) Extracted #55 with fragments in place.

removing caries using a small round bur (BR-45), resistance was felt, uncovering the presence of a metallic object. (Figure 4c) The access was subsequently enlarged to facilitate its removal. The metallic object was carefully extracted using Mathieu's pliers and a spoon excavator. Canals were instrumented using Kerr files (sizes 15K-25K, 25mm) with copious saline irrigation until complete patency was achieved. During the debridement process, multiple small black flecks, two fingernail fragments, and necrotic, discoloured pulp tissue were retrieved. (Figure 4d) A post-retrieval radiograph was then taken to confirm the complete removal of the foreign object and to establish the working length (Figure 4e & 4f). Subsequently, the canals were further instrumented using rotary files (Super Endo-25mm) with thorough saline irrigation to ensure complete cleaning and shaping. Obturation was then performed using 6% 25mm Gutta-Percha, followed by sealing of the access cavity with Type 2 glass ionomer cement (Shofu, Japan). (Figure 4g).

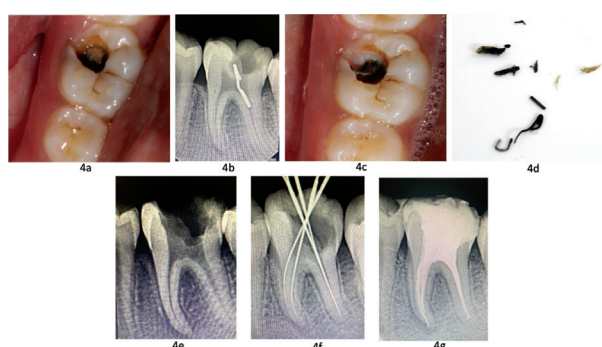


Figure 4: (4a) Pre-operative clinical image of #36; (4b) Pre-operative IOPA of #36; (4c) Image showing the exposed metal object from the access cavity of #36; (4d) Retrieved stapler pin, pencil graphite fragments and finger nail pieces. (4e) IOPA after retrieval of foreign objects in #36; (4f) Working length determination in #36; (4g) Obturated with gutta percha in #36.

Foreign object entrapment in the pulp space poses not only a risk of dental infection but also the potential for swallowing or aspiration of smaller objects that can potentially obstruct the airway. Swallowing foreign objects can result in chemical reactions within the body, leading to toxic effects. When such objects become lodged in soft tissues like the gums or soft palate, they may cause inflammation, scarring, infections, abscesses, cysts, swelling, or growths resembling tumours.⁽³⁵⁾ The effect of a foreign object in primary teeth can result in the perforation of the floor of the pulp chamber and subsequently disrupt the development of permanent teeth, leading to complications like odontoma, impaction, or dilaceration requiring immediate intervention.⁽³⁵⁾ The current systematic review showed that the majority of affected children were otherwise healthy and typically developing, with only isolated cases reporting behavioural challenges or special healthcare needs. Therefore, this behaviour appears to be common among the general paediatric population rather

Discussion

Dental caries can be a source of pain and discomfort in children. A prolonged delay in addressing their dental needs could result in the development of habits, such as placing foreign objects in the mouth to relieve this distress and irritation.⁽²⁷⁾ This also increases the likelihood of these items becoming lodged in their teeth, leading to infection.⁽²⁷⁾ Often, the parents are uninformed due to the associated fear factor.⁽²⁶⁾ In such instances, the foreign entity's existence is mostly discovered during routine dental X-rays, as in these reported series of cases.⁽²⁷⁾ This pattern was also reflected in the systematic review findings, where foreign objects were frequently detected incidentally during radiographic examinations rather than being voluntarily reported by parents or caregivers.

than being confined to children with special needs.

Across the reviewed studies and the present case series, a consistent behavioural trend was noted. Children tend to use easily accessible household or stationery items such as stapler pins, pencil tips, matchsticks and beads as coping mechanisms for unresolved pulpal pain. This highlights an important preventive opportunity for timely intervention of open carious lesions, and improved parental awareness may reduce self-injurious oral behaviours and prevent complications.

Although the results section presents detailed case descriptions, the broader review findings showed clear patterns in treatment decisions based on dentition and prognosis. In primary teeth, extraction was the most frequently reported treatment due to advanced infection or root resorption, whereas file-based retrieval and endodontic therapy were preferred in permanent teeth when the object was accessible and periapical involvement was limited. There is no standard recommendation for foreign body retrieval; various methods have been reported, such as ultrasonic equipment, fine forceps, endodontic files, and tweezers to re-negotiate the canal and complete treatment successfully.

Fragments of pencil tips consist of graphite (a form of carbon), clay (aluminium silicate), along with various waxes and lacquers. Although graphite and clay are chemically inactive, if they remain in tissue for an extended period, they can cause issues such as local pain, pigmentation, abscesses, and a non-allergic granulomatous reaction known as pencil granuloma.⁽³⁾ Eraser consists of sulphur that's incorporated during manufacturing to provide elasticity, explaining the radiopacity.⁽³⁶⁾ Stapler pin, on the other hand, is made of steel wire galvanised for durability and coated with zinc for corrosion resistance. The metal component remains radiopaque. These material properties influence their detectability and management, where radiopaque metals are easily identified, but radiolucent objects like wood may remain undetected radiographically, delaying diagnosis.

In the reviewed literature, multiple retrieval approaches have been documented to remove foreign objects from the pulp space of primary and permanent teeth (Graph 1). Extraction was the most frequently performed method in primary dentition, with 13 cases reported^(8-10,12-17), compared with only 5 cases in permanent teeth.^(9,19,24,30,32) Conversely, conservative retrieval using hand instru-

mentation was more often attempted in permanent teeth. The H file, for example, was the most commonly utilised method in permanent teeth, used in 7 cases^(7,13,21,27-29), and notably was not used in primary teeth. Additional manual strategies, such as K file, interlaced K files, and combinations like K- and H-files or file with tweezers combinations, were also exclusively used in permanent teeth.^(6,7,19,20,22,25,26,28)

Ultrasonic-assisted retrieval, such as an ultrasonic scaler combined with an explorer or tweezers, was used in both types of dentition, although more sparingly.⁽²⁴⁾ Simple tools like tweezers and explorers, alone or in combination with Stieglitz forceps, were also used in a few cases in permanent teeth.^(18,33,34)

A wide variety of foreign objects from the pulp spaces of both primary and permanent teeth are documented in the literature. (Graph 2) Stapler pins were the most prevalent objects in both dentitions, with equal occurrence in permanent (4 cases)^(2,19,23,27), and in primary teeth (4 cases).^(8,10,13,17) Composite objects like a stapler pin with metal wire, pencil lead, or aluminium foil were found in both groups, but were more frequently noted in permanent teeth.^(8,15)

Objects such as sewing needles, beads, metal pins, and screws were predominantly observed in permanent dentition, indicating more intentional or complex insertion behaviours.^(6,13,18,19,21,25,28-31,33) In contrast, simpler objects like paper clips and metal balls were found exclusively in primary teeth.^(9,16) Additionally, unusual materials like jewellery components, incense sticks, and matchsticks appeared only in permanent teeth.^(16,19,21,22,24,26,32)

A key limitation of this manuscript stems from the heterogeneity in reporting across the included literature. The absence of standardised protocols for documenting patient symptoms, foreign body retrieval methods, and long-term follow-up introduced potential bias and variability in the data. Furthermore, radiographic limitations posed diagnostic challenges, as conventional radiographs cannot detect radiolucent objects like wood or plastic. The retrospective nature of the data, primarily drawn from published case reports, is susceptible to missing or incomplete information, thereby impacting the comprehensiveness and generalizability of our findings. Moreover, limited behavioural and psychosocial documentation restricted a deeper understanding of why children engage in such self-injurious practices.

Future research should expand behavioural assessment, including parental awareness, dental anxiety, coping strategies, and accessibility to dental care. Development of standardised diagnostic and imaging protocols, including CBCT or MRI for non-radiopaque objects, is recommended to enhance early detection.

Implementing preventive educational programmes for parents and children is crucial to mitigating self-injurious behaviours. Additionally, laboratory studies are needed to understand the biocompatibility and tissue response of commonly inserted materials. Finally, expanding the dataset through larger systematic reviews or multicentre meta-analyses would provide a more robust understanding of the prevalence, patterns, and outcomes associated with intraoral foreign object entrapment.

This review provides the most up-to-date synthesis of paediatric cases reporting foreign body entrapment in pulp space, integrating evidence from over three decades and supplementing the literature with three new clinical cases. A predefined protocol, duplicate screening, and critical appraisal tools were used to enhance reliability.

Conclusions

Foreign body entrapment in the pulp space of children's teeth, though uncommon, can lead to persistent symptoms and serious complications if overlooked. This review and case series highlight how children may insert objects into open carious lesions, making diagnosis challenging. Prompt clinical and radiographic assessment is key to identifying and managing such cases effectively. Raising awareness among parents and dental professionals, along with early intervention and preventive education, can significantly reduce the risks and improve outcomes in paediatric dental care.

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Conflict of Interest

The authors declare no conflict of interest.

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Oral Health Behaviors and Predictive Factors Among Parents of Preschoolers in an Industrial Urban Setting: A Case Study in Mueang District, Samut Sakhon, Thailand

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Abstract

Objectives: Early childhood caries is a significant oral health issue that progresses rapidly and affects the long-term health and quality of life of preschool children. Therefore, this study aimed to study the oral health behaviors and their predictors among parents of preschool children in Samut Sakhon, Thailand.

Methods: A cross-sectional design was employed with a sample of 351 parents of preschool children, selected through multi-stage random sampling. Data were collected using a questionnaire developed based on theoretical frameworks and study objectives, comprising four parts: personal factors, oral health knowledge, Health Belief Model-based oral health beliefs, and parental oral health behaviors. The instruments demonstrated a content validity (IOC) of 0.66–1.00 and a Cronbach's alpha coefficient of 0.896. Descriptive statistics, correlation analysis, and stepwise multiple regression were used for data analysis.

Results: The results indicated that 53.6% of parents exhibited moderate oral health behaviors for their children (Mean=55.95, SD=10.575). Factors significantly predicting oral health behaviors, accounting for 32.4% of the variance ($R^2=0.324$, $p<0.05$), included cues to action ($\beta=0.323$), perceived barriers ($\beta=0.296$), oral health knowledge ($\beta=0.125$), educational background ($\beta=0.117$), and perceived severity of oral health issues ($\beta=0.103$).

Conclusions: Findings suggest the need for targeted interventions to improve oral health behaviors among parents, focusing on oral hygiene, milk bottle care, nutrition, and dental visits. Programs should raise awareness and provide educational resources on preschool oral health to promote better oral hygiene practices.

Keywords: children, health belief model, oral health behavior, predictive factors, preschool

Introduction

Oral health is one of the parts of desirable health affecting good health and quality of life.⁽¹⁾ 3.7 billion people worldwide have been affected by oral health problems, which lead to significant health, social, and economic burdens.⁽²⁾ Oral health problems can happen at any age, and the most common problem is dental caries.⁽²⁾ The incidence of dental caries is highest in childhood, even though it is preventable, with a prevalence as high as 53%. More than 530 million children worldwide have untreated deciduous teeth caries and are at high risk of growing up to be adults with oral health problems.⁽³⁾ The prevalence of deciduous tooth caries in young children in Asia is as high as 27.5%, with an average of 5.1 caries extracted and filled teeth per person.⁽⁴⁾ Dental caries in young children remains a serious public health problem that needs to be addressed.^(1,5,6)

Early childhood caries occurs in baby teeth in children aged from birth to 71 months.⁽⁷⁾ When caries in early childhood occurs, it will affect the quality of life, physical health, and development in various aspects in the long term. It also indirectly affects children's mental health, such as loss of confidence due to black caries, chipped teeth from caries, bad breath making them not dare to speak or smile, and lacking self-confidence.⁽⁸⁾ Children with oral health problems are 1.53 times less likely to have age-appropriate development than children without oral health problems⁽⁹⁾, and children with more than 4 caries are more likely to be underweight compared to children without caries.⁽¹⁰⁾ Therefore, dental caries in preschool children not only affect oral health but also affect children's overall health and quality of life.⁽⁶⁾

According to the report of the 9th National Oral Health Survey 2023 in Thailand⁽¹¹⁾ for children aged 3 and 5 years, when compared to the 8th National Oral Health Survey 2017⁽⁵⁾, early-stage tooth caries tended to increase by 38.0% in children aged 3 years and 45.5% in children aged 5 years.⁽¹¹⁾ Additionally, untreated tooth caries was as high as 46.1 % and 70.4 % in children aged 3 years and 5 years, respectively. Also, children aged 3 years had 40.6% of bacterial plaque while children aged 5 years had as high as 77.1% of bacterial plaque.⁽¹¹⁾ The factors that can reduce the risk of oral diseases include quality tooth brushing where parents must brush their children again, drinking fresh milk, and stopping using milk bottles when they are 1 year old.^(11,12) The survey revealed that parents

let their children brush their teeth by themselves by 31.1% in 3-year-old children and 71.2% in 5-year-old children. For milk drinking in children aged 3 and 5 years, it was found that 36.7% and 43.3% of children drank sour milk and sweetened milk at home, respectively.⁽¹¹⁾ It was also found that 38.0% of 3-year-old children used a bottle, and 15.2 % of 5-year-old children still sucked milk from a bottle. Therefore, paying attention and giving importance to the oral health of children from early childhood by parents is crucial to reduce the chance of tooth caries.⁽⁸⁾

Moreover, the health belief model affecting the oral health care of preschool children.⁽¹³⁾ This can be explained through the health belief model, which is a behavioral theory explaining how individuals' beliefs affect their health behaviors and the individuals under their care. These factors are related to, influence, and affect oral health behaviors among preschool children's parents. Past studies identified various factors that have the power to predict oral health behaviors among preschool children's parents in different provincial contexts of Thailand. However, in the context of urban industrial areas where life is hectic and most of the time is spent working, the factors of oral health behaviors among preschool children's parents may vary.

Samut Sakhon Province is a large industrial center of the country, with over 6,400 factories, as a top industrial city.⁽¹⁴⁾ Therefore, life is hectic, with overtime work and most of the time spent working. This affects the life and care of family members.⁽¹⁵⁾ In terms of oral health, Samut Sakhon Province is one of the target provinces in the 8th National Oral Health Survey in 2017⁽⁵⁾, which found that the prevalence of tooth caries in children aged 3 years was highest at 57.9% in the Central region and children aged 5 years at 74.2%.⁽⁵⁾ Moreover, data from public health officials who recorded data in the area found that plaque on the teeth, tooth decay, and gingivitis. Children also had tooth caries at a young age, although Samut Sakhon Province had a network of public health dentists and dentists who work both reactively and proactively.

Therefore, the researchers are interested in studying the factors predicting oral health behavior among preschool children's parents in Mueang District, Samut Sakhon Province, using personal factors, knowledge factors, and health belief model as variables in this research. This research aimed to study the oral health behaviors among preschool children's parents, the relationship,

and factors predicting oral health behaviors among preschool children's parents. The results will be information and guidelines for planning and developing appropriate models for oral health promotion among preschool children and solving dental health problems of preschool children under the context of an industrial city where parents have a busy life and spend most of their time working, for children to have good oral health, reduce oral and dental health problems, and prevent future tooth caries.

Materials and Methods

This study obtained a Human Research Ethics Certificate from the Faculty of Public Health, Mahidol University, MUPH 2024-058, on June 6, 2024.

Study design, population, and sample

This cross-sectional analytical study was conducted among parents of preschool children in Mueang District, Samut Sakhon Province, Thailand. The target population consisted of 1,637 parents whose children were enrolled in child development centers within the district.⁽¹⁶⁾ While, the sample included 351 parents of preschool children studying at the Child Development Center in Mueang District, Samut Sakhon Province. Calculated from The Daniel equation was employed to find the proportion estimation with known population size.⁽¹⁷⁾ From the calculation, the sample size was 292 people. To prevent errors during data collection and incomplete questionnaire responses, the researcher increased the size by 20%⁽¹⁸⁾, which is 59 people, resulting in a total of 351 people.

The sampling procedure involved four steps to enhance representativeness and minimize selection bias: Step 1: Five local administrative organizations (LAOs) in Mueang District, Samut Sakhon, with child development centers were randomly selected using simple random sampling without replacement from a total of 15 centers. Step 2: The number of parents to be included from each LAOs was calculated proportionally according to the number of preschool children enrolled. This proportional-to-size allocation ensures that LAOs with more children were represented appropriately in the final sample. Step 3: The total sample size of 351 parents was proportionally allocated across 10 child development centers that were located within the selected LAOs. Step 4: Within each center, parents were randomly selected from each cen-

ter using simple random sampling without replacement, based on a list of preschool children. Both the selection of the five LAOs (Step 1) and the parents (Step 4) were conducted using a computer-based random number generator to ensure true randomization. While simple random sampling without replacement technically means conditional probabilities change after each selection, this method ensures that every parent in the sampling frame had an equal and known initial probability of being selected, which is the foundational principle of this design. To minimize nonresponse bias, participants were informed about the study's purpose and assured of confidentiality. Participation was voluntary, and anonymous responses were collected during routine parent meetings organized by the centers.

Research instrument

The research instrument was a structured, self-administered questionnaire consisting of four parts with a total of 70 items. Part 1 covered personal factors with 8 questions; Part 2 assessed knowledge of oral health among preschool children's parents with 16 questions; Part 3 measured oral health belief of preschool children's parents with 26 questions; and Part 4 focused on oral health behaviors among preschool children's parents with 20 questions.

Part 1 (Personal factors) was measured using categorical scales, while Part 2 (Knowledge) consisted of 16 true or false items, where a correct answer was scored as 1 and an incorrect answer as 0. The total knowledge score ranged from 0 to 16. Part 3 (Oral health beliefs) comprised 26 items measured on a 5-point rating scale, ranging from 1 (Strongly disagree) to 5 (Strongly agree). The total belief score was the sum of all items ranged from 5 to 25, and Part 4 (Oral health behaviors) included 20 items assessing the frequency of behaviors on a 5-point rating scale, such as 0 (Never) to 4 (Always), resulting in a total score range of 0 to 80. For analysis, the scores for Part 2, 3, and 4 were categorized into three levels (Low, Moderate, High) using Bloom's cut-off points: Low (<60% of total score), Moderate (60-79%), and High ($\geq 80\%$).

The questionnaire was developed through a multi-stage process to ensure content validity and reliability. The initial items were constructed from a review of relevant literature on oral health behaviors and the Health Belief Model. Three experts in dental public health, health pro-

motion, and public health behavioral sciences evaluated the content validity of each item. The Index of Item–Objective Congruence (IOC) ranged from 0.66 to 1.00, indicating acceptable validity. A pilot test was conducted among 30 parents with similar characteristics to the study population to assess clarity, feasibility, and reliability. Feedback was used to revise ambiguous wording and ensure cultural appropriateness. Cronbach’s alpha coefficient for the entire instrument was 0.896, indicating high internal consistency. The reliability for the specific sub-scales was also confirmed: Part 2 (Knowledge) yielded a Kuder-Richardson 20 (KR-20) coefficient of 0.701, Part 3 (Oral health beliefs) had a Cronbach's alpha of 0.823, and Part 4 (Oral health behaviors) had a Cronbach's alpha of 0.833.

Data collection

Data were collected from August 16 to September 4, 2024. Initial arrangements were made with the 10 child development centers to schedule data collection. On the appointed dates, the researcher and assistant visited the centers to explain the study's purpose, objectives, and confidentiality measures to parents, requesting their cooperation. Participants signed consent forms before completing the questionnaires independently. Once completed, the questionnaires were collected for data analysis.

Statistical analysis

The data analysis was conducted with statistics including frequency distribution, percentage age, mean, and standard deviation. The data described personal factors, knowledge of oral health among children, the health belief model, and oral health behaviors among preschool children's parents. The relationship was analyzed by using Pearson's correlation and stepwise multiple linear regression analysis to identify factors predicting oral health behaviors and to generate the predictive equation for these predicting factors among preschool children's parents with a statistical significance of 0.05.

Results

Personal factors

Personal factors were divided into 2 sub-sections: general information and the level of knowledge of oral health behaviors among preschool children's parents as shown in Table 1. (1) General information: There were 351

parents. 271 people were female or 77.2%, and 80 people were male or 22.8%, with a mean age of 34.75 ± 7.868 years. As for the information on preschool children, 177 were male, or 50.4 % and 174 were female, or 49.6 %, with a mean age of 3.39 ± 0.559 years. and (2) The level of knowledge of oral health behaviors for preschool children's parents was at a high level with a mean knowledge score of 13.72 ± 2.053 points. 282 parents or 80.3% had knowledge about oral health care for preschool children at a high level.

Oral health behaviors among preschool children's parents

Parents had a moderate level of oral health behaviors among preschool children's parents with a mean score of 55.95 ± 10.575 . Most parents had a moderate level of oral health behaviors among preschool children's parents of 53.6%. Regarding oral cleaning behavior, most parents practiced it almost every time, namely brushing the child's teeth for at least 2 minutes (33.9%). Regarding milk bottle care, it was practiced every time, namely letting the child drink milk from a box instead of sucking from a bottle (44.7%). Regarding food care, most parents practiced it every time. The most practiced was choosing plain milk for the children (50.1%). Regarding taking the child to receive dental services, parents practiced it every time. The most practiced question was, "Do you take your children to the dentist when you know that your child has an oral health problem from a dental checkup at the child development center?" (35.0%).

Relationships and factors predicting oral health behaviors among preschool children's parents

The analysis results revealed that the variables were related to the oral health behaviors among children's parents, namely educational background, average monthly family income, and oral health belief model of preschool children. The results revealed that the correlation coefficients were between -0.367 and 0.594, and all variables were related to oral health behaviors among children's parents with statistical significance at 0.05 as shown in Table 2.

The result of the stepwise multiple regression analysis found that 5 variables could significantly predict oral health behaviors among preschool children's parents in Mueang District, Samut Sakhon Province at a statistical

Table 1: Personal factors classified by personal factors of parents and preschool children (n=351).

Personal factors	n	%
1. General information		
(1) Parents		
Gender		
Male	80	22.8
Female	271	77.2
Age		
20-30 Years	116	33.0
31-40 Years	159	45.3
41-50 Years	60	17.1
51-60 Years	16	4.6
M=34.75, S.D.=7.868, Min=20, Max=60		
Education background		
No education	8	2.3
Primary School	43	12.3
Junior High School	66	18.8
Senior High School/Vocational Certificate	98	27.9
Diploma / High Vocational Certificate	52	14.8
Bachelor Degrees	78	22.2
Higher than Bachelor Degree	6	1.7
Average total family income per month		
Less than 10,000 baht per month	30	8.5
10,001-15,000 baht per month	106	30.2
15,001-20,000 baht per month	85	24.2
20,001-30,000 baht per month	73	20.8
30,001-40,000 baht per month	20	5.74
40,001-50,000 baht per month	24	6.8
More than 50,000 baht per month	13	3.7
(2) Preschool children		
Gender		
Male	177	50.4
Female	174	49.6
Age		
3 Years	227	64.7
4 Years	111	31.6
5 Years	13	3.7
M=3.39, S.D.=0.559, Min=3, Max=5		
Birth order		
No. 1	208	59.3
No. 2	116	33.0
No. 3	24	6.8
No. 4	2	0.6
No. 5	1	0.3
2. The level of knowledge of oral health behaviors among preschool children's parents		
High level (13-16 points)	282	80.3
Moderate level (10-12 points)	59	16.8
Low level (0-9 points)	10	2.8
M=13.72, S.D.=2.053, Min=0, Max=16		

level of 0.05, arranged by the weight as follows: perceived motivators for parents to practice, perceived obstacles to oral health care, knowledge of oral health care for pre-school children, educational background, and perceived severity of oral health problems which could predict health promotion behaviors with statistical significance at 0.05, with a predictive power of 32.4%. When considering the direction and weight of the relationship of the predictive variables, there was a positive relationship, with the predictive equation as standard scores: $Z=0.323 (ZX2)+0.296 (ZX3)+0.125 (ZX4)+0.117 (ZX1)+0.103 (ZX5)$ as shown in Table 3.

Discussion

Overall, oral health behaviors among preschool children's parents were at a moderate level, or 53.6%. This may be because most parents still did not consistently practice oral health behaviors or parents believed that baby teeth are not important since permanent teeth will replace them later. Therefore, parents sometimes neglect to take care of their children's oral health⁽¹⁹⁾, resulting in parents' oral health care behaviors at a moderate level. In addition, the context of Mueang Samut Sakhon District is mostly an industrial area with 2 industrial estates^(20,21) and 3,928 factories.⁽²²⁾ The working-age population in

Mueang District, 94.89%.⁽²³⁾ Factory workers often lack personal time, affecting their quality of life and work-life balance. Since their primary focus is making a living, they may be unable to provide adequate care for their children.⁽²⁴⁻²⁶⁾ Therefore, children's oral health may be neglected. This is consistent with the study of factors predicting oral health behaviors among children aged 1.5 to 3 years of parents in Wiang Sa District, Nan Province, which found that 51.0 % of parents had a moderate level of oral health behaviors since parents did not practice oral health behaviors regularly and inconsistently.⁽²⁷⁾ Similarly, the study of factors related to oral health behaviors among preschool children's parents in Chamuang Subdistrict, Khuan Khanun District, Phatthalung Province found that most parents had a moderate level of oral health behaviors among preschool children (82.7%) since most parents may worked and could not take care of their children all the time.⁽²⁸⁾ This moderate level of oral health behaviors found in our study and other Thai contexts reflects a global challenge, particularly in industrial or low-income settings. The international studies have also found that parents employed in demanding, low-wage, or shift-based labor face significant time and resource constraints that directly impede consistent preventive health practices for their children.^(29,30) The fact that behaviors were moderate

Table 2: Results of correlation coefficient analysis (n=351).

Factors	M	SD	Min	Max	X1	X2	X3	X4	X5	(Y)
Perceived susceptibility (X1)	20.41	3.166	5	25	1.000	.195*	.428*	.506*	.386*	.383*
Perceived severity (X2)	20.64	3.359	5	25		1.000	.458*	.133*	.323*	.181*
Perceived benefits (X3)	26.67	3.011	6	30			1.000	-.176*	.594*	.366*
Perceived barriers (X4)	10.54	4.189	4	20				1.000	-.145*	-.367*
Cues to action (X5)	25.96	3.869	6	30					1.000	.435*
Oral health behaviors among children's parents (Y)	55.95	10.575	0	80						1.000

* $p<0.05$

Table 3: Results of multiple regression analysis (n=351).

Predictive factors	b	SE	β	t	p-value
Cues to action as motivators for parents' practices	0.883	0.132	0.323	6.682*	0.000
Perceived barriers to oral health care among children	0.741	0.119	0.296	6.238*	0.000
Knowledge of oral health care for preschool children	0.646	0.244	0.125	2.644*	0.009
Education background	9.536	3.636	0.117	2.623*	0.009
Perceived severity of oral health problems among children	0.324	0.151	0.103	2.149*	0.032
Constant=7.372, R=0.569, R ² =0.324, Adj.R ² =0.314, Durbin-Watson=1.923, F=33.070, * $p<0.05$					

Note: b=regression coefficient, β =standardized regression coefficient

rather than low suggests that parents may possess baseline knowledge, but the socioeconomic and employment context of Samut Sakhon likely creates a practice gap, preventing the translation of this knowledge into consistent, high-level protective behaviors. This high-stress environment, focused on economic subsistence, may lead to parental depression, mental health problems, and prioritization of immediate needs over preventive long-term health, a phenomenon documented in other vulnerable working populations.^(31,32) When considering the oral health behaviors among preschool children's parents in terms of oral cleaning, most parents had the behavior of letting the children brush their teeth and the parents brushed their children's teeth again, and also checked the cleanliness of the children's mouths after brushing their teeth in the morning and before bedtime. However, some parents have never done this for their children. This means letting the children brush their teeth without brushing their teeth again or checking the cleanliness after brushing their teeth. Children at this age could not help themselves so parents need to take care of them to have good oral and dental health. This is consistent with the study of factors associated with early childhood caries among children living in sugar palm plantation communities, Phetchaburi province, Thailand showing that children who received daily tooth brushing by their parents were related to dental caries among preschool children. Regular tooth brushing and the use of fluoride toothpaste could reduce dental caries.⁽³³⁾ Similarly, the study of Parents' oral health care behaviors and caries status of preschool children in Kaengkhroi District, Saraburi Province showed that baby teeth caries and the oral cleaning behaviors of parents were correlated.⁽³⁴⁾ Therefore, tooth brushing is crucial for preschool children as it helps prevent dental caries and promotes good oral health. Tooth brushing can remove bacterial plaque accumulated on the tooth surface, which is the main cause of dental caries. The results suggest that the primary challenge is not merely inadequate tooth brushing but rather insufficient parental assistance and supervision. This suggests that public health messages should extend beyond emphasizing the importance of brushing a child's teeth and instead provide practical strategies to facilitate parental involvement, even under conditions of fatigue following long work shifts. Addressing parental fatigue as a practical barrier, which arises from the demands of industrial work environments,

may therefore be more critical than focusing solely on a deficit in knowledge.

Factors that can predict oral health behaviors among preschool children's parents in Mueang District, Samut Sakhon Province with statistical significance at 0.05 with a predictive power of 32.4% included: (1) perceived parents' motivators to practice. Parents will tend to change their health behaviors only when they are aware of external or internal factors that motivate them to practice. Therefore, it can predict oral health behaviors among preschool children's parents ($\beta=0.323$) since most parents may be aware of the results of oral health examinations of preschool children in child development centers by dental personnel or from experiences of oral health problems that they do not want to happen to their children. This is consistent with the study of Rathajak *et al.*,⁽²⁷⁾ (2) perceived obstacles to oral health care can predict oral health behaviors among preschool children's parents ($\beta=0.296$) since most parents of preschool children may have low perceived obstacles to oral health care for preschool children. They believed that brushing their teeth repeatedly and checking their mouth after brushing is not a difficult and time-consuming task, and taking children to the dentist every 6 months is not an obstacle. This fosters the practice of oral health behaviors among preschool children's parent. This is consistent with the study by Rathajak *et al.*,⁽²⁷⁾ and Kabiri *et al.*,⁽³⁵⁾ which found that parents' perceived obstacles to preventing oral health problems in children can predict oral health behaviors. (3) Knowledge of oral health behaviors among preschool children's parents can predict oral health behaviors among preschool children's parents ($\beta=0.125$) since most of the parents of preschool children may have an understanding of oral care, practicing oral health behaviors for preschool children and promoting good oral health in children. This is consistent with the study of Kaushik and Sood⁽³⁶⁾, who found that parents' knowledge about oral care affected oral care among children, especially oral care during childhood, which can prevent oral health problems in the future. Knowledge makes parents aware of the importance of oral care in childhood and can promote good oral health behaviors among children. The study of Shan *et al.*,⁽³⁷⁾ found that parents' knowledge of oral care affected oral care among preschool children. Parents who have knowledge about oral care tend to promote good behaviors. (4) Parents' educational background can

predict the oral health behaviors among preschool children's parents ($\beta=0.117$) since parents with higher educational background may have more knowledge and skills in caring for children's oral health, which may result in parents having better behaviors in promoting oral health of preschool children. From the study of Chen *et al.*,⁽³⁸⁾ the educational background of parents is a factor affecting the oral health behaviors of children, where parents with higher educational background would take good care of their children's oral health. (5) Perceived severity of oral health problems can predict oral health behaviors among preschool children's parents ($\beta=0.103$) since most parents of preschool children may be aware that children with severe tooth caries would eat less food with lack of nutrients, and if tooth caries were not treated, it would cause facial swelling and premature loss of baby teeth. The perceived impact often encourages parents to be aware and improve their children's oral behaviors to prevent tooth caries and maintain their children's oral health properly. This is consistent with the study of Kabiri *et al.*,⁽³⁵⁾ that the perceived severity of children's oral health problems can predict oral health behaviors of parents.

However, this study has certain limitations. Unmeasured factors may have influenced parental behaviors. For example, parental dental anxiety may serve as a significant barrier to seeking care, irrespective of parental knowledge.^(39,40) Moreover, the influence of social support networks and alternative caregivers, such as grandparents who may play a critical role given the demands of parental work schedules, was not examined and warrants further investigation. Workplace-related factors, including the availability of paid leave for dental appointments and employer-supported health education, also constitute potentially important unmeasured variables that may mediate child oral health outcomes within industrial contexts. Therefore, our findings underscore the need for customized public health interventions that are tailored to this industrial community. To combat the significant barrier of parental time constraints, strategies must be highly accessible. This could include implementing oral health promotion programs directly at factory worksites, offering services like screenings, fluoride application, and education on-location. Furthermore, since health literacy was a key predictor, communication should be adapted for accessibility, prioritizing low-cost digital formats like social media videos over traditional, text-heavy pam-

phlets. At the policy level, it is essential for public health agencies to collaborate with factory owners in Samut Sakhon. These partnerships should aim to establish family-supportive policies, such as flexible work schedules to accommodate pediatric dental appointments or integrating child oral health education into existing employee wellness programs. By embedding support directly within the community's employment structure, this approach can effectively address the key resource barriers faced by parents.

Conclusions

This study identified that oral health behaviors among parents of preschool children in Samut Sakhon, an industrial province in Thailand, were moderate overall, indicating the need for targeted interventions across four domains: oral hygiene, bottle-feeding practices, dietary habits, and dental visitation. Parental perceived motivators, perceived barriers, and knowledge of preschool oral health emerged as the strongest predictors of behavior. However, our findings underscore the need for tailored interventions in this industrial community. The on-site programs offering screenings, fluoride application, and oral health education can help overcome parental time constraints. Communication should account for oral health literacy, favoring accessible digital formats. Collaboration between public health agencies and factory management to implement flexible schedules and integrate child oral health education into health promotion programs can effectively address parental resource barriers.

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Prevalence of Oral Lichen Planus in Northern Thai Patients with Hepatitis C Virus Infection

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Abstract

Objectives: This study aimed to investigate the prevalence of oral lichen planus (OLP) among individuals with hepatitis C virus (HCV) infection in upper northern Thailand and the potential association between OLP and HCV infection.

Methods: This cross-sectional study involved 1,025 participants, comprising 126 patients with confirmed HCV infection and 899 participants without HCV. All participants underwent structured interviews and clinical oral examinations by calibrated examiners. The diagnosis of OLP was established based on characteristic clinical features and confirmed by histopathological examination of oral mucosal biopsies. The statistical analysis used Pearson's Chi-square test and Fisher's exact test, with a significance level of $p < 0.05$.

Results: The prevalence of OLP was 2.38% in patients with HCV infection and 0.33% in those without HCV. The difference in OLP prevalence between the two groups was statistically significant ($p = 0.027$), suggesting a possible association between HCV infection and the development of OLP.

Conclusions: The findings indicated a significant association between HCV infection and OLP in this northern Thai cohort. Therefore, screening for OLP in patients with HCV is recommended for early detection and appropriate management.

Keywords: cross-sectional studies, hepatitis c virus, oral lichen planus, prevalence, Thailand

Introduction

Hepatitis C virus (HCV), an RNA virus first identified in 1989, is transmitted through contact with infected blood. Common routes of transmission include sharing injecting equipment, sexual contact involving blood, tattooing, and receiving unscreened blood transfusions.⁽¹⁾ In 2022, approximately 50 million people worldwide were living with chronic HCV infection, resulting in an estimated 242,000 deaths and 1 million new infections annually.⁽²⁾ Left untreated, chronic HCV infection can progress to cirrhosis, hepatocellular carcinoma, or liver-related death.⁽²⁾ In addition to liver disease, HCV infection is associated with various extrahepatic manifestations, including mixed cryoglobulinemia, non-Hodgkin's lymphoma, diabetes, porphyria cutanea tarda, and oral lichen planus (OLP).⁽³⁾

OLP is a chronic T-cell-mediated inflammatory disease that affects the oral mucosa.⁽⁴⁾ The global prevalence of OLP is 1.01%, with significant geographical variations.⁽⁵⁾ It is commonly found in patients aged 30–60 years. The five clinical types of OLP are reticular, plaque, papular, atrophic, and ulcerative.⁽⁶⁾ Histopathological features include a well-defined band-like infiltration of lymphocytes beneath the basement membrane, liquefaction degeneration of the basal cell layer, and an absence of epithelial dysplasia.⁽⁷⁾ Since 2005, the World Health Organization has classified OLP as an oral potentially malignant disorder (OPMD), with a malignant transformation rate of approximately 1–2%.⁽⁸⁾

The association between OLP and HCV was first reported in 1991.⁽⁹⁾ Subsequently, many studies globally have investigated this relationship, with conflicting findings. Although several studies have demonstrated a significant association between OLP and HCV^(10–22), others have not demonstrated a consistent association.^(23–32) In Thailand, two case-control studies have shown the association between OLP and HCV infection. Klanrit *et al.*⁽¹⁹⁾ reported that 8.33% of OLP patients were anti-HCV positive, while Manomaivat *et al.*⁽²²⁾ found an 8.9% HCV seroprevalence in OLP cases versus 0.99% among controls (odds ratio $\approx$ 9.78). Additionally, international studies have revealed notable geographical variations in this association. Recent meta-analyses indicate that approximately 7% of HCV patients worldwide present with OLP, a prevalence markedly higher than the general population (<1%).⁽³³⁾

Although previous Thai investigations suggest an association, no study has examined the prevalence of OLP among individuals with confirmed HCV infection in Thailand, including the northern region where demographic patterns differ. These variations highlight the need for local data. This study therefore aimed to determine the prevalence of OLP in HCV-infected and non-infected individuals in upper northern Thailand and to evaluate their potential association.

Materials and Methods

Ethical approval

This cross-sectional study received ethical approval from the Ethics Committee for Research on Humans at Chiangrai Prachanukroh Hospital (approval number: CR 0033.102/EC.66-451) before the commencement of data collection. The study was conducted at Chiangrai Prachanukroh Hospital, Chiang Rai, Thailand, with participant recruitment between July 2023 and May 2024. All participants were provided with comprehensive information on the study objectives and procedures and their rights as research participants. Written informed consent was obtained from all participants before enrollment, in accordance with ethical guidelines.

Participants

For the HCV infection group, patients were recruited from the Gastrointestinal and Liver Center at Chiangrai Prachanukroh Hospital. The inclusion criteria were (1) patients with anti-HCV antibodies detected using a chemiluminescent microparticle immunoassay (ARCHITECT anti-HCV assay; Abbott Laboratories, North Chicago, IL, USA) and (2) patients with serum HCV-RNA confirmed by reverse transcription-polymerase chain reaction (amplification test; Abbott Laboratories, North Chicago, IL, USA). Patients with antibodies against other hepatitis viruses, those with autoimmune mucocutaneous diseases, those taking medications known to cause lichenoid drug reactions⁽³⁴⁾, and those who declined biopsy when indicated were excluded.

For the control group, participants were recruited from the Health Checkup Center at Chiangrai Prachanukroh Hospital. Patients aged at least 30 years were included. The exclusion criteria were (1) patients with a history of hepatitis virus infection and (2) patients with a history of using drugs reported to cause lichenoid drug

reactions.⁽³⁴⁾ HCV infection in this group was excluded based on medical history only, as serologic testing was not performed; therefore, the possibility of unrecognized HCV infection cannot be entirely ruled out.

Sample size calculation

The sample size was calculated using a two-proportion formula, with a two-sided significance level of 0.05 and a statistical power of 0.80. Based on a previous study⁽¹⁶⁾, the estimated prevalence of OLP was 4.76% in patients with HCV infection and 0.67% in control patients. A control-to-case ratio of 7.13 was applied. Consequently, 126 patients with HCV infection and 899 without HCV were included in the study.

Data collection

Demographic data (including age and sex) and clinical data (including chief complaint, present illness, medical and dental history, and medication history) were collected from all patients. The clinical characteristics of OLP or OPMDs, including type, location, distribution, and photographs, were recorded.

Clinical assessment and definitive diagnosis

Oral examinations were performed by a single examiner (CA), a resident in general dentistry at Chiangrai Prachanukroh Hospital. The screening protocol for OLP and OPMDs was standardized through calibration sessions in collaboration with a Thai board-certified oral medicine (KI). This process achieved inter-examiner and intra-examiner reliability, with kappa values of 0.84 and 1.0, respectively.

Patients with clinical features of OLP or OPMDs were referred for confirmatory histopathological examination. Incisional biopsies were performed at the representative sites by an oral medicine specialist (DM). The tissue specimens were fixed in 10% neutral-buffered formalin and submitted for histopathological examination at the Faculty of Dentistry, Chiang Mai University. Histopathological diagnoses were performed by Thai board-certified oral and maxillofacial pathologists. The diagnosis of OLP was based on the clinical and histopathological criteria established by van der Meij and van der Waal in 2003.⁽⁷⁾ Only cases that fulfilled the strict diagnostic criteria for OLP were included. Lesions merely 'compatible with

OLP' or with overlapping lichenoid features were not classified as OLP.

Statistical analysis

The statistical analyses were performed using SPSS (version 26.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize demographic and clinical data. Categorical variables were presented as frequencies and percentages, and continuous variables were reported as means with standard deviations or medians, depending on data distribution. To compare the prevalence of OLP between the two groups, Pearson's Chi-square test and Fisher's exact test were applied, with the significance level set at $p < 0.05$.

Results

Demographic data

A total of 1,025 participants were enrolled, comprising 126 patients with HCV infection and 899 without HCV. The demographic data for both groups are summarized in Table 1. Significant differences in mean age and sex were observed between the groups. Among the patients with HCV infection, 71 were receiving sofosbuvir or velpatasvir (SOF/VEL), with or without ribavirin (RBV), and 55 had not initiated therapy at the time of the oral examination. There were statistically significant differences in age ($p < 0.001$) and sex distribution ($p = 0.005$) between groups. HCV-positive participants were older and included a higher proportion of males. These demographic differences may influence OLP risk and were therefore considered potential confounding factors in the interpretation of results.

Significantly higher prevalence of OLP in patients with HCV infection

Thirteen participants with clinically suspected OLP or OPMDs underwent biopsy, including four with HCV infection and nine without HCV. Definitive diagnoses included OLP, lichenoid reaction, discoid lupus erythematosus, and premalignant epithelial dysplasia, as shown in Table 2. The prevalence of OLP was 2.38% (95% CI: 0.49–6.80%) in HCV-positive patients and 0.33% (95% CI: 0.07–0.96%) in HCV-negative patients, representing a statistically significant difference between groups ($p = 0.027$).

Clinical characteristics of OLP in patients with and without HCV infection

In patients with HCV, the three cases of OLP included one man (aged 70 years) and two women (aged 40 and 58 years). The mean age of these three patients was 56.0 years, and clinically, one case presented with the ulcerative type while the remaining two exhibited the atrophic type. Representative clinical features are shown in Figure 1. One patient had been receiving SOF/VEL plus RBV for one month at the time of the oral examination and reported a burning sensation before treatment. The remaining two patients had not started antiviral therapy. No significant difference in the prevalence of OLP was observed between patients who received SOF/VEL and those who did not ($p=0.58$).

In patients without HCV, the three cases of OLP comprised two men (aged 52 and 65 years) and one woman (aged 54 years). Their mean age was 57.0 years, and all three cases presented with the atrophic clinical type. Representative clinical features are shown in Figures 2A-2C. Additionally, one case of a lichenoid reaction associated with amalgam restoration is presented in Figure

2D. Clinical characteristics of OLP lesions in both groups are summarized in Table 3.

Discussion

Multiple studies have investigated the association between OLP and HCV infection, but the evidence has remained variable across populations. While several reports have demonstrated a meaningful relationship between the two conditions⁽¹⁰⁻²²⁾, others have not shown a consistent association.⁽²³⁻³²⁾ These inconsistencies may reflect regional differences in host genetics, immune responses, or circulating HCV genotypes.⁽²²⁾ Our study provides new data from northern Thailand and demonstrates a significantly higher prevalence of OLP among patients with HCV infection compared with those without HCV. The prevalence observed in our cohort (2.38%) is consistent within the range reported internationally (1.5-4.94%).^(14,16,26,29,35-38) Moreover, the prevalence of OLP in the non-HCV group (0.33%) is also comparable to previously documented rates in control populations.^(16,26,29,35-37) After considering the significant differences in age and sex distribution between the two

Table 1: Demographic data in patients with and without hepatitis C virus infection.

	HCV-positive (n=126)	HCV negative (n=899)	p-value
Sex (n, %)			0.005*a
Male	74 (58.73)	407 (45.27)	
Female	52 (41.27)	492 (54.73)	
Age (years)			<0.001*b
Mean±SD	55.89±11.69	51.23±12.11	
Median	57	52	
Range	20-84	30-86	

HCV = hepatitis C virus, n = number of patients, SD = standard deviation

* $p<0.05$

^aChi-square test

^bIndependent-samples t-test

Table 2: Definitive diagnoses of oral lesions in patients with and without hepatitis C virus infection.

	HCV-positive (%) (n=126)	HCV negative (%) (n=899)	p-value ^a
Oral lichen planus	3 (2.38)	3 (0.33)	0.027*
Lichenoid reaction	0 (0)	1 (0.11)	1.000
Discoid lupus erythematosus	1 (0.79)	3 (0.33)	0.409
Premalignant epithelial dysplasia	0 (0)	2 (0.22)	1.000
Total	4 (3.17)	9 (1.00)	

HCV = hepatitis C virus, n = number of patients

* $p<0.05$

^aFisher's exact test

Table 3: Clinical characteristics and antiviral treatment of oral lichen planus in patients with and without hepatitis C virus infection.

	HCV-positive (%) (n=3)	HCV negative (%) (n=3)
Clinical type		
Ulcerative	1 (33.33)	0 (0)
Atrophic	2 (66.67)	3 (100)
Symptoms		
Symptomatic	3 (100)	2 (66.67)
Asymptomatic	0 (0)	1 (33.33)
Distribution		
Bilateral	3 (100)	3 (100)
Site		
Buccal mucosa	3 (100)	3 (100)
Gingiva	2 (66.67)	1 (33.33)
Lip vermillion	1 (33.33)	0 (0)
Multiple sites	3 (100)	3 (100)
SOF/VEL with or without RBV		
Yes	1 (33.33)	-
No	2 (66.67)	-
Sex		
Male	1 (33.33)	2 (66.67)
Female	2 (66.67)	1 (33.33)
Age (years)		
Mean±SD	56±15.10	57±7.00

HCV = hepatitis C virus, n = number of patients

groups, the association observed in this study remains consistent with prior evidence.⁽¹⁶⁾ Because the HCV-positive group was older and more predominantly male⁽³⁹⁾, these demographic factors may have contributed to the higher prevalence of OLP. Age is known to influence the occurrence of OLP, and sex-related differences in immune responses may also play a role⁽⁵⁾, therefore, demographic imbalance must be considered when interpreting our findings.

In Thailand, two studies have examined the prevalence of HCV infection among patients with OLP. Klanrit *et al.*,⁽¹⁹⁾ reported that 8.3% of patients with OLP in the central and northeastern regions were seropositive



Figure 1: Clinical features of oral lichen planus (OLP) in patients with hepatitis C virus (HCV) infection. (A) Ulcerative OLP of the upper labial mucosa in a 40-year-old woman receiving sofosbuvir/velpatasvir with ribavirin; (B) Atrophic OLP involving posterior maxillary gingiva and buccal mucosa in a 70-year-old man; (C) Bilateral atrophic OLP on buccal mucosa in a 58-year-old woman.

for HCV. Similarly, Manomaivat *et al.*,⁽²²⁾ found that 8.9% of OLP patients in the upper northern region tested positive for anti-HCV antibodies, compared to 1% in the control group. These findings, along with ours, provide bidirectional evidence supporting a potential association between HCV infection and OLP in the Thai population.

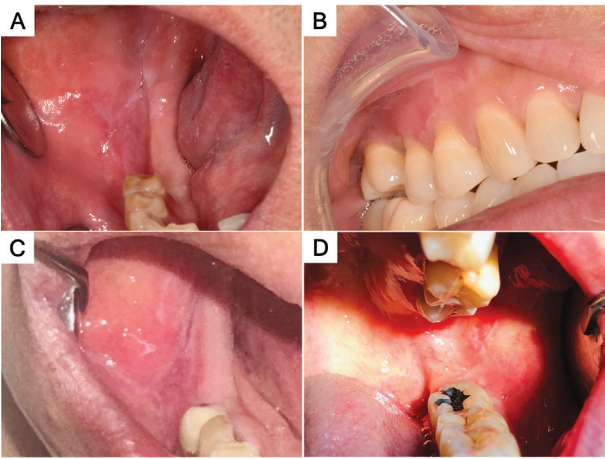


Figure 2: OLP and lichenoid reaction in HCV-negative patients. (A–C) Atrophic-type OLP: (A) 52-year-old man, buccal mucosa; (B) 54-year-old woman, upper labial gingiva; (C) 65-year-old man, buccal mucosa; (D) Oral lichenoid contact reaction adjacent to an amalgam restoration on the left buccal mucosa in a 55-year-old woman, with localized erythema and white striae.

The prevalence identified in this study aligns with international reports and underscores the relevance of evaluating OLP in patients with HCV infection in Thailand's northern region.⁽³³⁾

Several mechanisms have been proposed to explain this association, including immune-mediated cytotoxicity directed against basal keratinocytes, molecular mimicry between viral antigens and epithelial structures, and T-cell-driven chronic inflammation.^(40,41) Possible replication of HCV in extrahepatic tissues, including oral epithelial cells, may also contribute to mucosal immune dysregulation.^(42,43) These mechanisms may help clarify the limited proportion of individuals with HCV who develop OLP. In addition to these immunopathogenic pathways, the severity and chronicity of HCV infection may further influence the clinical expression of OLP. Long-standing HCV infection is associated with persistent immune activation and elevated systemic inflammatory burden, factors that may predispose patients to more symptomatic or recalcitrant mucosal disease.

Direct-acting antivirals (DAAs) such as SOF/VEL, with or without RBV, are highly effective in achieving a sustained virologic response in patients with chronic HCV infection, with response rates exceeding 97% across all genotypes.⁽⁴⁴⁾ In addition to viral clearance, several studies have reported improvement in HCV-related extrahepatic manifestations, including OLP, following DAA therapy, with significant symptom improvement observed during or after treatment.^(45,46) However, in our study, one patient who received SOF/VEL with RBV continued to experience symptomatic OLP despite achieving a virologic cure. This observation highlights the potential for persistent OLP symptoms following HCV eradication and indicates the need for further investigation into the mechanisms and timeline of extrahepatic response to antiviral therapy.

Since 2005, the World Health Organization has classified OLP as an OPMD, with a malignant transformation rate of 1.43%.⁽⁸⁾ The highest transformation rates are observed in the erosive (1.7%) and atrophic (1.3%) types.⁽⁴⁷⁾ Gandolfo *et al.*,⁽⁴⁸⁾ demonstrated that concurrent HCV infection and OLP increased the risk of oral cancer, with a risk ratio of 3.16. Previous studies have also reported an association between erosive OLP and HCV infection.^(11,49) In our study, one of three HCV-related OLP cases was ulcerative, and two were atrophic. These

findings suggest that HCV infection may be associated with more aggressive OLP types, which carry a higher risk of malignant transformation. Therefore, close monitoring of OLP in patients with HCV infection is crucial for the early detection and prevention of progression to oral cancer.

This study has several limitations. First, the single-center and cross-sectional design limits the ability to infer causality. Second, the small number of OLP cases restricts the statistical power to detect subgroup differences. Third, demographic imbalance between groups may have influenced the results. Fourth, HCV infection in the control group was excluded based on medical history without serologic testing, raising the possibility of unrecognized HCV infection. Finally, although strict diagnostic criteria were applied, some degree of overlap between lichenoid lesions and true OLP cannot be entirely ruled out. To enhance generalizability, multicenter and population-based studies across various regions of Thailand are recommended. Additionally, longitudinal research is needed to evaluate the efficacy of SOF/VEL in resolving OLP lesions and its potential impact on the risk of malignant transformation in HCV-related OLP. Further investigation into the pathogenesis of OLP in HCV infection, including the underlying molecular and immunological mechanisms, is also warranted. Finally, assessing the cost-effectiveness of incorporating OLP screening into HCV treatment protocols could inform clinical practice and health policy.

Conclusions

Our findings indicate a significant association between HCV infection and OLP. Therefore, screening for OLP in patients with HCV could be recommended for early detection and appropriate management.

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Conflict of Interest

The authors declare no conflict of interest.

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Effect of Cavity Configuration on the Fracture Strength of Composite-Restored Root-Filled Maxillary Premolars: An *In Vitro* Study

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Abstract

Objectives: To evaluate the fracture strength and fracture patterns of root-filled maxillary premolars restored with direct resin composite using three cavity configurations: occlusal, mesio-occlusal (MO), and mesio-occluso-distal (MOD).

Methods: Forty extracted maxillary premolars were randomly assigned to four groups (n=10): intact controls, occlusal, MO, and MOD restorations. Root canal treatment was performed for restored groups, followed by standardised cavity preparation and incremental restoration with nano-filled resin composite. Specimens were mounted with periodontal ligament simulation and loaded axially to fracture using a universal testing machine at 1 mm/min. Maximum fracture strength was recorded in Newtons. Fracture patterns were examined under 3× magnification and classified as favourable (Types 1-2) or unfavourable (Types 3-4). Differences among groups were analysed using one-way ANOVA with Games-Howell post-hoc tests at the significant level of 0.05.

Results: The control group showed the highest mean fracture strength (1265.7 N), followed by occlusal (846.1 N), MO (685.8 N), and MOD restorations (474.1 N). ANOVA revealed significant differences among all groups ($p < 0.001$). Favourable fracture types predominated in intact and occlusal groups, whereas MO and MOD restorations showed substantially higher proportions of unfavourable Type 3 and Type 4 fractures. The MOD group exhibited the most catastrophic failures, with nearly half classified as a Type 4 failure.

Conclusions: Cavity configuration significantly influenced both fracture strength and fracture pattern of restored root-filled maxillary premolars. Preserving marginal ridges produced higher strength and more favourable fracture patterns. Further laboratory and clinical studies are warranted to optimise the management of structurally compromised premolars.

Keywords: composite resin, dental cavity preparation, dental restoration, endodontics, tooth fractures

Introduction

The long-term survival of root canal-treated or root-filled teeth is influenced by the quality of the definitive coronal restoration, which must restore structural integrity and withstand functional loading.⁽¹⁾ Although root-filled teeth were previously believed to be inherently weaker due to dentinal dehydration⁽²⁾, altered mechanical properties⁽³⁾, and the loss of pulpal tissue and proprioceptive responses⁽⁴⁾, contemporary evidence suggests that the primary determinant of biomechanical compromise is not the root canal procedure itself but the loss of tooth structure associated with access cavity preparation, canal enlargement, and loss of peri-cervical dentine.^(1,5) A recent study also reinforced that preservation of tooth structure, especially the marginal ridges and proximal walls, plays a more critical role in load resistance than previously understood.⁽⁶⁾

Of particular importance is the integrity of the marginal ridge, which contributes substantially to the structural bracing of posterior teeth.⁽⁷⁾ Loss of a single marginal ridge reduces the fracture strength of posterior teeth by approximately 23%⁽⁸⁾, whereas loss of both ridges in mesio-occluso-distal (MOD) preparations produces the greatest decrease in fracture strength of root-filled teeth.⁽⁹⁾ Even when restored with composite resin, MOD cavities incorporating an endodontic access regain only limited fracture strength relative to intact teeth.⁽¹⁰⁾ Moreover, experimental work on root-filled teeth restored with MOD cavities has demonstrated that reinforcement strategies, such as root canal posts, do not fully recover the load-bearing capacity of intact teeth.⁽¹¹⁾ Similarly, a previous work evaluating varying mesial marginal ridge thicknesses showed a stepwise decline in fracture strength of root-filled maxillary premolars as ridge thickness decreases, with complete loss of the ridge resulting in the weakest performance, even when fibre reinforcement is used.⁽¹²⁾ These findings highlight that preservation of marginal ridges plays a more decisive role in the fracture strength of root-filled teeth than the choice of intracoronal reinforcement.

Maxillary premolars warrant special consideration, as vertical root fractures have been reported to occur frequently in both mandibular molars and maxillary premolars compared with other tooth types.⁽¹³⁾ Recent finite element analysis has shown that greater dentine loss during access cavity preparation in maxillary premo-

lars, particularly in designs that remove proximal walls, results in substantially higher stress concentrations across enamel, dentine, and the peri-cervical region compared with conservative designs.⁽¹⁴⁾ Their anatomical form, characterised by thin cervical dentine, steep cusp inclines and a prominent mesial root concavity, renders them highly susceptible to cusp flexure and structural failure under both axial and lateral loading.⁽⁹⁾ A recent systematic review and meta-analysis highlights that endodontically treated maxillary premolars are susceptible to fracture due to their anatomical and biomechanical characteristics, including thin cervical dentine and mesial root concavity. The review further indicates that, although fibre posts may increase fracture resistance compared with direct composite restoration without a post, fracture resistance generally remains inferior to that of sound premolars. Importantly, fracture behaviour of maxillary premolars appears to be strongly influenced by the amount and configuration of residual coronal structure, particularly marginal ridge preservation and the presence of MOD cavities, rather than being determined solely by the type of post system used.⁽⁹⁾

Despite the growing literature on minimally invasive access cavity designs and advancements in composite restorative materials^(15,16), uncertainty remains regarding how progressive loss of marginal ridges, ranging from occlusal access to mesio-occlusal (MO) and MOD cavity configurations, affects fracture strength and failure patterns in root-filled maxillary premolars restored without cuspal coverage. Although previous in-vitro evidence showed that adding buccal and palatal cusp coverage can increase fracture strength of root-filled maxillary premolars by 45% as compared with conventional MOD composite restorations⁽¹⁷⁾, such cuspal reduction is not universally practised among dentists.⁽¹⁸⁾ In many cases, particularly in teeth with preserved cusp height or when indirect coverage is postponed, restoring root-filled upper premolars using intracoronal composite alone may be the restorative option. However, the independent biomechanical influence of cavity configuration under these conditions remains incompletely defined. Therefore, understanding how specific cavity designs influence the fracture behaviour of root-filled premolars is essential for evidence-based restorative decision-making. Accordingly, the present study aimed to evaluate the fracture strength and fracture patterns of root-filled maxillary premolars

restored with direct resin-based composite using three cavity configurations: occlusal, MO, and MOD. The null hypothesis was that cavity configuration would have no significant effect on the fracture strength or fracture mode of restored root-filled premolars.

Materials and Method

Ethical approval

Ethical approval for the use of extracted human teeth was obtained from the National Health Service Research Ethics Committee. Ethics approval 16/WM/0236 (STH protocol number 18841). All procedures followed institutional laboratory safety standards and adhered to proper handling of biological specimens.

Sample size calculation

The sample size was calculated a priori using G*Power 3.1 (Heinrich-Heine University, Düsseldorf, Germany) for a one-way fixed-effects ANOVA (omnibus F-test). An effect size $f=1.03$ was derived from a previous similar study.⁽¹⁹⁾ Using this effect size, with a significance level $\alpha=0.05$, desired statistical power of 0.95, and four groups (three test groups and one control), the minimum total sample size required was 24 teeth, corresponding to 6 specimens per group. To compensate for potential exclusion of teeth due to undetected cracks, caries, or procedural errors during preparation and mounting, the calculated sample size was set at 40 teeth, yielding 10 specimens per group.

Sample selection and preparation

Forty freshly extracted maxillary permanent premolars were collected and stored in normal saline solution at room temperature and used within three months. Only single-rooted maxillary premolars were included. Root morphology was verified using pre-operative periapical radiographs taken in bucco-lingual (BL) and mesio-distal (MD) directions to confirm the absence of root bifurcation, external resorption, or severe curvature. Teeth with separated roots or marked anatomical variations were excluded to ensure standardisation. Canal configuration was not used as an exclusion criterion, as instrumentation was standardised across specimens. All teeth were then thoroughly debrided using a hand scaler to remove calculus, soft tissue remnants, and debris. Each sample was examined under an operating microscope ($3.0\times$

magnification) to verify the absence of cracks, structural defects, or previous restorations. Standardisation of size was achieved by measuring the BL and MD dimensions at the cemento-enamel junction (CEJ) level, and the occluso-gingival (OG) height from cusp tip to CEJ using a digital calliper (Mitutoyo Corp., Kawasaki, Japan) with 0.01 mm accuracy. The mean dimensions of the selected teeth were 9.15 ± 0.12 mm (BL), 7.38 ± 0.11 mm (MD), and 5.96 ± 0.10 mm (OG). Teeth were included if they were maxillary permanent premolars, caries-free, unrestored, single-rooted, without visible fractures, and within the standardised dimensional range.

The samples were randomly allocated into four groups ($n=10$ per group): Group A (root-canal-treated teeth restored with occlusal composite), Group B (root-canal-treated teeth restored with MO composite), Group C (root-canal-treated teeth restored with MOD composite), and Group D (intact, untreated teeth serving as control).

Root canal treatment procedure

Root canal treatment (RCT) was performed on teeth assigned to Groups A–C. Access cavities were prepared using a cavity access bur set (Dentsply Maillefer, Ballaigues, Switzerland). Coronal flaring of the canal orifice was accomplished using Gates Glidden drills (sizes 4, 3, 2, and 1; Dentsply Maillefer, Ballaigues, Switzerland) sequentially with an X-smart™ contra-angle handpiece (Dentsply Maillefer, Ballaigues, Switzerland). Apical preparation was carried out using stainless steel K-files (size 30; Dentsply Maillefer, Ballaigues, Switzerland) to a working length 0.5 mm short of the radiographic apex, employing a step-back technique in 1-mm increments.

During instrumentation, canals were irrigated with 5.25% sodium hypochlorite solution (NaOCl, Vishal Dentocare Pvt. Ltd., Ahmedabad, India). A final rinse with 17% ethylenediaminetetraacetic acid (EDTA; Pulpdent Corporation, Watertown, MA, USA) for 1 minute was followed by a final rinse of 5.25% NaOCl for another 30 seconds before drying. Canals were then dried with sterile paper points (Dentsply Maillefer, Ballaigues, Switzerland). Obturation was carried out using a size 30 matched-taper gutta-percha master cone (Dentsply Maillefer, Ballaigues, Switzerland) in combination with a zinc oxide–eugenol–based sealer (Tubli-Seal™ EWT, Kerr Endodontics, Orange, CA, USA). Cold lateral condensation was performed using size A and size B finger

spreaders (Dentsply Maillefer, Ballaigues, Switzerland) together with size A and B accessory gutta-percha points. Gutta-percha was vertically compacted 2 mm below the cemento-enamel junction (CEJ) using a heated hand instrument activated by an induction heater (Noflameplus, Micrium S.p.A., Avegno, Italy). After obturation, the pulp chamber and canal orifice were cleaned using alcohol-soaked cotton pellets to remove residual sealer and eugenol-containing materials. The teeth were kept at room temperature for 24 hours for the sealer to set.

Cavity preparation

Standardised cavity preparations were performed under water coolant using a high-speed handpiece (X-smart™, Dentsply Maillefer, Ballaigues, Switzerland) with tapered diamond burs (Komet Dental, Lemgo, Germany) under 3.0× magnification. The occlusal cavity (Group A) involved only the endodontic access cavity with a pulpal depth of 1 mm above the proximal CEJ. The average occlusal cavity depth measured from the central groove to the pulpal floor was standardised at 4±0.2 mm. The MO cavity (Group B) consisted of an access cavity plus a mesial box with a standardised 1/3 bucco-palatal width. The MOD cavity (Group C) incorporated both mesial and distal boxes, each also standardised to 1/3 bucco-palatal width. In the MO and MOD groups, proximal box depth extended to 1 mm above the CEJ to ensure uniform marginal ridge removal and wall thickness reduction. All cavity depths were standardised to 1 mm above the proximal CEJ. All preparations were verified for consistency using a periodontal probe (Hu-Friedy, Chicago, IL, USA).

Restorative procedure

Following RCT, gutta-percha was removed to 2 mm below the CEJ. A glass ionomer base (GC Fuji IX GP EXTRA, GC Corporation, Tokyo, Japan) was placed and allowed to set according to the manufacturer's instructions. Enamel and dentine were etched using 37% phosphoric acid for 20 seconds, rinsed thoroughly, and dried gently. A universal bonding agent (Scotchbond™ Universal Adhesive, 3M ESPE, St. Paul, MN, USA) was applied and light-cured for 15 seconds according to the manufacturer's instructions using an LED curing light (Henry Schein®, Gillingham, UK). The LED curing unit delivered a light intensity of 1000 mW/cm², verified

using a radiometer prior to use. All cavities were restored incrementally (~ 2mm) using a nano-filled resin composite (Filtek™ Supreme XTE Universal Restorative, shade A2B; 3M ESPE, St. Paul, MN, USA). Each increment was polymerised for 20 seconds using the same LED curing light. Restorations were finished and polished using the Enhance® Finishing and Polishing System (Dentsply Caulk, Milford, DE, USA). Completed specimens were stored in normal saline at room temperature before further procedures.

Sample mounting and periodontal ligament simulation

To simulate the periodontal ligament (PDL), a two-stage mounting method was employed based on Brosh *et al.*⁽²⁰⁾ Each tooth was coated with a thin layer of die separator (Renfert GmbH, Hilzingen, Germany) to create uniform spacing. Teeth were positioned upside down, with the long axis perpendicular to the horizontal plane, and embedded in Dublilil® 15 A/B silicone material (Dreve Dentamid GmbH, Unna, Germany) using a dental surveyor to ensure alignment and standardisation (Figure 1a). The embedding height was limited to 2 mm apical to the CEJ. After the silicone had set, cylindrical copper rings (RS Components Ltd., Corby, UK) were centred around the exposed root surface (Figure 1b). A polyurethane resin (AlphaDie® MF, Schütz Dental GmbH, Rosbach, Germany) was mixed according to the manufacturer's specifications and poured into the ring to envelop the exposed root. Once polymerised, the tooth was removed from the resin block, and the resulting socket was filled with a light-body polyvinyl siloxane impression material (President Plus® Light Body, Coltene/Whaledent AG, Altstätten, Switzerland). The tooth was immediately resealed and held in place until the material set (Figure 2). Excess silicone was trimmed using a size 11 surgical blade (Swann-Morton, Sheffield, UK). Only specimens with mobility grade 0 were accepted for mechanical testing.

Mechanical testing (fracture strength assessment)

Fracture strength was evaluated using a universal testing machine (Lloyd Instruments LRX, Ametek Inc., Fareham, UK). Each mounted specimen was positioned on the machine platform such that its long axis was perpendicular to the loading direction. A stainless-steel spherical indenter with a diameter of 4.5 mm (Ametek

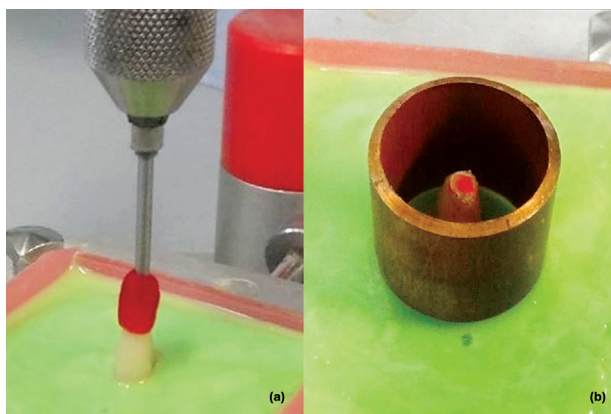


Figure 1: (a) The tooth sample was mounted upside down in the container containing silicone material with the aid of a dental surveyor; (b) The tooth sample was positioned in the centre of a cylindrical copper ring.

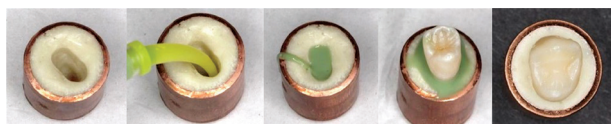


Figure 2: Composite image showing the injection of light-body silicone impression material into the tooth socket to simulate the periodontal ligament.

Inc., Fareham, UK) was attached to the crosshead, and a 1-mm-thick rubber dam sheet (Coltene Rubber Dam, Altstätten, Switzerland) was placed between the indenter and the occlusal surface to minimise stress concentration. A static compressive axial load was applied at a crosshead speed of 1 mm/min until catastrophic fracture occurred. The maximum load required to fracture each sample was automatically recorded in Newtons (N).⁽²¹⁾

Fracture pattern analysis

Fractured specimens were examined under 3.0× magnification using an operating microscope. Fracture patterns were classified into restorable (favourable) and non-restorable (non-favourable/catastrophic) fractures according to Soares's classification (Type 1 to Type 4).⁽¹⁰⁾

Type 1: fractures involving small tooth portions (coronal)

Type 2: fractures involving tooth portions (coronal) and cohesive failure of composite resin

Type 3: fractures involving tooth portions, with periodontal involvement and adhesive failure of composite resin

Type 4: vertical root/coronal fracture

For intact control teeth, Type 2 classification was assigned to fractures confined coronally without periodontal involvement, while Type 3 classification was assigned to fractures with periodontal involvement, consistent with the severity-based criteria of Soares *et al.*⁽¹⁰⁾ In these specimens, cohesive composite failure was not applicable, and classification was based solely on fracture extent and restorability.

Statistical analysis

Data analysis was performed using SPSS software (Version 24.0; IBM SPSS Inc., Chicago, IL, USA). Normality of distribution was assessed using the Shapiro–Wilk test. One-way analysis of variance (ANOVA) was conducted to compare mean fracture strength across the four groups. The Games–Howell post-hoc test was selected for multiple pairwise comparisons due to heterogeneity of variances. Statistical significance was set at $\alpha=0.05$ for all analyses. In addition, the distribution of favourable (Types 1–2) and unfavourable (Types 3–4) fracture modes among groups was compared using Fisher's exact test, as several expected cell counts were below five. Statistical significance was set at $\alpha=0.05$.

Results

Fracture Strength

Normality testing using the Shapiro–Wilk test confirmed that the data were normally distributed for all groups ($p>0.05$). Fracture strength values are summarised in Table 1 and illustrated in Figure 3. The control group (intact premolars) recorded the highest mean fracture strength (1265.7 N), whereas the MOD group showed the lowest (474.1 N). Among restored teeth, occlusal restorations demonstrated the greatest fracture strength (846.1 N), followed by MO (685.8 N) and MOD (474.1 N). These results show a clear reduction in fracture strength with increasing cavity complexity and loss of marginal ridge support. A one-way ANOVA confirmed significant differences among the groups ($F(3,36) = 36.27, p<0.001$), indicating that cavity design significantly influenced fracture strength. Levene's test ($p<0.05$) and Welch's test both indicated unequal variances; therefore, the Games–Howell post-hoc test was used. Pairwise comparisons (Table 2) showed significant differences between all groups ($p<0.05$). The control group differed from all

restored groups, and each restoration configuration differed significantly from the others. MOD restorations consistently showed the lowest fracture values. Overall, fracture strength decreased markedly with the loss of marginal ridges, with MOD cavities performing the poorest.

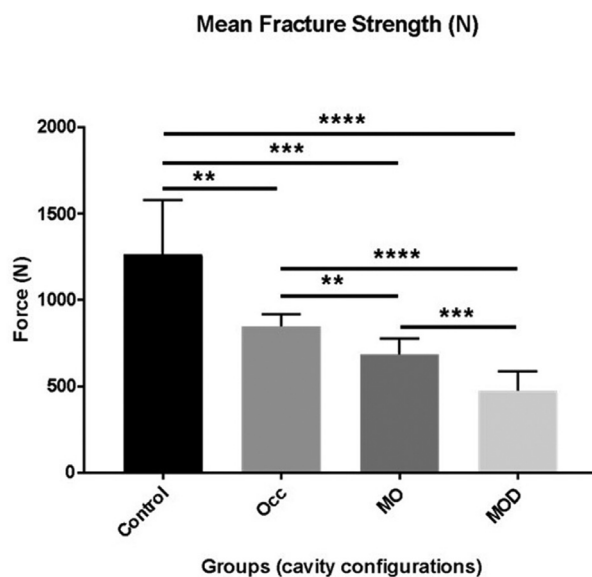


Figure 3: The mean fracture strength (N) of all groups.

Table 1: Fracture strength (N) of all tested groups.

Group	n	Mean (N)	SD	SE	95% CI (Lower)	95% CI (Upper)	Min (N)	Max (N)
Control	10	1265.70	312.40	98.79	1042.22	1489.18	977	1890
Occlusal	10	846.10	72.62	22.96	794.15	898.05	720	960
MO	10	685.80	90.31	28.56	621.19	750.41	570	882
MOD	10	474.10	113.40	35.86	392.98	555.22	228	586
Total	40	817.93	339.10	53.62	709.47	926.38	228	1890

CI: confidence interval; SD: standard deviation; SE: standard error

Table 2: Games–Howell post-hoc pairwise comparisons.

Group Comparison	Mean Difference (N)	SE	Sig.	95% CI (Lower)	95% CI (Upper)
Control – Occlusal	419.60*	101.42	0.009	109.14	730.06
Control – MO	579.90*	102.84	0.001	267.96	891.84
Control – MOD	791.60*	105.10	<0.001	476.81	1106.39
Occlusal – MO	160.30*	36.65	0.002	56.26	264.34
Occlusal – MOD	372.00*	42.58	<0.001	249.57	494.43
MO – MOD	211.70*	45.84	0.001	81.50	341.90

*Significant at $p < 0.05$

CI: confidence interval; MO: mesio-occlusal; MOD: mesio-occluso-distal; SE: standard error

Fracture pattern

The control group predominantly exhibited Type 1 fractures (6 out of 10), with no occurrence of Type 4 catastrophic fractures (Figure 4). In contrast, the occlusal group showed mostly Type 2 fractures (5 out of 10) and only one Type 4 fracture. The MO group displayed a higher proportion of severe fractures, with Type 3 fractures being the most frequent (7 out of 10) and 2 cases of Type 4 fractures. The MOD group demonstrated the most catastrophic outcomes, with nearly equal distribution of Type 3 (4 out of 10) and Type 4 fractures (5 out of 10). The frequency of unfavourable fractures (Types 3 and 4) increased with the complexity of the cavity design. MO and MOD restorations showed substantially more non-restorable, sub-CEJ fractures compared to the control and occlusal groups, which tended to exhibit more favourable, restorable fracture types. Fisher's exact test confirmed a statistically significant association between cavity configuration and fracture mode distribution ($p < 0.001$), indicating that increasing marginal ridge loss significantly increased the likelihood of unfavourable fractures.

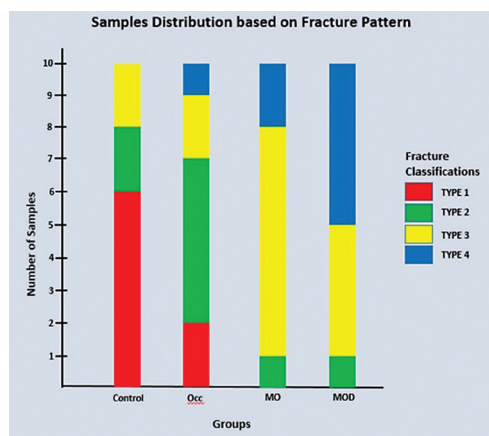


Figure 4: Distribution of samples according to fracture pattern across all groups.

Discussion

The present study investigated the effect of three cavity configurations, namely occlusal, MO, and MOD, on the fracture strength and fracture pattern of root-filled maxillary premolars restored with direct resin composite without cuspal coverage. The findings demonstrated that cavity configuration had a significant effect on the load-bearing capacity of restored teeth, with fracture strength decreasing substantially as cavity complexity increased. These results align with the well-established principle that the amount and configuration of remaining tooth structure are the primary determinants of biomechanical performance in root-filled teeth.^(6,9) Intact premolars in the control group exhibited the highest fracture strength, consistent with previous research showing that sound teeth withstand high occlusal forces and fail in more favourable patterns due to their intact structural bracing and preserved enamel “compression dome”.^(10,17,19) In contrast, all restored groups exhibited significantly lower fracture strength, reinforcing earlier findings that neither root canal treatment nor composite restoration can fully restore the mechanical integrity of intact teeth, particularly when marginal ridge loss is involved.^(6,22,23) The decline in fracture strength from occlusal to MO and finally MOD restorations reflects the increasingly detrimental effect of structural loss rather than the restorative material itself.

Among restored groups, occlusal restorations showed the highest fracture strength (846.1 N), approaching physiologic posterior occlusal loads and outperforming MO and MOD configurations. This supports the biomechanical principle that when both marginal ridges remain

intact, the tooth retains substantial structural integrity.⁽²⁴⁾ Finite element analyses have suggested that loss of proximal walls may exert greater influence on stress distribution than moderate variations in canal shaping, supporting the present finding that coronal structural integrity plays a critical biomechanical role.⁽⁶⁾ The significantly lower strength observed in MO preparations (685.8 N) demonstrates the importance of even a single marginal ridge, as its loss creates unilateral weakening and predisposes to flexure along the unsupported cusp. Notably, a recent comparative study suggested that conventional resin composite types may have a limited influence on fracture strength in extensive MOD cavities, although advanced fibre-reinforced materials may offer additional reinforcement potential.⁽²⁵⁾ These results further confirm that, although adhesive composites are excellent restorative materials for root-filled teeth, they cannot fully compensate for extensive structural loss when one or both marginal ridges are compromised.

Fracture pattern analysis reinforced the fracture strength findings. Intact teeth exhibited mostly Type 1 fractures, consistent with failures confined above the CEJ and considered restorable. Occlusal restorations showed predominantly Type 2 fractures, also largely favourable. In contrast, the MO and MOD groups demonstrated a much higher proportion of severe, non-restorable Type 3 and Type 4 fractures. MOD restorations, in particular, exhibited nearly half catastrophic Type 4 fractures extending below the CEJ, corroborating previous studies that correlate increased cavity size and marginal ridge loss with unfavourable fracture outcomes.^(8,26) In the present study, the proximal box width was standardised to approximately one-third of the bucco-palatal dimension, which inevitably reduced the remaining wall thickness in the MO and especially the MOD configurations. Given the average MD dimension of the selected premolars, this preparation likely resulted in residual wall thickness approaching the biomechanical threshold previously reported to compromise fracture resistance. These findings highlight that cavity configuration not only influences fracture load but also directly affects the restorability and clinical prognosis of failed teeth. From a clinical perspective, this highlights the importance of preserving marginal ridges whenever possible and suggests that MOD-restored premolars may benefit from additional reinforcement or cuspal coverage to reduce the risk of catastrophic fracture.⁽¹⁷⁾ Evidence

from a previous study also indicates that when residual wall thickness falls below 2 mm, cuspal coverage becomes the preferred approach capable of achieving satisfactory fracture strength in maxillary premolars.⁽²⁷⁾

Direct comparison with previous studies should be interpreted cautiously, as differences in load-testing protocols, such as indenter size, presence of an interface material, and crosshead speed, may influence fracture strength values. These methodological variations act as confounding factors that limit direct numerical comparison across studies. For instance, the present study used a 4.5-mm stainless-steel spherical indenter to simulate occlusal contact over functional cusp inclines and to distribute load over a broader area, and applied a static axial load at 1 mm/min. However, a previous similar study utilised a larger indenter diameter of 5.7 mm with a slower crosshead speed of 0.5 mm/min.⁽²⁵⁾ Chai *et al.*,⁽²⁸⁾ further highlighted that indenter geometry can substantially alter fracture initiation behaviour even in intact premolars, owing to changes in contact mechanics at the occlusal surface. Such findings reinforce that variability in testing configurations can shift fracture thresholds, complicating direct comparison across studies. Future investigations incorporating varying indenter geometries and angled loading protocols are recommended to better simulate functional occlusal contacts.

Several limitations must be considered in the present study. First, as with all *in vitro* studies, static loading cannot fully replicate complex intraoral conditions such as thermal fluctuations, cyclic fatigue, multidirectional forces, or long-term degradation of adhesive interfaces. The compressive or axial loading applied during the fracture strength test does not fully replicate intraoral conditions, where occlusal forces vary considerably in magnitude, direction, and dynamic loading patterns. Second, the present study evaluated only one composite resin material and did not assess alternative reinforcement strategies such as fibre-reinforced composite materials, bulk-fill composites, or cuspal coverage restorations. Future studies should incorporate cyclic fatigue testing, thermomechanical loading, and three-dimensional imaging of failure patterns to better simulate clinical function. Investigating cuspal coverage, indirect restorations, or novel composite reinforcement techniques for MOD preparations would also provide valuable insights. Ultimately, well-designed clinical trials are needed to validate these laboratory

findings and guide evidence-based restorative decision-making for root-filled maxillary premolars.

Conclusions

Within the limitations of this *in vitro* study, cavity configuration significantly influenced both fracture strength and fracture mode of root-filled maxillary premolars restored with direct resin composite without cuspal coverage. Preservation of marginal ridges resulted in higher fracture resistance and more favourable fracture patterns, whereas loss of one or both ridges substantially increased the risk of catastrophic fracture. These findings highlight the critical biomechanical importance of coronal structural preservation in restorative decision-making.

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Conflict of Interest

The authors declare no conflicts of interest.

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Time-Dependent Changes in the Mechanical Properties of Directly Printed Tera Harz TC-85 DAC (Direct Aligner Clear) After Manufacturing

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Abstract

Objectives: To investigate the time-dependent changes in flexural strength, tensile strength, and surface hardness of Tera Harz TC-85 DAC (Direct Aligner Clear) aligners after manufacturing.

Methods: The aligner specimens were fabricated using a 3D printer and tested for flexural strength, tensile strength, and surface hardness on days 1, 7, 14, 21, 30, and 60 after production. The flexural strength and tensile strength were tested by a universal testing machine, while the surface hardness was measured using a Shore type D durometer for the specimen surface hardness. Data were recorded and analyzed to determine changes in these mechanical properties for 60 days of room-temperature storage after manufacturing.

Results: Changes in the mechanical properties were observed over time. Compared to day 1, the mean tensile strength significantly decreased from day 7 to day 60 ($p < 0.05$), while the mean flexural strength significantly decreased from day 7 to day 30 ($p < 0.05$) with a significant increase in the mean flexural strength on day 60, compared to day 30 ($p < 0.05$). The mean surface hardness also significantly declined on day 21 ($p < 0.05$) with a gradual rise until day 60.

Conclusions: In general, the three mechanical properties of directly printed clear aligners decreased 7 days after manufacturing. However, these mechanical properties remained stable until day 60. Further studies are required to evaluate long-term stability of the aligners under various clinical conditions.

Keywords: 3D printing, clear aligner, flexural strength, tensile strength, surface hardness

Introduction

Up to the present, the demand for clear aligners in orthodontic tooth movement has been continuously increasing because they offer aesthetics, while still meeting the requirement of orthodontic treatment throughout the whole intervention. Additionally, use of clear aligners is not only effective in correcting malocclusions but also offers some advantages, such as shorter treatment times and less frequent dental visits, thus making the aligners ideal for patients who have time constraints. The aligner is highly aesthetic, enhances one's appearance, allows easy eating without interfering with chewing, and promotes good oral hygiene during the treatment. However, there are some limitations for clear aligners in correcting certain types of malocclusions.⁽¹⁾ Nowadays, thermoforming materials are usually used in producing clear aligners, which involves making a dental model as a mold.

Recently, a new resin material (Tera Harz TC-85) has been developed for production of clear aligners using direct printing. This material has the unique property of shape memory, which means its shape can be changed when exposed to heat but resumes its original form once the temperature decreases. This property helps to better control tooth movement and reduces pain and discomfort during insertion or removal of the aligners.⁽²⁾ A distinctive feature of clear aligner treatment is that all aligners are simultaneously manufactured at the beginning of the treatment and are worn in sequence.⁽³⁾ The TC-85 clear aligner is considered to be the first aligner to be directly printed using a three-dimensional (3D) printer. Moreover, it shows significantly better outcomes than the traditional thermoforming aligner materials.⁽⁴⁾ The TC-85 was developed to overcome some limitations of the thermoforming aligner materials currently available. The TC-85 material provides several benefits that include improvement of treatment effectiveness, patient comfort during wear, and a reduction in discomfort while inserting or removing the TC-85 aligner.

Additionally, the TC-85 material is durable, highly flexible, and easy to produce with minimal trimming. During the initial phase, TC-85 is stiff but it regains its original shape once placed in the mouth. Furthermore, the TC-85 allows a better control of tooth movement than thermoforming aligners and ensures its uniform thickness at every time point. The specific feature of treatment with clear aligners is the aligners are all produced at the same

time from the first to the last pairs at the beginning of orthodontic treatment, which are then worn in sequence.⁽³⁾ Clear aligners possess the property of maintaining their shape without many changes over time. Accordingly, it is necessary to study time-dependent changes of aligner specimens that are concomitantly produced, since time differences between their production and use could affect the mechanical properties of the TC-85 material. Therefore, the objective of this study was to investigate the flexural strength, tensile strength, and surface hardness of directly printed clear aligner specimens up to 60 days after production. The material used in this investigation was TC-85 DAC (Direct Aligner Clear), which was developed specifically for dental applications.

Materials and Methods

Sample size calculation

The sample size was determined using G*Power 3.1. Based on power analysis, the initial requirement of 4 specimens per group was increased by 25% to 5 specimens to enhance statistical power.⁽⁴⁾ For three mechanical tests (tensile, flexural, and hardness) across 6-time intervals, a total of 90 specimens were fabricated and tested.

Specimen fabrication and post-processing

The specimens were directly printed by a 3D printer using TC-85 DAC (Graphy Inc., Seoul, Korea) and designed by the SketchUp 2017 program version 17.2.2555 (Trimble Inc., Sunnyvale, CA, USA). The fabrication and post-processing procedures were standardized as follows:

- Specimen fabrication: The specimens were fabricated using a high-speed LCD-based 3D printer (NBEE, UNIZ, San Diego, CA, USA) with UNIZ Dental software. The specimens were printed using with TC-85 DAC resin at a layer thickness of 100 μm , and a total fabrication time of approximately 12 minutes.
- Post-printing and cleaning step: After printing, the specimens were washed in 90% isopropyl alcohol for 5 minutes to remove residual uncured monomer from the surface. Excess resin was subsequently removed using a centrifugation process at 400 rpm for 6 minutes.
- Post-curing step: To ensure maximum polymer conversion and mechanical stability, the specimens were post-cured using a UV post-curing machine equipped with a nitrogen-generator (Tera Harz Cure, Graphy Inc., Seoul, Korea) for 20 minutes.

- **Finishing:** After post-curing, the support structures were removed, and the specimens were polished and finished to the final dimensions.

All specimens were stored in light-tight and airtight containers at room temperature until testing.

A total of 90 specimens in three different sizes were fabricated according to the International Organization for Standardization (ISO) for particular shapes and dimensions. The specimens used for testing the tensile strength were formed into a dumbbell shape with dimensions of 5 mm (narrow section width) x30 mm (gauge length) x2 mm (thickness) that followed the ISO 527 standard. The specimen dimensions used for testing the flexural test were 10x80x4 mm, according to ISO 178, while those used for testing the surface hardness were 12x12x6 mm that conformed to the American Society for Testing and Materials (ASTM) D2240 standard (Figure 1).

Tensile strength testing

The testing was performed in accordance with the ASTM D638 standard using a universal testing machine (Instron®, Norwood, MA, USA) at a crosshead speed of 5 mm/min and a gauge length of 30 mm (Figure 1). The specimens were secured between the upper and lower grips, and the upper grip applied a tensile load until specimen failure. Load and elongation were recorded continuously to generate a load–displacement curve (N/mm²).

Flexural strength testing

The testing was performed using a universal testing machine in accordance with the standard three-point bending methodology (ISO 178/ASTM D790). Each specimen was positioned on two supporting pins with a 40-mm space apart. The crosshead speed was maintained at 2 mm/min, and a centrally placed loading pin applied a downward force until a maximum midspan deflection of 20 mm was achieved (Figure 1). The apparatus continuously recorded the applied load and displacement that produced a load–displacement curve (megapascal; MPa).

Surface hardness testing

The surface hardness was assessed using a Shore durometer (Bareiss®, Bareiss North America Inc, Ontario, Canada). The durometer was adjusted so that the indenter tip was positioned 10 mm above the specimen surface before testing (Figure 1). Measurement commenced im-

mediately upon pressing the device onto the specimen, during which the display flashed to indicate data acquisition. An audible signal confirmed the completion of each measurement. Each specimen was tested at three different points, and the mean hardness value was calculated for analysis.

All three mechanical tests were performed on days 1, 7, 14, 21, 30, and 60 following specimen fabrication (n=5 for each time point and test), and all results were recorded on standardized data collection forms.

Statistical analysis

Data are expressed as mean±standard deviation (SD; n=5). Normality and homogeneity of variance were verified using Shapiro-Wilk and Levene's tests, respectively. Differences were analyzed by one-way ANOVA, followed by Tukey's or Games-Howell post-hoc tests depending on variance equality. Statistical significance was set at $p<0.05$.

Results

The tensile strength decreased from day 1 to day 21 and then slightly increased up to day 60 (Figure 2). The average tensile strength was reported at 16.32 N/mm² with the highest value of 21.93 N/mm² on day 1 and the lowest value of 13.324 N/mm² on day 30. The mean tensile strength value on day 1 was found to be significantly greater than on days 7, 14, 21, 30, and 60 ($p<0.05$).

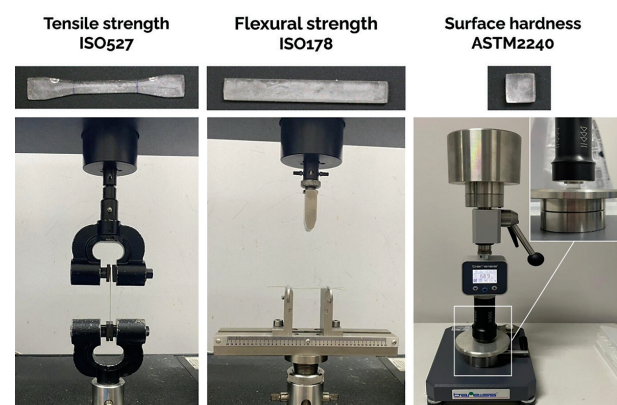


Figure 1: Three sizes of specimens were employed. (Left) Tensile strength specimens were formed into a dumbbell shape with dimensions of 5 mm (narrow section width) x30 mm (gauge length) x2 mm (thickness) (ISO 527 standard). (Middle) Dimensions of the flexural test specimens were 10x80x4 mm (ISO 178 standard). (Right) The dimensions of the surface hardness specimens were 12x12x6 mm (ASTM D2240 standard).

The flexural strength continuously decreased from day 1 to day 30, followed by an increase on day 60 (Figure 3) with the average flexural strength reported at 14.8987 MPa. The 1-day specimen showed the highest mean flexural strength at 22.632 MPa, whereas the lowest mean value at 11.242 MPa was observed on day 30. Accordingly, the mean flexural strength value on day 1 was found to be significantly greater than days 7, 14, 21, 30, and 60 ($p<0.05$).

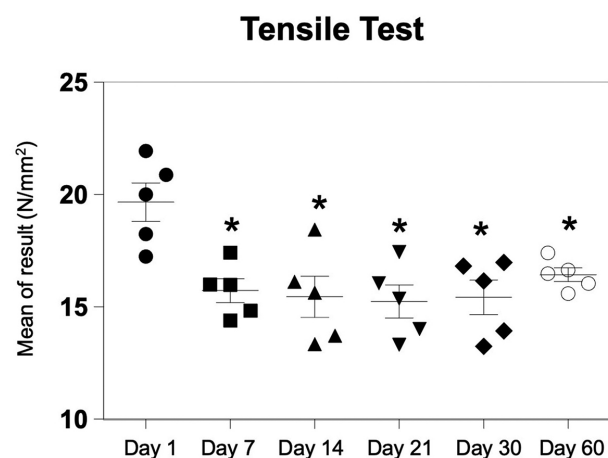


Figure 2: Dot plots illustrate the mean tensile strength values measured on days 1, 7, 14, 21, 30, and 60. Error bars represent the standard deviation ($n=5$). Statistical significance was set at $p<0.05$. *indicates a statistically significant difference compared with day 1, as determined by one-way ANOVA followed by post hoc analysis.

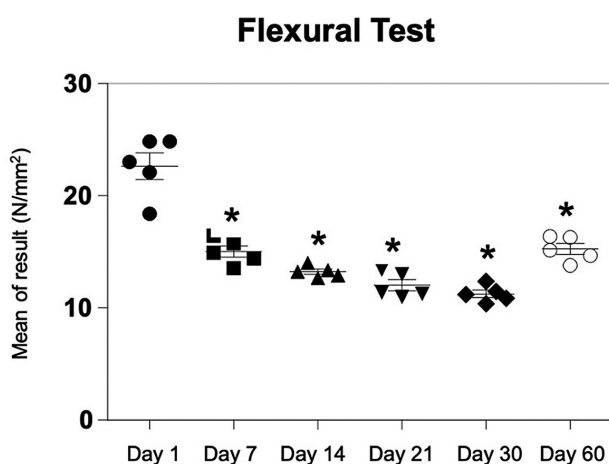


Figure 3: Dot plots illustrate the mean flexural strength values measured on days 1, 7, 14, 21, 30, and 60. Error bars represent the standard deviation ($n=5$). Statistical significance was set at $p<0.05$. *indicates a statistically significant difference compared with day 1, as determined by one-way ANOVA followed by post hoc analysis.

The average surface hardness value was reported at 67.405 with the mean highest value at 69.28 on day 1 and the mean lowest value at 65.41 on day 21 (Figure 4). Significant decreases in the mean surface hardness values of the specimen aligners were found on days 21, 30, and 60 compared to days 1, 7, and 14 ($p<0.05$; Figure 4).

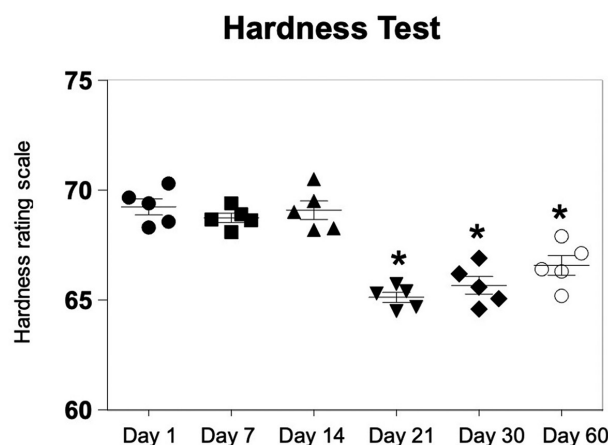


Figure 4: Dot plots illustrate the surface hardness values measured on days 1, 7, 14, 21, 30, and 60. Error bars represent the standard deviation ($n=5$). Statistical significance was set at $p<0.05$. *indicates a statistically significant difference compared with day 1, as determined by one-way ANOVA followed by post hoc analysis.

Discussion

The post-polymerization process in this study was monitored up to 60 days. The tensile strength demonstrated a decline until day 21, followed by a gradual recovery until day 60. The flexural strength decreased until day 30, after which it also increased on day 60. Similarly, the surface hardness declined on day 21 and rose slightly on day 60. These findings suggest that changes in the mechanical properties of directly 3D-printed aligners can be expected to decrease 7 days after manufacturing and remain stable until day 60. However, it is likely that these properties may continue to change beyond the observation period of this study. Moreover, it is important to note that external environmental factors, such as, temperature, humidity, storage conditions, and handling, can significantly influence the mechanical performance of clear aligners.^(6,7)

Our results align with a previous study by Mei *et al.*⁽⁶⁾ They reported that clear aligners exhibited significant reductions in flexural strength and hardness after days 7 and 10, respectively, while the tensile strength showed minor changes after day 21. Those results are

consistent with our findings that revealed progressive mechanical property degradation over time. Haruhisa *et al.*,⁽⁸⁾ referenced the ISO 20795-2 standards, which recommend that base polymers used in orthodontic appliances should have a flexural strength of at least 50 MPa and a flexural modulus of at least 1,300 MPa. However, our findings demonstrated flexural strength values that were below those thresholds, which were potentially due to differences in the materials and manufacturing processes, particularly the use of 3D printing technology that may impact mechanical performance. On the other hand, Siotou *et al.*,⁽⁹⁾ assessed Shore D hardness of aligner materials immediately after production and reported an average value of 61.71, which was slightly lower than the values obtained in our study using direct 3D printing methods. All of these discrepancies suggest that distinct fabrication processes play a critical role in determining material properties. Overall, our findings are consistent with those of a previous report⁽⁷⁾, in terms of the time-dependent changes in mechanical properties, thereby supporting the reliability of our results.

Changes in the mechanical properties of the printed specimens can be attributed to the continuation of the polymerization process even after completion of the curing stage. Photopolymerization can play a role in the process, in which monomers are cross-linked into polymer chains through light activation, which can alter the mechanical properties of the material.⁽¹⁰⁻¹²⁾ A previous study⁽¹³⁾, reported that the strength and dimensional accuracy of printed specimens may be influenced by the post-curing process, as each fabrication cycle may yield different material properties. Kim *et al.*,⁽⁶⁾ confirmed that the level of polymerization did not increase uniformly across the entire cross-section of the specimen, which raised further concerns regarding its effects on the mechanical strength of the material.

According to two studies by Jindal *et al.*,^(14,15) aligners fabricated using 3D printing technology were found to adequately meet the requirements of mechanical properties that make them effective appliances for facilitating tooth movement. In addition, aligners produced through this method can provide a highly accurate shape, which is a crucial factor in appropriately controlling the force and direction of tooth movement.⁽¹⁵⁾ The accuracy of the model used in aligner production is particularly important, as any dimensional inaccuracy may directly affect treatment

efficiency. Furthermore, the manufacturing and post-processing procedures involved in 3D printing require less time and complexity compared to a conventional aligner fabrication method. Therefore, 3D printing presents a clinically and technologically feasible alternative for aligner production.

During clinical use, clear aligners are subjected to complex mechanical forces, including localized stresses during tooth rotation, flexural forces during molar movement, and combined tensile and bending forces in patients with bruxism. TC-85 is a relatively new material for direct 3D-printed clear aligners. Previous research has demonstrated that the mechanical properties of in-house 3D-printed aligners were not significantly affected after one week of intraoral use.⁽¹⁶⁾ However, that study evaluated the appliances following clinical wear, reflecting material behavior under intraoral conditions. In contrast, the present study focused specifically on the assessment of mechanical properties before patient delivery, thereby investigating time-dependent changes occurring during the post-fabrication period rather than after clinical use.

In this study, the findings demonstrated time-dependent changes in mechanical properties, particularly within the first week after fabrication, whereas no further alterations were observed after day 21. However, in clinical practice, delivery of the appliance within one week may not be feasible, which could affect its mechanical properties at the time of patient delivery. Therefore, prolonged storage of the appliances prior to delivery to patients may potentially influence their material properties. This study provides preliminary data to support its clinical application.

A limitation of this study is the use of standardized test specimens, which do not fully replicate the complex morphology of clinical aligners. Consequently, caution should be exercised when extrapolating these mechanical results directly to clinical behavior, as aligner geometry significantly influences stress distribution and clinical efficacy. However, further investigations are warranted to evaluate long-term changes in the mechanical properties of aligners, in particular, a better understanding of the long-term stability and performance during extended storage is needed.

Conclusions

This study demonstrated that directly 3D-printed

TC-85 DAC aligners exhibited significant time-dependent changes in mechanical properties, likely due to ongoing post-polymerization. However, mechanical performance stabilized after day 21 and remained unchanged through day 60. Given the inherent complexity of 3D-printed materials under external loading, strict control of printing and post-processing parameters is essential to ensure consistent and reliable mechanical performance.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

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Effect of *Lactobacillus-Bifidobacterium* Probiotic Yogurt on Oral *Candida* Levels in Older Adults

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Abstract

Objectives: *Lactobacillus* and *Bifidobacterium* are increasingly incorporated in yogurt starters to enhance yogurts' probiotic properties. Since many *Lactobacillus-Bifidobacterium* probiotic strains are recognized for their antifungal activities against oral *Candida* species. The aim of this study was to investigate the effects of daily administering of yogurt containing *Lactobacillus acidophilus*, *Lactobacillus paracasei*, and *Bifidobacterium lactis* on the levels of oral *Candida* and other factors relating to oral candidiasis.

Methods: The experiment was conducted using a double-blind randomized placebo-controlled study in which 60 older adults were allocated into two groups. After baseline examination and randomization, the control group was given the plain yogurt, while the experimental group was given the probiotic yogurt, twice daily. Saliva samples were collected at baseline and after the administration period of two weeks.

Results: The experimental group demonstrated a significant reduction in oral *Candida* counts ($p < 0.05$), accompanied by significant increases in unstimulated salivary flow rate and salivary pH ($p < 0.05$).

Conclusions: The short-term consumption of yogurt containing *Lactobacillus acidophilus*, *Lactobacillus paracasei*, and *Bifidobacterium lactis* may provide an alternative method for the prevention of oral candidiasis and xerostomia.

Keywords: *Candida*, older adults, oral candidiasis, probiotics, yogurt

Introduction

Oral health problems constitute a significant concern among older adults due to age-related physiological changes and the presence of comorbid conditions that increase susceptibility to oral diseases.⁽¹⁻³⁾ Furthermore, older adults often experience limited access to dental care as a result of financial constraints, reduced mobility, and insufficient oral health awareness, highlighting the importance of preventive strategies and regular dental assessments.⁽⁴⁾

Xerostomia, or dry mouth, is a common oral condition in older adults and is frequently associated with medication use. Reduced salivary flow compromises the oral defense system and increases the risk of oral candidiasis.^(5,6) In recent years, the prevalence of oral candidiasis has increased substantially, particularly among older adults and immuno-compromised individuals.⁽⁷⁾ Oral candidiasis is primarily caused by infection with *Candida* species, most commonly *Candida albicans* (*C. albicans*), and is characterized by local discomfort, pain, dysgeusia, and dysphagia, which may ultimately lead to nutritional deficiencies.⁽⁸⁾ Moreover, older adults and immunocompromised populations exhibit a higher incidence of invasive candidiasis, which is associated with increased morbidity and mortality.⁽⁸⁾

Antifungal agents such as fluconazole, miconazole, and nystatin remain the mainstay of treatment for oral candidiasis. Although these therapies are generally effective, their use is limited by potential adverse effects and the growing concern of antifungal resistance.⁽⁹⁾ Consequently, increasing attention has been directed toward the development of alternative preventive and therapeutic approaches. Natural interventions, including bioactive compounds and probiotics, have demonstrated potential in reducing *Candida* infections through the inhibition of virulence factors and modulation of the oral microbiota.⁽¹⁰⁻¹²⁾ Probiotics may be administered orally, commonly through dietary sources, to enhance their therapeutic effects in the oral cavity.

Lactobacillus and *Bifidobacterium* species, particularly *Lactobacillus acidophilus* (*L. acidophilus*), *Lactobacillus paracasei* (*L. paracasei*), and *Bifidobacterium animalis* subsp. *lactis* (*B. lactis*), have been widely incorporated into dairy products, especially yogurt, to enhance probiotic properties. Both *L. acidophilus* and *L. paracasei* have demonstrated inhibitory effects against oral *Candida*

species, underscoring their potential role in maintaining oral health.⁽¹³⁻¹⁵⁾ Although evidence regarding the direct effects of *B. lactis* on oral *Candida* remains limited, its antimicrobial activity against periodontopathogens has been reported.⁽¹⁶⁾ The effect of administering these probiotic strains with food on the levels of oral *Candida* species and other factors related to oral health is not yet well understood.

Therefore, the present study aimed to investigate the effects of short-term, regular consumption of yogurt containing *Lactobacillus*–*Bifidobacterium* probiotics, specifically *L. acidophilus*, *L. paracasei*, and *B. lactis* on oral *Candida* levels and oral parameters associated with candidiasis, including salivary flow rate and salivary pH.

Materials and Methods

Ethical approval

The study protocol was reviewed and approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University (Protocol No. 27/2021; approved June 7, 2021). All participants received comprehensive information regarding the study objectives and procedures and provided written informed consent prior to participation.

Study design and participants

This study employed a randomized, double-blind, placebo-controlled design with two parallel groups over a two-week intervention period. Participants were randomly assigned to either the control or experimental group by research assistants using block randomization. Throughout the intervention, participants consumed 120 g of yogurt twice daily.

A total of 60 individuals aged ≥ 60 years residing in the Doi Saket District, Chiang Mai Province, Thailand, were recruited. After providing informed consent, participants completed a questionnaire addressing demographic characteristics and medical history, followed by an oral examination and saliva collection. All participants received standardized oral hygiene instructions and were instructed to refrain from using probiotic products, antifungal or antibacterial agents, and antiseptic mouth rinses during the study period (Figure 1).

Inclusion criteria were the presence of oral *Candida* colonization without clinical signs of oral candidiasis or other oral mucosal lesions. Exclusion criteria included

uncontrolled systemic diseases (American Society of Anesthesiologists classification III–VI), history of organ transplantation, lactose or dairy intolerance, cancer, history of radiotherapy, smoking, use of topical or systemic antifungal or antibacterial agents or antiseptic mouth rinses within 30 days prior to enrollment, reported probiotic consumption, dementia, and inability to comply with study instructions. Discontinuation criteria were participants who took any probiotic, smoking, use of topical or systemic antifungal or antibacterial agents or antiseptic mouth rinses during the experiment period.

Yogurt preparation and consumption protocol

Both plain yogurt and probiotic yogurt used in this study were supplied by Sunrise Dairy Co., Ltd. (Lat Bua Khao Subdistrict, Sikhio District, Nakhon Ratchasima

Province, Thailand). The plain yogurt was produced using a mixed starter culture of *Streptococcus thermophilus* (*S. thermophilus*) and *Lactobacillus bulgaricus* (*L. bulgaricus*), with a total viable count of 2.44×10^9 CFU/g. The probiotic yogurt was prepared using a mixed starter culture containing *S. thermophilus*, *L. bulgaricus*, *L. acidophilus*, *L. paracasei*, and *B. lactis*, with a total viable count of 1.51×10^9 CFU/g.

Both yogurt types were specifically manufactured for the study and packaged identically in 120-g white containers. The products were comparable in color, flavor, and texture, ensuring blinding of both participants and investigators.

Participants were instructed to consume one cup of yogurt in the morning after breakfast and one cup in the evening after dinner for two consecutive weeks. They

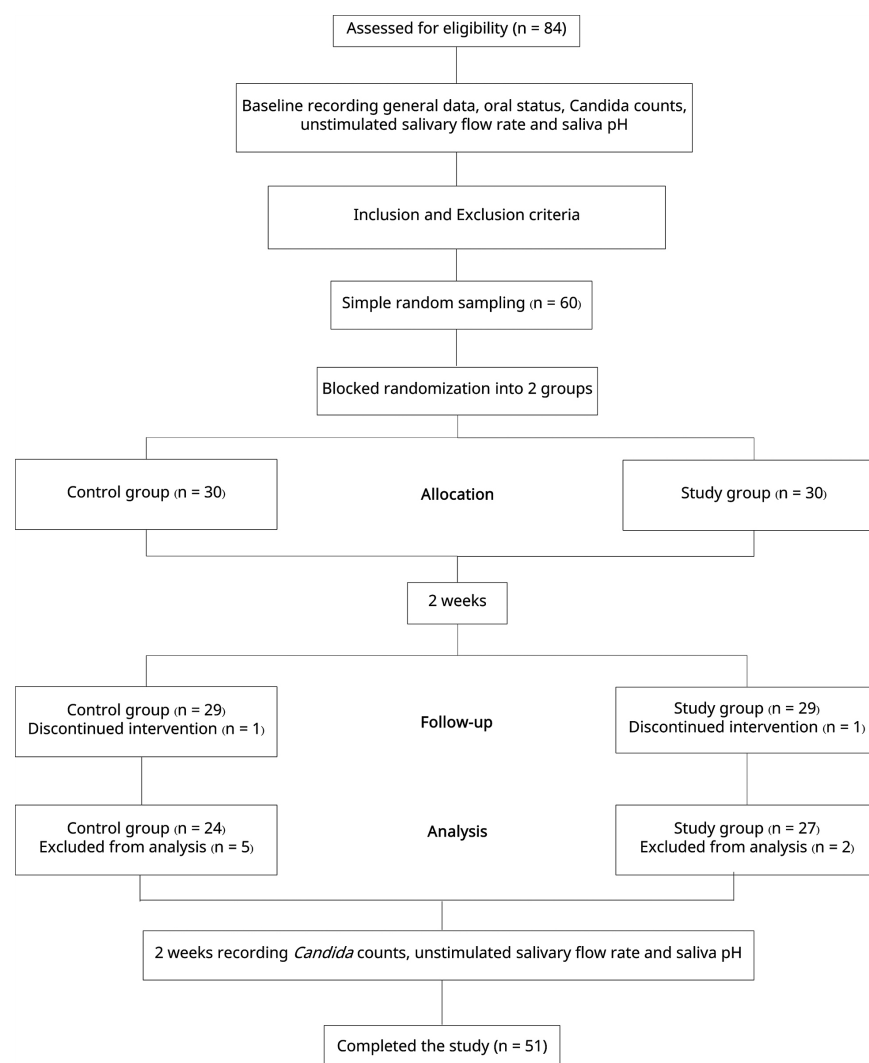


Figure 1: Experimental protocol of the study.

were advised to refrain from drinking water or performing oral hygiene procedures for at least one hour following yogurt consumption.

Saliva collection and oral sampling

Oral *Candida* sampling was conducted at two time points: at baseline prior to yogurt consumption and at the end of the two-week intervention. All samples were collected between 08:00 and 11:00 a.m. Participants were instructed to abstain from eating and drinking (except water) for at least one hour prior to sampling.

Following sample collection, participants rinsed their mouths with 10 mL of water for 60 seconds to remove food debris, followed by a 60-second rinse with 10 mL of phosphate-buffered saline (PBS). The rinse samples were transported under refrigerated conditions to the laboratory and processed on the same day.

Unstimulated salivary flow rate and salivary pH were measured at baseline and at the end of week 2. Participants were instructed to refrain from speaking or chewing during saliva collection. Unstimulated saliva was collected over a 5-minute period by expectorating saliva accumulated in the floor of the mouth into a graduated cylinder. Salivary pH was measured using a LAQUAtwin pH-22 pocket pH meter, which was calibrated prior to each use.

Microbiological analysis

Mouth-rinse samples were centrifuged at 1,700 rpm, 320 g for 10 minutes, and the resulting pellets were re-suspended in 1 mL of PBS. *Candida* quantification was performed using the spread plate technique. A 100- μ L aliquot of the suspension was inoculated onto HiCrome *Candida* Differential Agar (HiMedia, India), which allows differentiation of *Candida* species namely *C. albicans*, *C. krusei*, *C. tropicalis* and *C. glabrata* based on coloration and colony morphology. Then the samples were incubated aerobically at 37 °C for 48 hours. Colony-forming units (CFU/mL) were enumerated, and all samples were analyzed in duplicate.

Statistical analysis

Data distribution was assessed using the Kolmogorov–Smirnov test. As *Candida* colony counts did not follow a normal distribution, nonparametric statistical tests were applied. The Mann–Whitney U test was used to compare *Candida* colony counts between the control

and experimental groups at baseline and post-intervention, while the Wilcoxon signed-rank test was used for within-group comparisons.

Parametric tests were applied to variables with normal distribution, including unstimulated salivary flow rate and salivary pH. The independent samples t-test was used to compare these variables between groups at baseline and after the intervention, and the paired t-test was used for within-group comparisons. Data are presented as mean $\pm$ standard error (SE). Statistical analyses were performed using SPSS software (version 26.0; SPSS Inc., Chicago, IL, USA), and a p -value <0.05 was considered statistically significant.

Results

Of the 60 participants, 51 completed the experiment protocol (24 in the control group and 27 in the experimental group), resulting in a dropout rate of 15% because of incomplete consuming yogurt as per the research requirements. At baseline, no significant differences were observed between the control ($n=24$) and experimental groups ($n=27$) in demographic or oral health parameters (all $p>0.05$). The mean age was comparable between groups (67.00 ± 0.88 vs. 67.48 ± 0.82 years, $p=0.691$), and all participants were female. No significant differences were found in BMI, number of systemic diseases, number of teeth, number of decayed teeth, DMFT index, number of occlusal pairs, or denture use, indicating that the two groups were well balanced at baseline (Table 1).

Oral *Candida* colony counts

Mean oral *Candida* colony counts, expressed as log CFU/mL, at baseline and after the two-week intervention period are presented in Table 2 and Figure 2. The mean log *Candida* colony counts were comparable between the control group (1.00 ± 0.12 log CFU/mL) and the study group (1.10 ± 0.09 log CFU/mL) at baseline ($p=0.422$). After two weeks, the study group demonstrated a significant reduction in *Candida* colony counts (0.70 ± 0.10 log CFU/mL) compared with baseline ($p<0.001$), whereas no significant change was observed in the control group (baseline: 1.00 ± 0.12 vs. two weeks: 0.96 ± 0.15 log CFU/mL; $p=0.796$). Although the mean *Candida* level was lower in the study group than in the control group at two weeks, the between-group difference was not statistically significant ($p=0.125$).

Unstimulated saliva flow rates

Baseline unstimulated salivary flow rates were similar between the control (0.32 ± 0.04 mL/min) and study groups (0.31 ± 0.03 mL/min) ($p=0.881$). After two weeks, the study group showed a significant increase in salivary flow rate (0.45 ± 0.05 mL/min) compared with baseline ($p<0.001$). In contrast, the control group showed no statistically significant change (baseline: 0.32 ± 0.04 vs. two weeks: 0.36 ± 0.05 mL/min; $p=0.337$). The between-group comparison at two weeks did not reach statistical significance ($p=0.164$). (Figure 3).

Saliva pH

Mean salivary pH values at baseline and after the intervention are illustrated in Figure 4. The baseline salivary pH values did not differ significantly between the control (6.87 ± 0.10) and study groups (6.74 ± 0.11) ($p=0.394$). After two weeks, the study group demonstrated a significant increase in salivary pH (7.07 ± 0.09) compared with baseline ($p=0.003$). The control group showed a slight but non-significant increase (baseline: 6.87 ± 0.10 vs. two weeks: 6.99 ± 0.08 ; $p=0.136$). No statistically significant difference was observed between groups at the two-week follow-up ($p=0.544$).

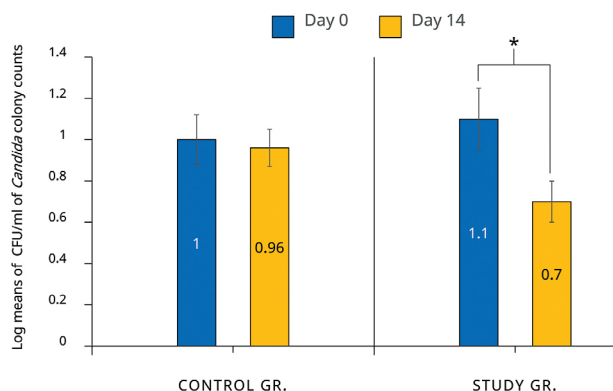


Figure 2: Means and standard error of *Candida* colony counts, *significant difference in *Candida* colony counts ($p<0.05$).

Discussion

Older adults exhibit increased susceptibility to oral candidiasis. Antifungal drugs serve as the main treatment; however, the increasing experience of side effects and the prevalence of multidrug-resistant *Candida* species represent a considerable public health concern. Consequently, novel techniques are required to decrease the prevalence

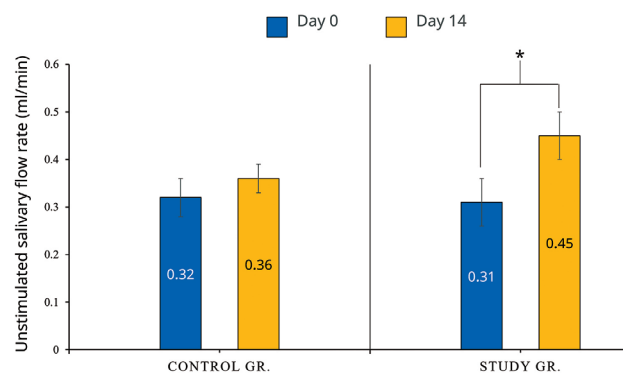


Figure 3: Means and standard error of unstimulated salivary flow rates, *significant difference in unstimulated salivary flow rates ($p<0.05$).

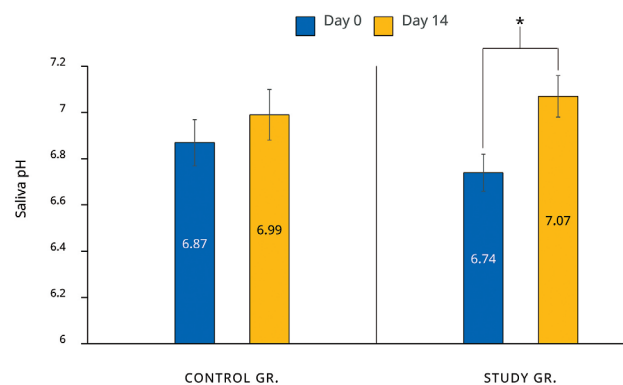


Figure 4: Means and standard error of saliva pH, *significant difference in saliva pH ($p<0.05$).

of *Candida* infections. Studies indicate that probiotics may serve as an effective alternative treatment for oral candidiasis. From our study, a significant reduction in *Candida* colony counts was observed in the experimental group consuming the probiotic yogurt for two weeks, whereas no significant reduction was noted in the control group consuming the yogurt without probiotics. No significant differences were observed in general data and oral status between the control group and the experimental group across all variables.

Our study indicates that the intake of this specific *Lactobacillus-Bifidobacterium* probiotic yogurt may significantly decrease oral *Candida* levels in older adults. This probiotic formula contains yogurt starters, *S. thermophilus* and *L. bulgaricus*, along with probiotic strains *L. acidophilus*, *L. paracasei*, and *B. lactis*. The control yogurt contained solely the yogurt starters *S. thermophilus* and *L. bulgaricus*. Previous studies have documented the antifungal effects of probiotic species, including those

Table 1: General statistics and oral health conditions of participants in the control and experimental groups at baseline.

Characteristic	Control group (n=24)	Study group (n=27)	p-value
Age	67.00±0.88	67.48±0.82	0.691 ^I
Females, n (%)	24 (100)	27 (100)	
BMI	24.44±0.62	23.83±0.75	0.291 ^M
Number of diseases	1.25±0.24	1.11±0.19	0.715 ^M
Number of teeth	23.83±1.45	23.33±1.38	0.67 ^M
Number of decayed teeth	1.33±0.4	0.56±0.13	0.365 ^M
DMFT	9.83±1.43	10.18±1.42	0.865 ^M
Number of occlusal pairs	4.71±0.48	5.26±0.56	0.212 ^M
Denture wearers	0.12±0.07	0.22±0.08	0.368 ^M

^IIndependent Samples Test, ^MMann-Whiney U Test; *p-value<0.05 is considered statistically significant.

Table 2: Comparison of the control and study group with respect to *Candida* colony counts, unstimulated salivary flow rates and saliva pH at baseline and two weeks.

Variables		Control group	Study group	p-value
<i>Candida</i> colony counts (Log means of CFU/mL)	Baseline	1.00±0.12	1.10±0.09	0.422 ^M
	2 weeks	0.96±0.15	0.70±0.10*	0.125 ^M
	p-value	0.796 ^W	0.000 ^W	
Unstimulated salivary flow rates (mL/min)	Baseline	0.32±0.04	0.31±0.03	0.881 ^I
	2 weeks	0.36±0.05	0.45±0.05*	0.164 ^I
	p-value	0.337 ^P	0.000 ^P	
Saliva pH	Baseline	6.87±0.10	6.74±0.11	0.394 ^I
	2 weeks	6.99±0.08	7.07±0.09*	0.544 ^I
	p-value	0.136 ^P	0.003 ^P	

^MMann-Whiney U Test, ^WWilcoxon Signed Ranks Test, ^IIndependent Samples Test, ^PPair t-Test, *p-value<0.05 is considered statistically significant.

utilized in the probiotic yogurt formula examined in our study, on *Candida*. A study indicated that probiotic tooth-pastes with *L. acidophilus* and *L. paracasei* exhibited a more significant inhibitory effect on *C. albicans* than those without probiotics.⁽¹³⁾ A separate study demonstrated that *L. paracasei* and *Lactobacillus rhamnosus* exhibited the most significant effects on *C. albicans in vitro*.⁽¹⁷⁾ Furthermore, both the cells and cell-free supernatants of *L. acidophilus* and *Lactobacillus plantarum* exhibited antifungal activity against oral *Candida* species.⁽¹⁸⁾ The main mechanisms of the action of probiotics, such as elimination and inhibition of the growth of pathogenic microorganisms through competition for receptor sites and the secretion of metabolites with antifungal activity, as well as the stimulation of specific and non-specific immune responses by activating T-lymphocytes, and stimulating the production of cytokines, make it possible

to also effectively use antifungal.⁽¹⁹⁾

In an *in vivo* study, the administration of locally applied probiotics (*Bifidobacterium longum*, *L. bulgaricus*, and *S. thermophilus*) demonstrated improvements in specific clinical conditions and a reduction in the prevalence of *Candida* species.⁽²⁰⁾ A separate study indicated that daily intake of *B. lactis* may lower the risk of oral candidiasis in healthy elderly individuals.⁽²¹⁾ The findings indicate a potential role of probiotic *Bifidobacterium* strains in the inhibition of *Candida* species. Nonetheless, the species of *Bifidobacterium* and the methods of probiotic administration varied from those employed in our study. Because the benefits of probiotics are strain specific⁽²²⁾, therefore, each probiotic strain in the yogurt formula utilized in our study requires further evaluation to assess its effects on oral *Candida* in future research.

Our study revealed a notable secondary outcome

associated with probiotic yogurt consumption: a significant increase in unstimulated salivary flow rate and saliva pH compared to baseline measurements. Hatakka *et al.*,⁽²³⁾ previously noted an increase in saliva quantity following 16 weeks of daily consumption of probiotic cheese by the participants. The mechanisms underlying these effects are not yet fully understood. A separate *in vivo* study indicated that short-term daily consumption of probiotics through curd in the diet significantly increased salivary pH and decreased salivary counts of *Streptococcus mutans*.⁽²⁴⁾ One prospective clinical study in edentulous patients found that 60 days of daily probiotic supplementation significantly increased both unstimulated and stimulated saliva volume compared to baseline. This suggests a possible effect on salivary output in individuals dry mouth.⁽²⁵⁾ Previous studies suggest probiotics can raise salivary pH and buffering capacity, which might support saliva's protective functions, though results vary by strain and study design.⁽²⁶⁾

The control group exhibited a slight, non-significant decrease in *Candida* colony counts after two weeks of administration of plain yogurt without probiotics compared to the baseline level. The increases in unstimulated salivary flow rate and saliva pH in this group were also not statistically significant. The additional probiotic strains in the yogurt given to the experimental group demonstrated direct effects on oral *Candida*, unstimulated salivary flow, and saliva pH. It is unclear whether all probiotic strains contributed to these effects or if the observed outcomes resulted from the synergistic effects of the multi-strain combination. Studies indicate that the application of multi-strain probiotics may improve their efficacy in pathogen inhibition. A combination of microbial species exhibiting varying inhibitory effects on pathogens may provide a wider range of action compared to a single strain.⁽²⁷⁾ Additional investigation is required prior to reaching a conclusion on this specific point.

Conclusions

Daily consumption of a commercially available yogurt containing multiple probiotic strains (*L. acidophilus*, *L. paracasei*, and *B. lactis*) for two weeks resulted in a significant reduction in oral *Candida* colony counts, along with increases in unstimulated salivary flow rate and salivary pH in older adults. These findings suggest that probiotic yogurt consumption may represent a promising

adjunctive strategy for reducing the risk of oral candidiasis and xerostomia. Nevertheless, further studies involving larger and more diverse populations, as well as longer intervention and follow-up periods, are required before this approach can be recommended for routine clinical practice.

Conflict of Interest

The authors declare that there are no conflicts of interest with any of the companies which manufactured the yogurt employed in this study. The company provided the product used in this research. The company had no role in the study design, data collection, analysis, interpretation, or manuscript preparation.

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Utility of Palatal Height in Oral Screening for Obstructive Sleep Apnea: A Correlational Analysis in a Thai Adult Group

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Abstract

Objectives: This study investigated associations between palatal height (PH) and polysomnographic (PSG) parameters in obstructive sleep apnea (OSA) patients. The upper posterior arch width (UPAW) and the scalloped tongue and oral torus distributions across PH were also assessed.

Methods: Gender, age, body mass index, Thai version of the Epworth sleepiness scale score, and PSG parameters were obtained from medical records of 60 adult OSA patients. Scalloped tongue and oral torus were clinically examined. PH and UPAW were measured using digitized models from 3D scans of dental plaster casts. Based on the median PH, participants were stratified into two groups (PH<17.58 mm, n=30; PH≥17.58 mm, n=30). At $p<0.05$, statistical analyses included independent t- or Mann–Whitney U tests, chi-square or Fisher's exact tests, and Spearman's rank or Pearson's correlation coefficients.

Results: A significant intergroup difference ($p=0.037$) was detected in UPAW only. In those with a PH<17.58 mm, PH was moderately correlated with nadir oxygen saturation ($r=0.557$), apnea-hypopnea index ($r=-0.536$), and respiratory disturbance index ($r=-0.419$). Severe and moderate scalloped tongues were seen in the PH<17.58 mm and PH≥17.58 mm groups, respectively. A weak correlation ($r=0.368$, $p=0.048$) was found between UPAW in the PH<17.58 mm group and scalloped tongue. A significant difference in oral torus distribution was observed between groups ($p<0.001$), with the majority of patients in both groups exhibiting no torus.

Conclusions: Although PH alone is not a definitive predictor of OSA severity, it may be simple for dentists to assess and must be interpreted cautiously in light of other factors.

Keywords: craniofacial morphology, obstructive sleep apnea, palatal height, polysomnography, upper posterior arch width

Introduction

Obstructive sleep apnea (OSA) contributes to fatigue, reduced quality of life, and an increased risk of metabolic disorders.^(1,2) Dentists can play a role in early detection of patients at risk for OSA⁽³⁾, given its association with craniofacial abnormalities, such as maxillary constriction, mandibular deficiency, and increased cranial base flexion.⁽⁴⁾ In addition, deviations in palatal height (PH) have been reported to adversely affect upper airway dimensions and reduce tongue space, which in turn may contribute to the development of OSA.⁽⁴⁻⁶⁾ In addition, a comprehensive assessment should incorporate multidimensional analysis to fully understand craniofacial morphology.⁽⁷⁾ In particular, evaluation of upper intertooth distances may help identify maxillary constriction, which could be related to upper airway compromise in OSA.⁽⁵⁾

PH can be assessed during routine dental examinations. One study found higher PH in patients with OSA compared to controls⁽⁵⁾, although other studies did not confirm this finding.^(8,9) Interestingly, among individuals with mild to moderate OSA, reduced PH has been associated with a higher oxygen desaturation index, indicating a deterioration in oxygen saturation levels during sleep.⁽¹⁾ The presence of a scalloped tongue⁽¹⁰⁾ and mandibular torus⁽⁹⁾ has also been associated with increased OSA risk. Polysomnography (PSG) is the gold standard for diagnosing OSA, using an apnea-hypopnea index (AHI) and a respiratory disturbance index (RDI). Based on these indices, OSA severity is classified as mild (5-14 events/hour), moderate (15-30 events/hour), and severe (over 30 events/hour).^(2,11,12) Nadir oxygen saturation (nadir SpO₂), which indicates the lowest oxygen level during sleep, is another important parameter.⁽¹³⁾ In Thai populations, the Thai version of the Epworth sleepiness scale (TESS) is used to assess daytime sleepiness.⁽¹⁴⁾

Despite several investigations into the relationship between craniofacial characteristics and OSA, the role of PH remains unclear due to some inconsistent findings.^(1,5,8) Therefore, this study aimed to investigate the association between OSA patients' PH and parameters derived from their PSG parameters.

Materials and Methods

This cross-sectional study was approved by the Naresuan University Human Research Ethical Committee, Thailand (IRB No. P1-0011). Patients over 20 years of

age were selected from individuals diagnosed with mild, moderate, or severe OSA at Naresuan University Hospital Otorhinolaryngology Sleep Clinic between May and November 2024.

Strict inclusion and exclusion criteria were applied to minimize selection bias. Eligible patients were required to present with a permanent dentition and have an AHI and RDI ≥ 5 events per hour, as determined by a somnologist. Patients were excluded if they were undergoing an orthodontic treatment at the time of the study or had previously undergone such treatment; had a completely edentulous mouth or lacked dental landmarks; or had a history of an OSA treatment that could affect arch morphology.

Following the impression of the upper dental arch using irreversible hydrocolloid (Algisor; Lascod, Florence, Italy), a dental cast was fabricated using stone plaster (Type 3 Prestia; Siniat, Chonburi, Thailand). The plaster cast was subsequently scanned using a three-dimensional scanner (3Shape E4; 3Shape Inc., Copenhagen, Denmark). A digitized upper model was then constructed and analyzed using a software program (Orthoanalyzer; 3Shape Inc.). In the digitized model, a line drawn between bilateral upper first molars' central pits was designated as the reference plane, and its distance was considered the upper posterior arch width (UPAW).⁽¹⁵⁾ PH (Figure 1) was defined as the perpendicular distance from the reference plane to the median palatine raphe's deepest point (red point in Figure 1) determined on the digitized model by naked eyes. Based on the median PH value, the overall patients (n=60) were divided into two groups.

Data on gender, age, body weight, body height, and PSG parameters-AHI, RDI, nadir SpO₂, and OSA severity (mild, moderate, or severe)-were obtained from patients' medical records. Daytime sleepiness was assessed using the TESS. Scalloped tongue (none, mild, moderate, or severe) described in a report⁽¹⁰⁾ and oral tori (torus absent or only palatal torus, only mandibular torus, or both palatal and mandibular tori present) were confirmed by oral examinations.

The reliability of PH measurement was evaluated by repeating the assessments by the same examiner after a one-week interval. Intraexaminer reliability was assessed using the intraclass correlation coefficient, with values exceeding 0.80 indicating excellent agreement.

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistics were used to summarize demographic and clinical data. Continuous variables were compared using independent t- or Mann–Whitney U tests for parametric and nonparametric data, respectively. Categorical variables were analyzed using chi-square or Fisher's exact tests. Correlations were assessed using Spearman's rank or Pearson's product-moment correlation coefficients. No sensitivity analysis was conducted. A $p < 0.05$ indicated statistical significance.

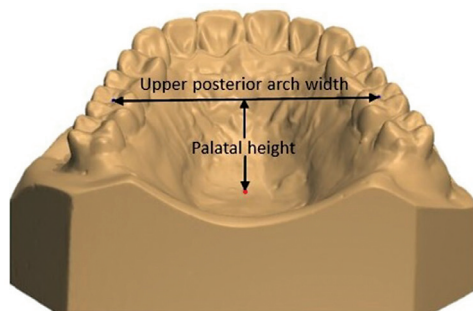


Figure 1: Measurement of the palatal height and upper posterior arch width in a digitized three-dimensional upper dental model. A line drawn between bilateral upper first molars' central pits is designated as a reference plane and its distance is considered upper posterior arch width. Palatal height is the perpendicular distance from the reference plane to the median palatine raphe's deepest point (red point) determined on the digitized model by naked eyes.

Results

The calculated median PH was 17.58 mm. This value was used to divide 60 patients into the group with $PH < 17.58$ mm ($n=30$) and that with $PH \geq 17.58$ mm ($n=30$). Table 1 shows no significant intergroup difference ($p > 0.05$) in gender, age, body mass index, AHI, RDI, nadir SpO_2 , or TESS score. The UPAW in the $PH < 17.58$ mm group was significantly narrower ($p=0.037$) than that in the other group.

In the $PH \geq 17.58$ mm group, a significant difference in OSA severity distribution was observed ($p=0.007$), with severe OSA being the most common, followed by moderate and mild levels. No such difference was found in the $PH < 17.58$ mm ($p=0.061$).

Both PH groups showed significant intra- and intergroup differences in scalloped tongue severity ($p < 0.05$). Severe and moderate scalloping were most frequently observed in the $PH < 17.58$ mm and $PH \geq 17.58$ mm groups, respectively.

The presence of torus did not significantly differ

between the two PH groups ($p=0.095$) but showed a significant difference within each group ($p < 0.001$). In both groups, the majority had no torus, though prevalence was slightly higher in the $PH \geq 17.58$ mm group.

In the $PH \geq 17.58$ mm group and in the overall sample, no significant correlation was observed between PH and OSA variables (Table 2). In contrast, PH in the $PH < 17.58$ mm group showed a moderately negative correlation with AHI ($r=-0.536$, $p=0.002$) and RDI ($r=-0.419$, $p=0.021$) and a moderately positive correlation with nadir SpO_2 ($r=0.557$, $p=0.001$) (Table 2).

No significant correlation was detected between the UPAW in the overall PH or other variables. UPAW in the $PH < 17.58$ mm group showed a weakly positive correlation ($r=0.368$, $p=0.048$) with scalloped tongue (Table 3).

Discussion

Investigations into the associations between PSG parameters and PH with a more comprehensive multidimensional consideration of UPAW in the OSA patients, along with evaluations of the distributions of scalloped tongue and oral torus between the two PH groups, were conducted in this study. Significant correlations ($p < 0.05$) were identified between some PH values and PSG parameters, despite prevailing inconsistencies in the literature regarding the association between PH and OSA.^(1,9)

No significant difference ($p > 0.05$) in AHI, RDI, nadir SpO_2 , or TESS score was observed between the PH groups. However, significant correlations ($p < 0.05$) among these parameters were identified within the $PH < 17.58$ mm group, suggesting an effect of reduced PH on respiratory disturbances. In addition, the $PH < 17.58$ mm group possessed a significantly narrower UPAW than the other, illustrating a consistency with findings in some reports.^(1,16) An inverse correlation between PH and the oxygen desaturation index has been reported, possibly due to reduced palatal volume and limiting tongue space, which may result in the promotion of posterior tongue position that compromised upper airway patency during sleep. These mechanisms may contribute to increased OSA severity.

Analyses of OSA severity revealed a significant increase in the $PH \geq 17.58$ mm group ($p=0.007$). Nevertheless, no significant correlation was found between PH and OSA severity in either group ($p=0.192$). Despite the highest number of patients with severe OSA in the

Table 1: Patients' characteristics stratified by their palatal height (PH).

Patients' characteristics	N	PH<17.58 mm (n=30)	PH≥17.58 mm (n=30)	p-value
Gender				
Male	41	18 (60.0%)	23 (76.7%)	0.165 ^a
Female	19	12 (40.0%)	7 (23.3%)	
Age* (years)	60	47.29±12.55	48.52±10.83	0.686 ^b
Body mass index* (kg/m ²)	60	29.24±6.64	29.55±6.29	0.796 ^c
Apnea-hypopnea index* (events/hour)	60	35.23±30.60	42.52±28.27	0.154 ^c
Respiratory disturbance index* (events/hour)	60	44.21±40.00	45.39±30.06	0.322 ^c
Nadir oxygen saturation* (percentage)	60	77.93±12.74	77.33±12.06	0.790 ^c
Thai version of the Epworth sleepiness scale score*	60	7.8±3.73	8.40±4.27	0.564 ^b
Upper posterior arch width* (mm)	60	48.76±3.93	50.25±3.57	0.037 ^{c,**}
Severity of obstructive sleep apnea				
Mild	11	8 (26.7%)	3 (10.0%)	0.192 ^a
Moderate	16	6 (20.0%)	10 (33.3%)	
Severe	33	16 (53.3%)	17 (56.7%)	
p-value		0.061 ^a	0.007 ^a	
Scalloped tongue				
None	2	2 (6.7%)	0	0.024 ^{d,**}
Mild	7	6 (20%)	1 (3.3%)	
Moderate	23	7 (23.3%)	16 (53.3%)	
Severe	28	15 (50.0%)	13 (43.3%)	
p-value		0.008 ^a	0.002 ^a	
Torus				
Torus absent	46	20 (66.7%)	26 (86.7%)	0.095 ^d
Only palatal torus present	3	1 (3.3%)	2 (6.7%)	
Only mandibular torus present	7	6 (20.0%)	1 (3.3%)	
Both palatal and mandibular tori present	4	3 (10.0%)	1 (3.3%)	
p-value		<0.001 ^a	<0.001 ^a	

*The values are expressed in mean±standard deviation.

**Significant intergroup differences at $p<0.05$.

^aChi-square, ^bindependent t-, ^cMann-Whitney U, and ^dFisher's exact tests.

Table 2: Correlations (ρ) between variables and palatal height (PH).

Variable	Overall PH (N=60)		PH<17.58 mm (n=30)		PH≥17.58 mm (n=30)	
	ρ	p-value	ρ	p-value	ρ	p-value
Apnea-hypopnea index	0.043	0.743	-0.536	0.002*	-0.116	0.541
Respiratory disturbance index	0.000	0.997	-0.419	0.021*	-0.051	0.788
Nadir oxygen saturation	0.098	0.456	0.557	0.001*	-0.009	0.962
TESS score	0.111	0.397	0.119	0.529	0.049	0.795
Severity of obstructive sleep apnea	0.012	0.926	-0.349	0.059	0.103	0.587
UPAW	0.103	0.432	-0.195	0.302	0.056	0.767
Scalloped tongue	0.023	0.860	-0.062	0.746	-0.069	0.719

*Significant correlations at $p<0.05$ from two-tailed tests.

Note: All correlations are analyzed by Spearman's rank correlation coefficient, except those between TESS scores and each PH, that between UPAW and the overall PH, and that between UPAW and the PH<17.58 mm groups by Pearson's product-moment correlation coefficient. Abbreviations: TESS, Thai version of the Epworth sleepiness scale; UPAW, upper posterior arch width.

Table 3: Correlations (ρ) between variables and upper posterior arch width (UPAW) value in each palatal height (PH) group.

Variable	UPAW in each PH group					
	overall PH (N=60)		PH<17.58 mm (n=30)		PH $\geq$ 17.58 mm (n=30)	
	ρ	<i>p</i> -value	ρ	<i>p</i> -value	ρ	<i>p</i> -value
Apnea-hypopnea index	0.167	0.201	0.065	0.732	0.211	0.262
Respiratory disturbance index	0.184	0.159	0.118	0.534	0.188	0.319
Nadir oxygen saturation	-0.105	0.424	0.046	0.810	-0.206	0.275
TESS score	-0.047	0.724	-0.303	0.103	0.034	0.857
Severity of obstructive sleep apnea	0.194	0.137	0.098	0.608	0.203	0.221
Scalloped tongue	0.243	0.062	0.368	0.048*	0.008	0.967

*Significant correlations at $p<0.05$ from two-tailed tests.

Note: All correlations are analyzed by Spearman's rank correlation coefficient, except that between TESS score and UPAW in the overall PH and that between TESS score and UPAW in the PH<17.58 mm groups by Pearson's product-moment correlation coefficient.

Abbreviation: TESS, Thai version of the Epworth sleepiness scale.

PH $\geq$ 17.58 mm group, this did not necessarily indicate an association between an increased PH and a greater OSA severity. The anatomical feature alone may not offset other factors contributing to OSA severity.⁽¹⁷⁾ Moderate correlations should then be interpreted with caution. Some possible confounders, such as craniofacial pattern, ethnicity, and body mass index, must also be considered.^(1,9,18) A significant intergroup difference ($p=0.037$) in UPAW was detected. However, the analyses disclosed no significant inter- or intragroup correlation between PH and UPAW, indicating no relationship between them. These may indicate that the observed association reflects a grouping effect rather than a direct linear relationship between the two variables.

Scalloped tongue refers to indentations along the tongue's lateral borders, which are usually caused by repeated pressure against the teeth's lingual surfaces.⁽¹⁰⁾ This condition has been reported to result from palatoglossal disproportion, either independently or in combination with tongue enlargement.⁽¹⁹⁾ It may also be associated with maxillary constriction, which can be indicated by the PH and UPAW.⁽²⁰⁾ Maxillary constriction is considered a risk factor for OSA.^(8,21,22) A high and narrow palatal vault, which is related to a reduced arch width, limits the transverse space available for the tongue and may contribute to the development of scalloped tongue. In this study, the moderate and severe forms of scalloped tongue were more frequently observed in both PH groups, but there was no significant correlation ($p>0.05$) between them. However, a weakly positive correlation ($r=0.368$, $p=0.048$) between UPAW and scalloped tongue was

detectable in the PH<17.58 mm group, possibly due to a narrowed oral cavity. Almost all OSA patients in this study possessed scalloped tongues, explicable by rhythmic masticatory muscle activity often associated with respiratory events and cortical arousals in sleep apnea.⁽²³⁾

Torus is an anatomical variation that may be a risk factor for OSA, and its prevalence varies across countries and ethnic groups.⁽²⁴⁾ Mandibular torus has been proposed to contribute to limited tongue volume⁽²⁵⁾ and influence airway patency.⁽⁹⁾ Similarly, palatal torus may reduce oral cavity volume and affect tongue position. In this study, the absence of torus was the most common finding in both PH groups. These results suggest that the presence of torus may not be a predominant feature among OSA patients, regardless of palatal morphology.

This study has some limitations. First, its cross-sectional design prevents conclusions about causal relationships. Only associations between variables could be identified. Second, the patients were classified based on their median PH. Using different PH cutoffs and measurement methods may yield different findings, warranting further investigation. Variations in the measurement methods and mean values of PH across diverse populations have been documented.⁽²⁶⁻²⁸⁾ Differences in the PH measurement approaches persisted, even in a study conducted in Thailand.⁽²⁹⁾ Third, all patients were Thai, whose craniofacial characteristics are different from those of other ethnic groups. It may limit the applicability of the results to other populations. Fourth, this study included a relatively small sample size ($n=60$). No priori power analysis was conducted, due to a suggestion by the central

limit theorem that 30 (or more) participants are sufficient for a parametric estimation.⁽³⁰⁾ This may have limited the ability to detect some smaller, yet clinically relevant, differences.

These findings suggested that PH and UPAW may not be key determinants of OSA severity.⁽¹⁷⁾ The oral cavity proper is a complex three-dimensional structure, and additional anatomical parameters, such as palatal surface area and sagittal dimension, should be considered.^(1,7,31) Moreover, evaluations of soft tissue structures^(9,21) and cephalometric analyses^(5,32,33) may provide a more comprehensive understanding of anatomical factors contributing to OSA.

Conclusions

Within the limitations of this study, it can be concluded that PH alone may not be a reliable predictor of OSA. Significantly moderate correlations between PH and AHI, RDI, and nadir SpO₂ values were observed in patients with PH<17.58 mm. These associations should be interpreted with caution, and PH assessment should be considered alongside other clinical factors, when deciding whether to refer patients for further sleep assessment.

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Conflict of Interest

The authors declare no conflict of interest.

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Assessment of Mandibular Posterior Available Space in Skeletal Class I and Class III Malocclusion Patients

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Abstract

Objectives: This study aimed to compare the mandibular posterior available space between patients with skeletal Class I and skeletal Class III malocclusion.

Methods: The retrospectively analyzed cone-beam computed tomography (CBCT) scans from 60 Thai orthodontic patients with normodivergent patterns. Patients were allocated to skeletal Class I or Class III; Class III severity was stratified by Wits appraisal. Mandibular posterior available space (MPAS) was measured on axial slice of CBCTs at the crown level and at root levels 3, 6 and 9 mm (RL₃, RL₆ and RL₉) apical to the cemento-enamel junction. Comparisons of the mandibular posterior available space between skeletal Class I and Class III groups were performed using the Mann-Whitney U test. The value of $p < 0.05$ was considered statistically significant for differences.

Results: No statistically significant differences in MPAS were detected between the skeletal Class I and Class III groups. Within the Class III group, MPAS did not differ significantly between non-severe and severe subgroups. Regarding mandibular third-molar status, Class III subjects with a mandibular third molar exhibited significantly greater MPAS at RL₆ and RL₉ compared with those without a third molar. In the Class I group, MPAS values did not differ significantly between the third-molar and non-third-molar subgroups.

Conclusions: The MPAS did not differ significantly between skeletal Class I and Class III patients. Clinically, these findings highlight the importance of individualized, CBCT-based evaluation rather than reliance on generalized characteristics such as skeletal classification.

Keywords: cone-beam computed tomography, mandibular posterior available space, orthodontics, retromolar space

Introduction

Molar distalization is a non-extraction treatment modality to correct molar relationships and alleviate dental crowding. The advent of temporary anchorage devices (TADs) enables predictable molar distalization with minimal patient compliance.⁽¹⁻⁴⁾ The success of molar distalization depends on the identification of the mandibular posterior available space (MPAS; also known as the retromolar space), which refers to the retromolar space located posterior to the mandibular dentition, typically distal to the mandibular second molar, that is available for distal movement of the mandibular molars. MPAS represents the anatomical limit for distal tooth movement. Evaluation of the posterior available space in both the mandibular retromolar and maxillary tuberosity regions is essential prior to treatment, as inadequate assessment may lead to periodontal complications and orthodontically induced root resorption.⁽⁵⁻⁷⁾

Previous studies have identified limitations in MPAS using panoramic radiographs and lateral cephalograms, revealing that the mandibular distal space is confined to the anterior border of the ramus.^(8,9) However, the inherent two-dimensional (2D) nature of panoramic radiographs and lateral cephalograms limits these imaging modalities, leading to potential confusion in anatomical landmark identification due to superimposition, differential magnification, and radiographic distortion. With the introduction of cone-beam computed tomography (CBCT), three-dimensional (3D) evaluation of MPAS has become possible. CBCT provides high-resolution 3D volumetric images of the craniofacial complex, allowing clear multi-planar and cross-sectional visualization of dentoalveolar and skeletal structures without superimposition seen in conventional 2D radiographs. Therefore, CBCT allows a more accurate 3D assessment of MPAS by visualizing the posterior available space along the root length, rather than relying on projected 2D landmarks.⁽¹⁰⁾ Recent findings suggest that the lingual cortical plate of the mandible, rather than the anterior border of the ramus, serves as the true posterior anatomical limit for molar distalization, as the MPAS decreases apically.^(5,7,10-13) Both sagittal and vertical skeletal relationships influence the MPAS, which is the largest in patients with skeletal Class III and hypodivergent vertical discrepancies, while it is the smallest in patients with skeletal Class II and hyperdivergent vertical discrepancies.^(5,7,11,12) Nevertheless, previous

research has mainly focused on mild-to-moderate skeletal discrepancies, and data on patients with severe skeletal Class III malocclusion remain limited. Despite undergoing orthognathic surgery, cases involving severe skeletal discrepancies sometimes require molar distalization to alleviate crowding.

Therefore, the present study aimed to compare the MPAS between patients with skeletal Class I and skeletal Class III malocclusion. The null hypothesis was that no significant differences exist in the MPAS between patients with skeletal Class I and III malocclusion.

Materials and Methods

The inclusion criteria were (1) adult patients aged 18 to 30 years; (2) patients with a normodivergent facial profile, defined as a sella-nasion to mandibular plane angle (SN-GoGn) between 30° and 38°; (3) acceptable skeletal symmetry (Menton deviation < 4 mm, assessed on a frontal CBCT view using a midsagittal reference plane); and (4) intact roots without anomalies such as idiopathic root resorption or severe dilacerations. The exclusion criteria included (1) the presence of prostheses or missing teeth except for third molars in the mandibular arch; (2) pathological periodontal conditions with alveolar bone loss with a CEJ to alveolar bone crest distance > 2 mm; (3) history of previous orthodontic treatment, and (4) congenital craniofacial anomalies.

The sample comprised 60 Thai orthodontic patients who required CBCT images for diagnosis and treatment planning. This retrospective study was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University, Thailand (No. 31/2024). All patients provided written informed consent before participation in the study.

To calculate the required minimum sample size, a pilot study was performed. The sample size calculation was done using the G*Power software (version 3.1.9.4, University of Kiel, Germany). Considering an effect size set of 0.755, power of 85%, and a significance level of 5%, the final sample required 28 subjects per group. However, to allow for possible exclusions, incomplete records, or unusable data, 60 participants were included to ensure that the final sample size remained sufficient for statistical analysis.

Patients who met the inclusion criteria were assigned to two groups based on a combined assessment of the

ANB angle and Wits appraisal: Patients with a skeletal Class I relationship ($n=30$) was defined as an ANB angle of $2^\circ \pm 2^\circ$ and a Wits appraisal between -3 and $+3$ mm, and patients with a skeletal Class III relationship ($n=30$) was defined as an ANB angle $<0^\circ$ and a Wits appraisal <-3 mm. Within the Class III group, severity was further stratified using the Wits appraisal into mild-to-moderate discrepancy (Wits ≥ -9.5 mm; $n=15$) and severe discrepancy (Wits <-9.5 mm; $n=15$).

Pretreatment lateral cephalograms were obtained with the participants in maximum intercuspation, with the lips at rest, and with the Frankfort horizontal plane maintained parallel to the ground while the patients were seated in a standardized natural head position. The lateral cephalograms were generated from CBCT images and digitally traced using Dolphin Imaging Software version 11.9 (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). All measurements were performed by a single operator. To assess intra-operator reliability, lateral cephalograms of 10 subjects were traced and measured twice, with a two-week interval between the two sessions. The pretreatment CBCT images were obtained from three-dimensional imaging Cone-beam computed tomography using a NewTom Giano (Verona, Italy) CBCT unit at 90 kV, an $8\text{ cm} \times 8\text{ cm}$ field of view, and a voxel size of 0.16 mm . The Digital Imaging and Communications in Medicine (DICOM) files from CBCT were acquired and imported into Dolphin Imaging software to determine the MPAS. The 3D images were reoriented using specific reference planes to facilitate accurate analysis and interpretation. The horizontal reference plane was established by connecting the midpoint of the mandibular incisor tip and the mesiobuccal cusps of the mandibular first molars, effectively representing the mandibular occlusal plane. The midsagittal plane was constructed using anatomical landmarks, including the crista galli, anterior nasal spine (ANS), and the midpoint of the maxillary incisor tip. Using these reference planes, the CBCT images were reoriented to ensure standardized and reproducible orientations for accurate analysis (Figure 1).

The MPAS at the crown level (CL) and root level (RL) were measured on the axial slice of the CBCT image. The shortest distance between the mandibular second molar crown and the inner cortex of the ramus was measured parallel to the posterior cuspal line, which connects the buccal cusps of the mandibular first and second molars

at a level 2 mm below the mandibular occlusal plane at the CL (Figure 2). At the RL, the shortest distances between the mandibular second molar root and the inner lingual cortex of the mandibular body were measured parallel to the posterior cuspal line at depths of 3 mm, 6 mm, and 9 mm (RL₃, RL₆, RL₉) on the axial slices with the distal cemento-enamel junction (CEJ) of the second mandibular molar as the reference level (RL₀; Figure 3).

All measurements were performed by one investigator. Intra-examiner measurement error was assessed by remeasurement of CBCT images after a two-week interval. Intraclass correlation coefficient (ICC) analysis for the two measurements was carried out to investigate intra-examiner reliability. The intraclass correlation in the present study showed good agreement between measurements, with the ICC ranging from 0.991 to 0.997.

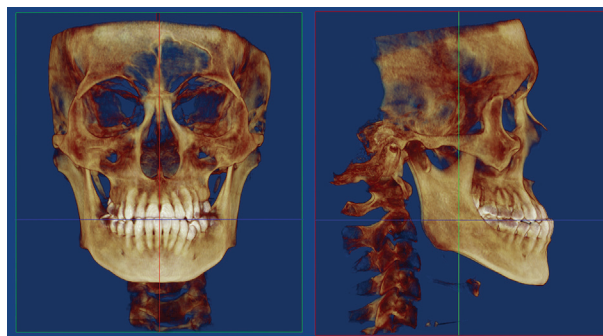


Figure 1: Reference used for this study. The mandibular occlusal plane (blue line): connection of the mesiobuccal cusps of the mandibular first molars and the mandibular central incisor tip. The midsagittal plane (Red line): passing through anterior nasal spine (ANS), crista galli and midpoint of the maxillary incisor tip.

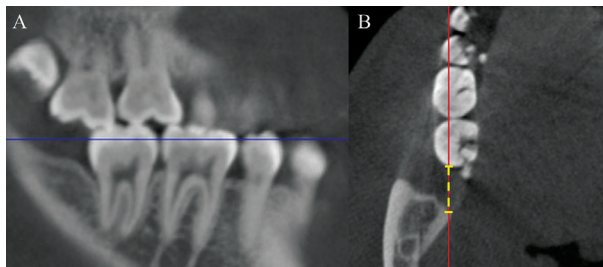


Figure 2: Mandibular posterior available space (MPAS) measured at crown level (CL). (A) Sagittal view at crown level; (B) Axial view at crown level; yellow line is MPAS, red line is posterior cuspal line which connects the buccal cusps of the mandibular first and second molars.

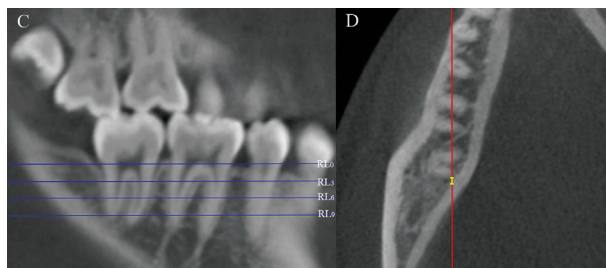


Figure 3: Mandibular posterior available space (MPAS) measured at cementoenamel junction (CEJ), 3 mm, 6 mm and 9 mm apical to CEJ level (RL₀, RL₃, RL₆ and RL₉). (C) Sagittal view; (D) Axial view; yellow line is MPAS, red line is posterior cuspal line.

Statistical analysis

Data analysis was performed using SPSS (Statistical Package for the Social Sciences, Chicago, IL, USA) version 25.0.1.0 for Windows. Descriptive statistics were used to summarize the baseline characteristics of participants.

Data distribution was assessed with the Shapiro–Wilk test and found to be non-normal. Side-to-side comparisons using the Wilcoxon signed-rank test revealed a significant difference between right and left measurements; therefore, the two sides were analyzed separately.

Comparisons of the MPAS between skeletal Class I and skeletal Class III groups were performed using the Mann–Whitney U test. $p < 0.05$ was considered statistically significant.

To evaluate the effect of the mandibular third molar on MPAS, both sides of 60 patients were classified into two subgroups: third-molar present and third-molar absent (extracted or congenitally absent). The Mann–Whitney U test was used to compare MPAS values between these two groups. Chi-square tests were applied to examine differences in baseline characteristics and categorical variables related to MPAS between the sample groups.

Results

The final sample included 60 sides for each skeletal group (Class I and Class III). The mean ages of patients in the Class I and Class III groups were 25.3 ± 4.0 years and 24.8 ± 4.9 years, respectively (Table 1). The distribution of male and female participants did not differ significantly between the two groups by the Pearson's chi-square test ($p = 0.598$). Patient demographic and skeletal characteristics are summarized in Table 1.

Across all measurement levels, the left and right

MPAS values showed no significant differences, except within the Class III group at 6 mm ($p = 0.014$) and 9 mm ($p = 0.006$) below the CEJ, where statistically significant side-to-side differences were observed (Table 2). When comparing skeletal classifications, no statistically significant differences in MPAS were observed between the Class I and Class III groups at any measurement level (Table 3). However, a trend toward slightly larger MPAS measurements in the Class III group was noted across most planes, although it did not reach statistical significance ($p > 0.05$). There were no statistically significant differences in MPAS when comparing the skeletal Class III non-severe and severe groups (Table 3).

Regarding mandibular third-molar presence, a mandibular third molar in the Class III group was associated with significantly greater MPAS distances at RL₆ ($p = 0.045$) and RL₉ ($p = 0.029$), with the non-third-molar group exhibiting smaller MPAS values at these levels. However, no significant differences were observed at the remaining measurement levels. Within the Class I group, MPAS distances were significantly greater at RL₀ ($p = 0.045$) while no significant differences were observed at the remaining measurement levels between the third-molar and non-third-molar groups (Table 4). Additionally, MPAS differed significantly between males and females only in the Class I group at the crown level (CL) and at the RL₀ level, whereas no significant sex-related differences in MPAS were found at the remaining levels in Class I or at any level in Class III (Table 5).

Discussion

As a non-extraction modality, molar distalization offers an attractive option for correcting molar relationships and managing dental crowding. However, its success depends on the space available posterior to the mandibular dentition. Clinically, skeletal Class III patients are usually expected to have a larger MPAS than Class I patients, implying a potentially more favorable environment for distalization. Multiple variables may affect the MPAS^(5,7,11,12), underscoring the need for accurate MPAS evaluation because the effective distalization space could be modified by factors beyond sagittal skeletal pattern. This study compared the MPAS between patients with skeletal Class I and III malocclusions using CBCT imaging to provide a 3D understanding of posterior anatomical limitations.

Table 1: Patient characteristics^a.

	Number	Age ^b	ANB ^b	SN-MP ^b	Mandibular length (Co-Gn) ^b	Gender ^c	
						Male (%)	Female (%)
Class I	30	25.3±4.0	2.6±1.1	29.1±2.9	127.1±9.5	N=13 (43.33%)	N=17 (56.67%)
Class III	30	24.8±4.9	-2.6±1.7	28.8 ±2.0	135.0±10.8	N=11 (36.67%)	N=19 (63.33%)
<i>p</i>	-	0.561	0.000*	0.579	0.002*	0.598	

^aValues are presented as mean±standard deviation.^bIndependent sample t-test.^cChi-square test.*Statistically significant at $p<0.05$ **Table 2:** Comparison of the mandibular posterior available space (MPAS) between the left and right side between Class I and Class III group^a.

Depth	Class I			Class III		
	Right ^b (n=30)	Left ^b (n=30)	<i>p</i>	Right ^b (n=30)	Left ^b (n=30)	<i>p</i>
CL	10.9	11.9	0.174	11.3	11.3	0.504
RL ₀	10.7	11.3	0.465	11.2	11.2	0.984
RL ₃	3.8	4.0	0.509	4.4	3.7	0.086
RL ₆	2.3	2.4	0.992	3.5	2.3	0.014*
RL ₉	1.1	1.1	0.964	2.2	1.3	0.006*

^aAll data is presented as median.^bData analyzed with Wilcoxon Signed rank test.

“Depth” is the depth at which the mandibular posterior available space (MPAS) was measured; “CL” is the depth at the level of 2 mm below mandibular plane; “RL₀” is the depth at the level of cemento-enamel junction (CEJ), “RL₃”, “RL₆” and “RL₉” are the depth at the levels 3 mm, 6 mm, and 9 mm apical to CEJ.

*Statistically significant at $p<0.05$ **Table 3:** Comparison of the mandibular posterior available space (MPAS) between Skeletal Class I and Skeletal Class III patient among different planes^a.

Depth	Skeletal pattern					<i>p</i>
	Class I ^b (n=60)	Class III ^b (n=60)	<i>p</i>	Class III ^b (n=60)		
				Non-severe ^b (n=30)	Severe ^b (n=30)	
CL	11.0	11.3	0.212	11.2	11.7	0.403
RL ₀	10.8	11.2	0.317	10.9	11.5	0.492
RL ₃	3.9	3.9	0.259	4.0	3.8	0.813
RL ₆	2.6	2.8	0.198	2.6	3.0	0.976
RL ₉	1.1	1.7	0.107	1.8	1.7	0.959

^aAll data is presented as median.^bData analyzed with Mann-Whitney U test.*Statistically significant at $p<0.05$

Table 4: Comparison of the mandibular posterior available space (MPAS) between mandibular third-molar present group and third-molar absent group^a.

		Present ^b	Absent ^b	<i>p</i>
Class I		n=37	n=23	
	CL	10.7	11.1	0.082
	RL ₀	10.4	11.7	0.045*
	RL ₃	4.0	3.9	0.456
	RL ₆	2.6	2.1	0.166
	RL ₉	1.2	1.0	0.244
Class III		n=26	n=34	
	CL	11.4	11.3	0.210
	RL ₀	11.3	10.9	0.296
	RL ₃	4.0	3.8	0.257
	RL ₆	3.5	2.3	0.045*
	RL ₉	2.2	1.4	0.029*

^aAll data is presented as median.^bData analyzed with Mann-Whitney U test.*Statistically significant at $p < 0.05$ **Table 5:** Comparison of the mandibular posterior available space (MPAS) between Skeletal Class I and Skeletal Class III patient between female and male patients^a.

Depth	Skeletal pattern					<i>p</i>
	Class I ^b (n=60)		<i>p</i>	Class III ^b (n=60)		
	Male (n=26)	Female (n=34)		Male ^b (n=22)	Female ^b (n=38)	
CL	12.1	10.2	0.010*	11.3	11.4	0.824
RL ₀	12.2	10.4	0.015*	11.3	11.1	0.753
RL ₃	4.1	3.5	0.189	4.5	3.8	0.060
RL ₆	2.4	2.2	0.864	3.5	2.5	0.958
RL ₉	1.1	1.2	0.911	2.1	1.4	0.253

^aAll data is presented as median.^bData analyzed with Mann-Whitney U test.*Statistically significant at $p < 0.05$

There were no significant between-group differences in age or sex distribution between the skeletal Class I and III groups; however, mandibular length differed significantly, with the Class III group exhibiting a greater mandibular length than the Class I group. With respect to sex, significant differences were observed only at CL and RL₀ in the Class I group, whereas no significant sex-related differences were detected at the remaining root levels in either group. Because the clinically MPAS is generally evaluated at the root level rather than at the crown level, these findings suggest that any potential sex effect on MPAS may be limited. Notably, the sagittal comparison of MPAS between these skeletal patterns showed that the MPAS of Class III patients was not significantly greater

than that of Class I patients at any measurement level, although a tendency toward larger values in the Class III group was noted. This overall pattern was consistent with the findings of Kim *et al.*,⁽¹⁶⁾ who reported no significant differences in MPAS among different skeletal patterns, although some studies have described larger MPAS values in Class III patients compared with Class I subjects in some measurement levels.^(11,13,14) The explanation for the larger MPAS in Class III patients lies in skeletal morphology and dental characteristics. Class III individuals generally present with a greater mandibular body length and lower molars that are relatively upright or lingually inclined compared with Class I patients, contributing to an increased MPAS for distalization.^(17,18)

Although a trend toward a larger MPAS in Class III patients was observed, the lack of statistical significance in our data underscores the multifactorial nature of posterior anatomic limitation and the need for population-specific normative values in future research. This finding also highlights the importance of individualized assessment of distalization potential rather than relying solely on skeletal classification. Regardless of the overall sagittal skeletal dimension, previous anatomical and CBCT-based studies have consistently demonstrated that the MPAS gradually decreases as measurements approach the root apex.^(5,10-14) This progressive reduction reflects the V-shaped anatomy of the mandibular basal bone, where the available space becomes narrower at the apical level compared with the crown or CEJ level. Consequently, the true anatomical limitation for molar distalization lies closer to the apical level rather than the coronal region.^(5,10-14)

In the current investigation, the median MPAS at the occlusal level was 11.0 mm in Class I patients and 11.3 mm in Class III patients, which corresponds with the previous study of Kim *et al.*,⁽¹⁰⁾ who reported a mean retromolar space at the CL of 9.88 mm. The minimum MPAS values were observed near the root apex level (specifically, 9 mm apical from the CEJ), where the median distances were approximately 1.1 mm in the Class I group and 1.7 mm in the Class III group. In comparison, a previous study that assessed MPAS at 6 mm apical to the furcation level reported mean values of 3.78 mm for Class I and 4.43 mm for Class III.⁽¹⁸⁾ Given an average root trunk length of 3.0 mm, these measurements are considered comparable to those at the 9.0 mm level in the present study.⁽¹²⁾ These findings suggest that the MPAS values in the present study were smaller than those reported previously. This discrepancy could be explained by differences in ethnicity between study populations and methodological variations, including differing horizontal reference levels and measurement planes used to determine the minimum distance available for molar distalization. In this study, MPAS measurements were performed along the cuspal line, which was considered a reliable reference for estimating the axis of distalization. The validity of using the cuspal line as a reference is supported by studies indicating that the angle between the cuspal line and the sagittal line remains relatively constant across individuals.^(7,14) This geometric consistency reinforces its suitability as a stable and reproducible reference for MPAS assessment.

This study also compared the MPAS between skeletal Class III non-severe and severe cases and found no significant differences between these two subgroups. This suggests that, among patients with Class III malocclusion, the MPAS may not vary according to the severity of the sagittal discrepancy. Within the current study, the Wits appraisal was selected to stratify Class III severity because, although the ANB angle was the most commonly used cephalometric indicator of maxillomandibular anteroposterior discrepancy, its validity as a true measure of jaw relationships has been questioned. The ANB angle was influenced by the position of the nasion, and the rotation of the jaws could affect the ANB angle.⁽¹⁹⁾ However, the Wits appraisal uses the functional occlusal plane as a reference and, therefore, jaw rotation relative to cranial reference planes had less influence on the severity of jaw disharmony.⁽²⁰⁾ Mandibular length has been considered a marker of Class III severity. Although mandibular length was greater in the Class III group than in the Class I group in this study, the MPAS did not differ significantly, suggesting that mandibular length might not be directly associated with the MPAS.

Although this study controlled vertical skeletal patterns by including only normodivergent patients, the influence of vertical divergence on MPAS is clinically relevant and should be considered in treatment planning. Previous literature consistently demonstrates a strong association between vertical facial pattern and the space available for molar distalization, and hyperdivergent patients typically exhibit the smallest MPAS and the highest risk of cortical contact, whereas hypodivergent patients present the largest MPAS.^(5,7,12) By standardizing vertical skeletal characteristics, this study aimed to isolate the effect of sagittal discrepancy and minimize confounding from vertical morphological variations.

Similarly, the presence or absence of the mandibular third molar was not consistently associated with MPAS across the measured levels. Although significant differences were observed only at a few reference levels, while most measured levels showed no significant differences. Therefore, any influence of the mandibular third molar on MPAS appears to be level-specific rather than being consistent across all measurements, and should be interpreted with caution when compared with prior studies reporting no overall effect of third-molar status on MPAS.^(7,10,11,15) However, when the mandibular third molar status was

further classified according to the eruption or impaction type, discrepancies among studies were observed. For example, patients with normally erupted or vertically impacted mandibular third molars exhibited larger MPAS compared with those with missing, horizontally impacted, or mesially inclined third molars.⁽¹³⁾ These findings suggest that while the presence or absence of a third molar may not be a determinant, its specific eruption status and angulation could influence the extent of MPAS.

A primary limitation of this study was its exclusive focus on hard tissue morphology, without consideration of soft tissue structures. The thickness of soft tissue in the retromolar area is a clinically relevant factor that may restrict distal tooth movement and predispose patients to complications such as pericoronitis or mucosal impingement.^(10,21) In addition, mandibular third molars were not categorized separately as congenitally absent or previously extracted, although these conditions may influence posterior bone morphology. Therefore, potential confounding from pooling them should be considered when interpreting the results. Moreover, sagittal morphology indicators, such as ANB angle, mandibular length, and the degree of Class III discrepancy, were not reliable predictors of greater MPAS in our study. This finding suggests that skeletal classification and conventional sagittal cephalometric parameters alone should not be used as indicators of posterior clearance or distalization feasibility. For vertical skeletal evaluation, the SN-MP angle was used to define the vertical skeletal pattern in this investigation. To enhance the robustness of future studies focusing on vertical control, incorporating additional conventional cephalometric indicators, such as the Frankfort mandibular plane angle or facial height index, is warranted to provide a more comprehensive characterization of the vertical dimension. Although transverse skeletal discrepancy was minimized by including only subjects with acceptable skeletal symmetry (Menton deviation < 4 mm), its potential influence on MPAS could not be evaluated and warrants further investigation.

Clinically, this research implies that safe and effective molar distalization requires individualized assessment rather than reliance on generalized data or standard cephalometric norms. Treatment decisions should not depend solely on factors such as sex, third-molar presence, or skeletal classification, but should include the direct measurement of each patient's local anatomy and

vertical pattern. Accordingly, individualized CBCT-guided planning is strongly recommended, utilizing measurements parallel to the cuspal line to accurately quantify the minimum MPAS and implement conservative safety margins that ensure predictable and biologically safe molar distalization. The results also highlight the need to integrate anatomical limitations with biomechanical considerations when planning mandibular molar distalization. Because the MPAS narrowed substantially toward the apex, force systems that generated uncontrolled tipping or excessive distal root movement were more likely to encounter cortical boundaries. Clinicians may need to modify mechanics, such as using TAD-supported bodily movement, segmented arch techniques, or incorporating controlled crown tipping to minimize apical displacement and maintain the root within the biologically safe zone. Future work combining MPAS quantification with 3D finite element analysis may provide deeper insight into stress distribution patterns and help refine safer, more efficient distalization protocols.

Conclusions

The MPAS did not differ significantly between skeletal Class I and Class III patients at any measurement level, although there was a tendency toward larger MPAS in the Class III group. The MPAS progressively decreased toward the root apex, with the minimum distance observed at 9 mm apical to the CEJ, emphasizing the apical region as the anatomical limit for mandibular molar distalization. In contrast, no conclusive association was identified between MPAS and either sex or the presence/absence of the mandibular third molar in this study. Clinically, these findings highlight the importance of individualized, CBCT-based evaluation rather than reliance on generalized characteristics such as skeletal classification or third-molar status. Applying conservative safety margins based on apical MPAS values is essential to avoid complications such as cortical interference, dehiscence, or root resorption.

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Conflict of Interest

The authors declare no conflict of interest.

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The Interplay of Loneliness, Oral Health and Quality of Life: A Study of Thai Older Adults

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Abstract

Objectives: This study aimed to examine the association between oral health, oral health-related quality of life (OHRQoL) and loneliness among Thai older adults.

Methods: A cross-sectional study was conducted among 421 adults aged 60 and older in Ang Thong Province, Thailand. Data were collected through structured interviews and oral examinations. Loneliness and OHRQoL were assessed using the Thai version of the 6-item Revised UCLA Loneliness Scale (RULS-6), and the Thai version of The Oral Health Impact Profile 14 (OHIP-14), respectively. Statistical analyses included correlation, univariate, and multivariate linear regression.

Results: The average (standard deviation) loneliness score was 7.76 (3.46). All OHIP-14 domains were significantly associated with loneliness. The strongest correlation was observed in the psychological discomfort domain ($r=0.31$), followed by the handicap domain. In the multivariate analysis, significant predictors of increased loneliness included greater age, living alone, smoking history, semi-dependence, and psychological discomfort. Interestingly, psychological disability was found to be inversely associated with loneliness.

Conclusions: Certain domains of OHRQoL, especially psychological discomfort, were positively associated with loneliness among older Thai adults. Factors such as age, living status, smoking history, and functional ability also played significant roles.

Keywords: aging, loneliness, oral health, oral health-related quality of life

Introduction

Like much of the world, Thailand is experiencing a growing elderly population and is approaching a “completed aged” society in which at least 20% are over the age of 60. Currently, 12.6 million (nearly 19%) of Thailand’s 66.7 million people are aged 60 or older.⁽¹⁾ The elderly often face loneliness, an emotional state characterized by a perceived gap between the social relationships that individuals desire and the relationships that they have, and it can undermine overall well-being.⁽²⁾ Loneliness has become a significant public health issue. In 2023, the World Health Organization (WHO) declared loneliness a global public health concern.⁽³⁾ Loneliness worsens various health outcomes, most notably affecting mental health and overall well-being.⁽⁴⁾ It has been associated with depression and other mental health problems^(4,5), physical disability^(6,7), reduced quality of life (QoL)^(4,8), and risky behaviors such as smoking.^(9–11) Many studies have addressed the impact of loneliness on general health and behavior. However, research on its relationship with oral health and oral health-related quality of life (OHRQoL) remains limited, especially among older adults. OHRQoL reflects how oral conditions affect daily life and overall well-being. It considers the severity, frequency, or duration of impacts that are significant enough to influence one’s perception of life quality.⁽¹²⁾ OHRQoL encompasses four dimensions: oral function, orofacial pain, orofacial appearance, and psychosocial impact.⁽¹³⁾ The psychosocial dimension considers the emotional and social consequences of oral health problems. Poor oral health and low OHRQoL have been associated with feelings of loneliness.^(14–16) However, studies exploring this association are limited, notably among older Thai adults, whose cultural context may differ from that of other populations. In Thailand, loneliness in older adults is often related to living arrangement and lack of family engagement. Individuals living alone report greater loneliness, and older adults who do not participate in family activities tend to feel more isolated.⁽¹⁷⁾ Therefore, examining loneliness in Thai older adults provides important insight for culturally appropriate interventions. This study aims to examine the association between oral health, OHRQoL and loneliness among Thai older adults.

Material and Methods

Study design and ethical approval

This cross-sectional study was approved by the Ethical Review Board of the Ang Thong Provincial Public Health Office (ATGEC 23/2567).

Setting and sample

The study was conducted from March to May 2024 among community-dwelling older adults aged 60 years and older in Ang Thong Province, Thailand. A quota sampling method was used to recruit 421 participants. Individuals with cognitive impairment (as assessed by the Mini-Cog test) or communication difficulties were excluded. The sample size was determined using G*Power for linear multiple regression (fixed model) with a priori analysis, which considered an effect size of 0.09, a significance level of 0.05, a power of 0.90, and included 30 predictors.⁽¹⁸⁾

Data collection

Structured interviews were conducted at the village town hall or the community health center during community activities. These interviews collected data on demographics, health conditions and behaviors, oral health behaviors, and overall oral health status and function, including group eating avoidance and eating problems. Oral examinations assessed the number of remaining teeth and occluding tooth pairs.

Loneliness was measured using the Thai version of the 6-item Revised UCLA Loneliness Scale (RULS-6).⁽¹⁹⁾ This unidimensional scale has demonstrated good reliability, with Cronbach’s $\alpha=0.83$.⁽¹⁹⁾ Each item began with a question stem, ‘How much of the time do you feel..’, and used a four-point response scale: 1 (often), 2 (sometimes), 3 (rarely), and 4 (never).⁽¹⁹⁾ Scores range from 6 to 24, with higher scores indicating greater levels of loneliness.⁽¹⁹⁾

Oral health-related quality of life (OHRQoL) was measured using the Thai version of the Oral Health Impact Profile 14 (OHIP-14).^(20,21) This tool evaluates seven domains: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. Participants reported the frequency of oral health impacts experienced

over the past four weeks using a 5-point response scale ranging from 0=never to 4=very often. Higher scores indicate poorer OHRQoL.^(20,21)

Data analysis

Statistical analyses were performed using IBM SPSS version 29.0. Descriptive statistics, including means and standard deviations, were used to summarize demographic, behavioral, and oral health data. Independent t-tests and one-way ANOVA were employed to assess factors related to loneliness. Pearson correlation was used to assess the relationship between loneliness and OHRQoL. Both univariable and multivariate regression analyses were conducted to explore the associations between oral health, OHRQoL, and loneliness. A *p*-value below 0.05 was considered statistically significant.

Results

A total of 421 older adults participated in the study. Their average age was 70.38 years (standard deviation, SD: 7.18), with most participants aged between 60 and 69 years. Additionally, 51.1% of the participants were female. The majority were married (70.3%), lived with family members (54.9%), and had completed only elementary education (72.2%). In terms of health conditions, 75.1% had systemic diseases, with a median of two diseases (Interquartile range: 0.5-2). Regarding oral health, 66.7% had 20 or more remaining teeth, while 77.2% had between 0 and 3 natural occluding tooth pairs. Furthermore, 44.7% reported experiencing difficulties with eating or chewing (Table 1).

Significant differences in RULS-6 scores were observed based on demographic, health, and oral health factors. Loneliness scores increased with age, with the following averages (SD): 7.20 (2.65) for ages 60-69 years, 7.90 (3.73) for ages 70-79 years, and 9.41 (4.61) for those aged 80 years and older ($p<0.001$). Higher loneliness scores were found among individuals living alone (9.31 (4.72)), those with lower education levels ($p=0.005$), non-exercisers ($p<0.001$), and smokers ($p=0.025$). Participants who were semi-dependent or dependent had significantly higher loneliness scores (15.33 (5.64)) compared to independent individuals (7.59 (3.21)) ($p<0.001$). Additionally, participants with 20 or more teeth reported higher loneliness scores (8.02 (3.72)) than those with fewer than 20 teeth (7.23 (2.80)) ($p=0.026$). Those who avoided group eating (8.94 (4.69)) and those with eating

or chewing difficulties (8.17 (3.97)) also exhibited higher loneliness scores ($p<0.05$) (Table 1).

The average (SD) loneliness scores, using the Thai RULS-6, ranged from 1.19 (0.60) for item 4, "How often do you feel left out?" to 1.40 (0.79) for item 6, "How often do you feel people are around you but not with you?" (Table 2).

The study also found that participants had an average (SD) overall OHIP-14 score of 5.46 (7.84). Among the assessed domains, the physical pain domain had the highest mean (SD) score of 1.58 (1.92). The item most affected in this domain was "Discomfort when eating," which scored an average (SD) of 0.94 (1.24). In contrast, the lowest mean scores (SD) were noted in the social disability domain 0.30 (0.90). There were also low scores for the items "Difficulty relaxing" in the psychological disability domain and "Irritability with others people" in the social disability domain, both with a mean (SD) score of 0.17 (0.53) (Table 3).

Univariate analysis of loneliness using simple regression revealed several factors significantly associated with loneliness ($p<0.05$). These factors included age, marital status (previously married), living alone, number of systemic diseases, lack of exercise, smoking (ex-smokers), and self-ability (semi-dependent or dependent). Oral health factors that were significantly associated with loneliness included having more than 20 remaining teeth, avoiding group eating, and experiencing eating problems. OHIP-14 factors significantly associated with loneliness were functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap ($p<0.05$) (Table 4).

Multivariable analysis adjusting for confounders showed that age, living alone, smoking (ex-smokers), and self-ability (semi-dependent or dependent) remained significant predictors of loneliness. Among OHIP-14 factors, psychological discomfort was positively associated with loneliness, whereas psychological disability was negatively associated (Table 5).

Discussion

This study examined the association between loneliness, oral health, and OHRQoL among Thai older adults, revealing a significant relationship among these factors. The relationships presented mixed outcomes. A poorer OHRQoL was significantly associated with

Table 1: Demographic characteristics, health conditions, oral health behavior, and loneliness scores of Thai older adults (N=421).

	N	%	Loneliness (RULS-6)		F or t	p
			Mean	SD		
Demographics						
Age (years)						
60-69 years	215	51.1	7.20	2.65	10.375	<0.001 ^b
70-79 years	145	34.4	7.90	3.73		
More than 80 years	61	14.5	9.41	4.61		
Gender						
Male	125	29.7	8.14	3.74	1.492	0.136 ^a
Female	296	70.3	7.59	3.32		
Marital status						
Single	55	13.1	7.93	3.58	2.373	0.094 ^b
Married	231	54.9	7.44	3.17		
Previously married	135	32.1	8.24	3.83		
Living arrangements						
Alone	48	11.4	9.31	4.72	6.072	0.003 ^b
Spouse	69	16.4	7.91	3.11		
Family	304	72.2	7.48	3.24		
Highest education level						
None	9	2.1	8.67	5.32	5.377	0.005 ^b
Elementary or less	310	73.6	8.05	3.64		
Secondary or higher	102	24.2	6.80	2.37		
Health conditions and behavior						
Presence of systemic disease						
No	105	24.9	7.40	2.98	1.225	0.221 ^a
Yes	316	75.1	7.88	3.60		
Regularly exercises						
No	94	22.3	8.97	4.70	3.918	<0.001 ^a
Yes	327	77.7	7.41	2.92		
Smoking						
Non-smokers	366	86.9	7.58	3.29	3.708	0.025 ^b
Ex-smokers	36	8.6	8.83	4.21		
Current smokers	19	4.5	9.11	4.52		
Self-ability						
Independent	412	97.9	7.59	3.21	7.018	<0.001 ^a
Semi or Dependent	9	2.1	15.33	5.64		
Oral health behaviors						
Brushing						
No	23	5.5	7.91	3.30	0.221	0.825 ^a
Yes	398	94.5	7.75	3.47		
Use of extra cleaning instruments						
No	307	72.9	7.85	3.67	0.932	0.352 ^a
Yes	114	27.1	7.50	2.79		
Wearing dentures						
No	311	73.9	7.74	3.35	0.639	0.528 ^b
Yes, good denture	86	20.4	8.01	3.94		
Yes, poor-fitting denture	24	5.7	7.13	2.94		
Dental visit within the past year						
No	275	65.3	7.96	3.69	1.622	0.106 ^a
Yes	146	34.7	7.38	2.95		

	N	%	Loneliness (RULS-6)		F or t	p
			Mean	SD		
Oral health status and function						
Number of remaining teeth						
0-19 teeth	140	33.3	7.23	2.80	2.228	0.026 ^a
20 or more teeth	281	66.7	8.02	3.72		
Number of natural occluding tooth pairs (pairs)						
0-3	325	77.2	7.89	3.64	1.404	0.161 ^a
4 or more	96	22.8	7.32	2.73		
Total occluding pairs (pairs)						
0-3	266	63.2	7.85	3.54	0.744	0.458 ^a
4 or more	155	36.8	7.59	3.32		
Avoid group eating						
No	372	88.4	7.60	3.24	2.561	0.011 ^a
Yes	49	11.6	8.94	4.69		
Eating problems						
No	233	55.3	7.42	2.94	2.210	0.028 ^a
Yes	188	44.7	8.17	3.97		

^aIndependent samples t-test, ^bOne-way ANOVA.

Table 2: Frequency of responses to items in 6-Item Revised UCLA Loneliness Scale (RULS-6) in Thai older adults (N=421).

Item	Mean	SD	Never		Hardly ever		Sometimes		Regularly	
			n	%	n	%	n	%	n	%
1. How often do you feel that you lack companionship?	1.33	0.76	347	82.4	18	4.3	47	11.2	9	2.1
2. How often do you feel alone?	1.31	0.76	359	85.3	6	1.4	45	10.7	11	2.6
3. How often do you feel that you are no longer close to anyone?	1.22	0.62	369	87.6	15	3.6	33	7.8	4	1.0
4. How often do you feel left out?	1.19	0.60	379	90.0	7	1.7	31	7.4	4	1.0
5. How often do you feel that no one really knows you well?	1.30	0.72	348	82.7	26	6.2	39	9.3	8	1.9
6. How often do you feel that people are around you but not with you?	1.40	0.79	325	77.2	27	6.4	64	15.2	5	1.2
RULS-6 total score	7.76	3.46								

RULS-6: 6-Item Revised UCLA Loneliness Scale

increased feelings of loneliness, aligning with previous studies.⁽¹⁴⁻¹⁶⁾ Specifically, the psychological discomfort domain, which is characterized by feeling of self-consciousness and tension related to oral health issues, showed the strongest positive correlation with loneliness. Notably, the psychological disability domain exhibited an inverse relationship, indicating that individuals who found it difficult to relax and experienced feelings of embarrassment may feel less lonely. This unexpected finding could reflect social coping mechanisms or cultural factors that warrant further investigation.

Although oral health factors were excluded from the final model in the multivariate analysis, some factors were significantly related to loneliness in the bivariate analy-

sis. However, in this study, participants with 20 or more remaining teeth had significantly higher loneliness scores compared with those who had fewer than 20 teeth. This finding was unexpected and inconsistent with previous studies⁽²²⁾, which reported that fewer remaining teeth were associated with higher levels of social isolation and loneliness. One possible explanation is that older adults with more teeth might have higher expectations of their oral and social functioning, such as eating together with family in Thai culture. When such expectations are unmet, they may perceive greater loneliness. Furthermore, older individuals who experienced eating problems or avoided group meals were more likely to feel lonely. Previous studies have shown that limited social interaction during

Table 3: Mean, SD and frequency of responses to items in the Oral Health Impact Profile 14 (OHIP-14) in Thai older adults (N=421).

Domain/Item	Mean	SD	Never		Hardly ever		Occasionally		Fairly often		Very often	
			n	%	n	%	n	%	n	%	n	%
Functional limitation	1.16	1.87										
Difficulty pronouncing words	0.54	1.03	306	72.7	44	10.5	41	9.7	17	4.0	13	3.1
Decreased sense of taste	0.62	1.08	297	70.5	36	8.6	54	12.8	21	5.0	13	3.1
Physical pain	1.58	1.92										
Painful aching in the mouth	0.65	1.02	278	66.0	46	10.9	76	18.1	10	2.4	11	2.6
Discomfort when eating	0.94	1.24	241	57.2	37	8.8	95	22.6	25	5.9	23	5.5
Psychological discomfort	0.78	1.54										
Self-consciousness	0.48	0.98	322	76.5	36	8.6	36	8.6	16	3.8	11	2.6
Feeling tense	0.31	0.76	349	82.9	30	7.1	30	7.1	9	2.1	3	0.7
Physical disabilities	0.80	1.47										
Unsatisfactory diet	0.46	0.88	316	75.1	37	8.8	52	12.4	12	2.9	4	1.0
Interrupting during meals	0.34	0.77	338	80.3	35	8.3	37	8.8	9	2.1	2	0.5
Psychological disabilities	0.43	1.05										
Difficulty relaxing	0.17	0.53	374	88.8	27	6.4	17	4.0	2	0.5	1	0.2
Feeling of embarrassment	0.27	0.74	363	86.2	20	4.8	27	6.4	6	1.4	5	1.2
Social disabilities	0.30	0.90										
Irritability with others	0.17	0.53	371	88.1	34	8.1	11	2.6	4	1.0	1	0.2
Difficulty performing usual tasks	0.13	0.45	383	91.0	27	6.4	8	1.9	2	0.5	1	0.2
Handicap	0.40	1.07										
Decreased life satisfaction	0.21	0.59	364	86.5	31	7.4	22	5.2	3	0.7	1	0.2
Inability to function effectively	0.19	0.61	372	88.4	27	6.4	15	3.6	4	1.0	3	0.7
OHIP-14 total score	5.46	7.84										

OHIP-14: Oral Health Impact Profile 14

Table 4: Correlation between oral health-related quality of life (OHIP-14) and loneliness (RULS-6) in Thai older adults (N=421).

Domain	r	95% CI
Functional limitation	0.22	0.13, 0.31
Physical pain	0.18	0.08, 0.27
Psychological discomfort	0.31	0.22, 0.39
Physical disabilities	0.20	0.11, 0.29
Psychological disabilities	0.16	0.06, 0.25
Social disabilities	0.20	0.10, 0.29
Handicap	0.25	0.15, 0.33
OHIP-14 total score	0.27	0.18, 0.36

OHIP-14: Oral Health Impact Profile 14, r: Pearson correlation coefficient, CI: confidence interval

meals can contribute to feeling of loneliness and increase the risk of depressive mood.^(23,24)

In terms of OHRQoL, both correlation analysis and bivariate analysis shown that all domains were significantly associated with loneliness, with poorer OHRQoL leading to heightened feelings of loneliness.^(14,15) Oral health and function influence OHRQoL by affecting key aspects such as eating, speaking, smiling, and engaging

in social interactions.⁽²⁵⁾ These findings imply that compromised oral function may contribute to social isolation, potentially due to feelings of embarrassment, difficulties with chewing, or avoidance of social dining situations.

After adjusting for confounding factors in the multivariate model, significant predictors of loneliness included age, living alone, ex-smoking status, self-ability, psychological discomfort, and psychological disability.

Table 5: Relationship between oral health, oral health-related quality of life and loneliness in Thai older adults (N=421).

Variables	Univariate analysis			Multivariate analysis		
	B	95% CI	p	B	95% CI	p
<i>Demographic data</i>						
Age (years)	0.102	0.057, 0.147	<0.001	0.047	0.002, 0.092	0.041
<i>Gender</i>						
Male	0.549	-0.174, 1.273	0.136			
<i>Marital status</i>						
Single	0.490	-0.526, 1.506	0.344	0.425	-0.532, 1.383	0.383
Previously married	0.800	0.066, 1.533	0.033	0.670	-0.041, 1.381	0.065
<i>Living arrangement</i>						
Alone	1.836	0.793, 2.878	0.001	1.539	0.566, 2.512	0.002
Spouse	0.436	-0.459, 1.331	0.339	0.438	-0.415, 1.290	0.313
<i>Highest education level</i>						
Elementary or less	-0.622	-2.895, 1.652	0.591			
Secondary or higher	-1.863	-4.201, 0.475	0.118			
Health conditions and behavior						
<i>Presence of systemic disease</i>						
Yes	0.477	-0.288, 1.241	0.221			
Number of systemic diseases	0.352	0.069, 0.635	0.015	0.158	-0.106, 0.422	0.239
<i>Regularly exercises</i>						
Yes	-1.558	-2.340, -0.776	<0.001	-0.683	-1.420, 0.054	0.069
<i>Smoking</i>						
Ex-smokers	1.251	0.072, 2.430	0.038	1.520	0.448, 2.591	0.006
Current smokers	1.523	-0.065, 3.112	0.060	0.852	-0.602, 2.306	0.250
<i>Self-ability</i>						
Semi- or Dependent	7.741	5.573, 9.909	<0.001	5.863	3.659, 8.067	<0.001
Oral health behaviors						
<i>Brushing</i>						
Yes	-0.164	-1.623, 1.294	0.825			
<i>Use of extra cleaning instruments</i>						
Yes	-0.353	-1.099, 0.392	0.352			
<i>Wearing denture</i>						
Yes, good denture	0.275	-0.553, 1.104	0.514			
Yes, poor-fitting denture	-0.611	-2.052, 0.829	0.405			
<i>Dental visit within the past year</i>						
Yes	-0.573	-1.267, 0.122	0.106			
Oral health status and function						
<i>Number of remaining teeth</i>						
20 or more teeth	0.793	0.093, 1.492	0.026	0.112	-0.545, 0.769	0.738
<i>Number of natural occluding tooth pairs (pairs)</i>						
4 or more	-0.563	-1.352, 0.225	0.161			
<i>Total occluding pairs (pairs)</i>						
4 or more	-0.260	-0.947, 0.427	0.458			
<i>Avoids group eating</i>						
Yes	1.337	0.311, 2.362	0.011	0.102	-0.881, 1.085	0.838
<i>Eating problems</i>						
Yes	0.745	0.082, 1.408	0.028	0.421	-0.257, 1.099	0.223
Oral Health Related-Quality of Life (OHIP-14)						
Functional limitation	0.411	0.238, 0.584	<0.001	0.020	-0.203, 0.244	0.859
Physical pain	0.319	0.149, 0.489	<0.001	-0.023	-0.250, 0.205	0.845
Psychological discomfort	0.694	0.489, 0.900	<0.001	0.668	0.327, 1.008	<0.001
Physical disabilities	0.476	0.254, 0.697	<0.001	-0.197	-0.539, 0.146	0.260
Psychological disabilities	0.518	0.207, 0.830	0.001	-0.544	-1.023, -0.065	0.026
Social disabilities	0.754	0.392, 1.116	<0.001	0.450	-0.037, 0.937	0.070
Handicap	0.788	0.488, 1.088	<0.001	0.232	-0.151, 0.615	0.234

B: Regression coefficient

This study found that loneliness increased with age. However, several previous studies reported that age was not directly linked to loneliness, suggesting that other factors such as income, health, or social self-efficacy may play a stronger role.⁽²⁶⁻²⁸⁾ The discrepancy in findings may be explained by the focus of our study on older adults only, whereas many prior studies examined a broader age range. We consider that in the Thai context, older adults may face greater social withdrawal with increasing age, especially if physical limitations or loss of social roles occur, which could explain the higher loneliness scores in this group. While some studies have shown different trajectories of loneliness across the life course⁽²⁸⁾, our findings highlight that interventions for loneliness in Thailand should particularly address the needs of the oldest age groups.

Moreover, this current study found that older adults living alone experience greater loneliness, which aligns with previous studies.^(17,29) A study in Thailand reported that older adults living alone exhibited higher levels of loneliness, emphasizing the importance of family activities as a key factor.⁽¹⁷⁾ Another Thai study reached similar conclusions, highlighting the crucial role of family caregivers as the primary source of support in preventing social isolation among older adults.⁽²⁹⁾

Additionally, the study found that former smokers tend to experience greater loneliness. Although no study has explicitly confirmed this association, it can be hypothesized that individuals who previously smoked may have already been encountering feelings of loneliness. After quitting, their loneliness may not have diminished, possibly due to increased health awareness or social changes. Research involving older Chinese adults revealed that former smokers had higher odds of reporting depression, while current smokers were more likely to experience a loss of interest, both of which are associated with loneliness.⁽⁹⁾ Furthermore, smoking is often viewed as highly antisocial.⁽³⁰⁾ A longitudinal study indicated that, after a 12-year follow-up, smoking was associated with increasing social isolation and loneliness in older adults.⁽¹⁰⁾ Wootton *et al.*,⁽¹¹⁾ provide tentative evidence of a causal, bidirectional relationship between loneliness and smoking, particularly suggesting that the initiation of smoking may contribute to increased feelings of loneliness.

The results indicated that participants who were semi-dependent or dependent reported higher levels of loneliness. This findings aligns with previous research

and confirms the association between self-ability and loneliness.^(6,7) Furthermore, Shamlou *et al.*,⁽⁷⁾ found a significant negative relationship between self-care ability with loneliness, as well as social isolation. This suggests that older adults experiencing greater loneliness and more severe social isolation tend to have poorer self-care ability. Limitations in self-care and daily functioning may contribute to social withdrawal and increased in feelings of loneliness. These findings highlight the need for interventions aimed at oral health, enhancing social support, and promoting self-care abilities to help reduce loneliness in older adults.

A key strength of this study is its comprehensive assessment of both oral health and loneliness among participants, providing a multidimensional understanding of their interrelationships. Among the limitations, this study is cross-sectional, which restricts the ability to establish causal relationships between OHRQoL and loneliness. Longitudinal studies would be useful to clarify causality and explore potential influencing factors. Additionally, the participants in this study were community-dwelling older Thai adults actively engaged in community activities, which may have contributed to the relatively low levels of reported loneliness.

Conclusions

A lower OHRQoL was associated with heightened feeling of loneliness, particularly due to psychological discomfort. Additionally, psychological disability showed an inverse association with loneliness. Other significant factors contributing to loneliness included living alone, having a history of smoking, and experiencing semi-dependence.

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Conflicts of Interest

The authors declare no conflict of interest.

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Efficacy of Topical Pomegranate Peel Extract on Burning Sensation in Patients with Oral Lichenoid Lesions: A Randomized Controlled Trial

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Abstract

Objectives: Oral lichenoid lesions (OLL) are successfully treated with various treatment modalities, including corticosteroids. Nevertheless, corticosteroids have side effects which could be overcome with the use of natural remedies such as pomegranate (*Punica granatum* L) peel extract without having adverse effects. Thus, the present study aimed to assess the efficiency of topical pomegranate peel extract (TPPE) in treating OLL as compared to a frequently used topical corticosteroid.

Methods: This randomized controlled trial- double blinding study included 50 patients suffering from OLL. They were equally divided into the experimental group (treated with 10% TPPE) and the control group (treated with topical corticosteroids). Two clinical parameters: 1. Sign score for severity and extent of the lesion, and 2. VAS score for burning sensation were assessed after 15 days and 1 month from initial visit.

Results: The significant reduction was observed in VAS score on the 2nd and 3rd Visits as compared to 1st Visit (baseline) in Experimental group patients. However, comparison of mean VAS score among two groups revealed no difference on 2nd and 3rd Visits, depicting non-significant results, suggesting that both drugs are equally effective in reducing the burning of oral mucosa. Regarding the mean sign score of patients in the experimental group, no significant reduction is found on comparison of mean sign score of 2nd and 3rd Visits with the 1st visit results were statistically nonsignificant.

Conclusions: TPPE, a novel intervention, alleviate the symptoms like burning sensation of OLL which is usually the major concern for the patients.

Keywords: burning, corticosteroid, lichenoid lesion, pomegranate, sign score

Introduction

Oral lichenoid lesions (OLL) or reaction represents a group of oral lesions having common clinical and histologic appearance but having different aetiologies that include oral lichen planus, lichenoid drug eruptions, lichenoid contact reactions or lichenoid reactions of graft versus host disease.⁽¹⁾ Immunity plays a role in etiopathogenesis of these conditions. Whether it be drug induced or contact reactions, delayed hypersensitivity may play a vital role which is associated with immunologic response and may result in the formation of white and red lesions in the oral cavity.⁽¹⁾

OLL presents clinically as white keratotic reticular white patches, papules, or plaques due to increase keratinisation of the affected mucosa and in other cases white lesions maybe mixed with erythematous erosive lesion which may cause irritation and burning sensation to the mucosa.⁽²⁾ Burning of oral mucosa that causes oral discomfort, difficulty in eating is a major concern as it affects quality of life of an individual.

A number of therapeutic options such as corticosteroids, immunomodulatory agents, retinoids, UV irradiation, lasers etc are existing, but none are curative.⁽²⁾ Thus, the management is directed at reducing the symptoms, and to provide comfort to the patient. Usually, corticosteroid is considered as first drug of choice. Localized lesions are treated using topical application whereas widespread lesions are managed by intralesional injections or systemic steroids.⁽²⁾ Nonetheless, a number of side effects are known to be associated with the use of corticosteroids.⁽³⁾ Due to possibility of steroids causing adverse effects various plant-based remedies have been researched for the past years where Pomegranate is one such which is of great interest to researchers. Pomegranate (*Punica granatum* L) belongs to family Punicaceae that is identified by its various health benefits such as immunomodulatory activities, antioxidants, anticariogenic, anti-inflammatory and anti-microbial properties.⁽⁴⁾ These properties that pomegranate possessed is believed to be caused by its constituents such as polyphenol which may include ellagic acid, anthocyanins, Gallo tannins and flavonoids constituents.⁽⁵⁾ Pomegranate and its extracts have been proposed to be helpful in the treatment of OLL mainly due to its immunomodulatory effects, but scanty literature is available related to this.⁽⁶⁾ Thus, the present study evaluated the efficiency of topical pomegranate peel

extract (TPPE), a novel intervention in the management of OLL by comparing with one of the commonly used drugs, that is topical corticosteroid.

Materials and Methods

The present randomized controlled trial- double blinding study was carried out after obtaining Institutional Ethical approval (Reference Number- DMIMS (DU)/ IEC/ 2022/ 1160) and Clinical Trial Registration, India (CTRI/2024/10/075071). The study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki (2000). The patients who were ready to participate were included in the study after obtaining their informed written consent. Statistically derived sample size was total 50 patients.⁽¹⁾ The patients were randomly assigned to either the TPPE or corticosteroid group using computer-generated random numbers, with allocation concealed in sealed opaque envelopes. A double-blind design was implemented, where both patients and outcome assessors were unaware of the treatment allocation to minimize bias.

The justification for sample size calculation is as under.⁽¹⁾

The sample size formulae used are as follows:

$$n_1 = \frac{(\sigma_1^2 + \sigma_2^2 / \kappa)(z_{1-\alpha/2} + z_{1-\beta})^2}{\Delta^2}$$

The notation for the formulae is:

n1= Sample size of Group 1

β = sample size of Group 2

σ1= standard deviation of group 1

σ 2 = standard deviation of group 2

Δ = difference in group means

K= ratio = n2/n1.

Z1-α/2 = two- sided Z value (eg. Z = 1.96 for 95% confidence interval).

Z1-β = power

Mean sign score in group C = 2

Mean sign score in group P = 1.64 σ1= SD of sign score in group C = 0.39

σ2 = SD of sign score in group P = 0.50

For detecting mean difference of 0.36 i.e. Δ = 2-1.64 = 0.36

K = 1

$$N = \frac{(0.39 \times 0.39 + 0.50 \times 0.50)(1.96 + 0.84)^2}{0.36 \times 0.36}$$

$$= 24.32 = 25 \text{ patients needed in each group } (25 \times 2 = 50)$$

Power of the Test: 80%

Level of significance: 5% (95% confidence interval)

The patients in the age range of 18-60 years, having clinical presentation of signs and symptoms of OLL were considered for inclusion in the study while the patients who have taken or taking treatment for the lichenoid lesions, patient with associated malignant lesions, the patient with history of pomegranate allergy, the patients suffering from any systemic disorder and taking treatment for the same were excepted.

Regarding the diagnosis of OLL, there is a diagnostic dilemma between oral lichen planus (OLP) and OLL. However, OLL lacks characteristic bilateral presentation.⁽⁷⁻⁹⁾ While OLP lesions commonly present as asymptomatic white striae with a bilateral symmetrical distribution, predominantly on the buccal mucosa. Unilateral presentation of OLP is atypical. It is reported that, clinically and histologically, it is not possible to distinguish between OLP from OLL as they share common clinical and histological features.⁽⁷⁾ Still based on the modified WHO criteria, the unilateral lesions typical of OLP fall under the category of OLL in spite of being histopathologically typical of OLP.⁽⁷⁾ Therefore, the patients with clinical presentation of unilateral, localized keratotic white patch, papules, or plaque with striations or white lesions may be mixed with erythematous erosive lesion with burning sensation in their oral cavity were diagnosed as OLL and irrespective of the cause for the same were recruited for inclusion in the study.⁽⁸⁾

Two clinical parameters were assessed in this study.

1. Sign score: To see the severity and extent of the lesion using criteria given by Thongprasom *et al.*⁽¹⁰⁾ Depending on the clinical presentation and size of the lesion, score varies from 0 to 5.

- 5 = (white striae with an erosive area > 1 cm²)
- 4 = (white striae with an erosive area < 1 cm²)
- 3 = (white striae with an atrophic area > 1 cm²)
- 2 = (white striae with an atrophic area < 1 cm²)
- 1 = (mild white striae only)
- 0 = (no lesions, normal mucosa).

2. Intensity of burning sensation by Visual Analogue Score (VAS). The assessment of these parameters was performed by a single researcher who was blinded to the type of treatment of the particular patient.

Initially the detailed patient history and detailed clinical examination findings were recorded. Then the patients were explained about the use of the particular drug. Experimental group received 10% TPPE gel and Control group have to use 0.1% Triamcinolone acetonide gel in orabase. Patients were told to apply the gel on the lesion 3 times a day and should not eat, drink or rinse for next 15 minutes. The readings of the first visit were recorded as baseline. Recall visits were done after 14 days and 1 month from the first visit (1st Visit being baseline). Improvement in severity, extent of the lesion and burning sensation was assessed in each patient during every visit. All data were tabulated in excel sheet and subjected for statistical evaluation.

Method of preparation of TPPE

Following the standard protocol the gel was prepared under all aseptic conditions by using an extract of Pomegranate peel. Pomegranate peel is finely minced in a blender. It is then placed in an extractor where alcohol is added and heated to 70 degrees for 1 hour. After 1 hour of heating, alcohol is allowed to evaporate and the residue becomes Pomegranate peel extract. Then 1.8-gram quantity of Carbopol 940 (Lubrizol company, analytical grade) at a concentration of 0.8% is poured in 200 mL distilled water which was used as gel base. One gram of already prepared TPPE was added to Carbopol gel base along with 100 mL glycerin for humectant property and mixed with continuous stirring for 30 min. Triethanolamide is also added to it dropwise which is a thickening agent and having preservative property. The final TPPE gel was dispensed in 10 mL dropper bottles on which the manufacturing and expiry dates of the gel were mentioned. Triamcinolone was used as a commercial preparation, triamcinolone acetonide 0.1%, (marketed by Troikaa Pharmaceuticals Ltd.)

Observations and result

The study patients were 50 in number divided in two equal groups. They were in 18 to 42 years age range. The most of the patients (32 out of 50) were in the third decade. The mean age of patients in Experimental group

was 22.12 ± 8.95 and in Control was 26.08 ± 6.65 . Amongst all patients, 22 (44%) were male, 28 (56%) were female. With reference to oral region, the buccal mucosa was the most common site, while the buccal vestibule, lingual mucosa, retromolar region and labial mucosa were also affected by lichenoid lesion in this study. The parameters recorded on 1st visit (baseline), 2nd visit and 3rd visit were as follows:

The mean VAS score of patients in Experimental group on 1st visit was 2.64 ± 1.33 , 1.28 ± 0.99 on 2nd Visit and 0.14 ± 0.36 on 3rd visit where improvement was observed on the 2nd and 3rd visit) with reduction in VAS score with statistically significant value of 0.001 (Table 1). However, comparison of mean VAS score among two groups revealed no much difference between the two groups with *p* value being 0.15, 0.30 and 0.54 for 1st, 2nd and 3rd visits respectively which is non-significant (Table 2 & Graph 1). This observation shows that both

the drugs are equally effective in reducing the burning of oral mucosa.

The mean sign score of patients in Experimental group was 2.57 ± 0.85 , 2.50 ± 0.75 and 2.42 ± 0.75 in 1st, 2nd and 3rd visit respectively (Table 3). Decrease of the extent of the lesion was not very much evident in 2nd or 3rd visit with *p* value of 0.33 and 0.16 respectively which is non-significant. Similarly, the non-significant results were observed in mean Sign Score on comparison between two groups at 1st, 2nd and 3rd visits, the *p* values being 0.13, 0.08 and 0.09 in 1st, 2nd and 3rd visits respectively. (Table 4 and Graph 2)

Nevertheless, Figures 1 and 2 showing satisfactory response to TPPE in one of the OLL patients. Figure 1 showing OLL with sign score 5 and Figure 2 showing reduction to sign score 1 on 3rd visit treated with TPPE.

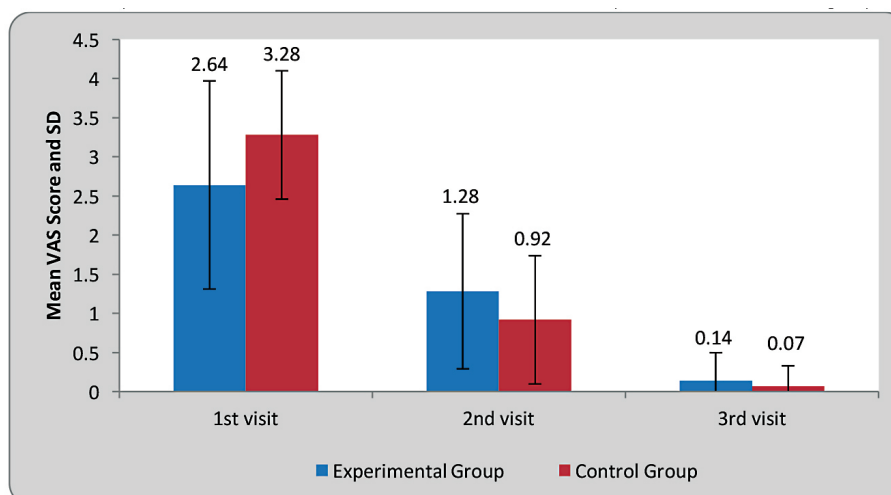
None of the patients reported with the side effect of the drugs Irrespective of the medication used for treating

Table 1: Comparison of mean VAS score at 2nd and 3rd visit compared with 1st visit in experimental group (Wilcoxon Signed Rank Test).

Visit	Mean $\pm$ SD	Mean Difference	z-value	p-value
1 st (Baseline)	2.64 ± 1.33	-	-	-
2 nd	1.28 ± 0.99	1.35 ± 0.92	3.30	0.001, S
3 rd	0.14 ± 0.36	2.50 ± 1.22	3.32	0.001, S

Table 2: Comparison of mean VAS score at 1st, 2nd and 3rd visit in experimental & control Groups (Mann Whitney U Test).

Visit	Visit	Experimental Group	Control Group	z-value	p-value
1 st (Baseline)	1 st visit	2.64 ± 1.33	3.28 ± 0.82	1.42	0.15, NS
2 nd	2 nd visit	1.28 ± 0.99	0.92 ± 0.82	1.01	0.30, NS
3 rd	3 rd visit	0.14 ± 0.36	0.07 ± 0.26	0.60	0.54, NS



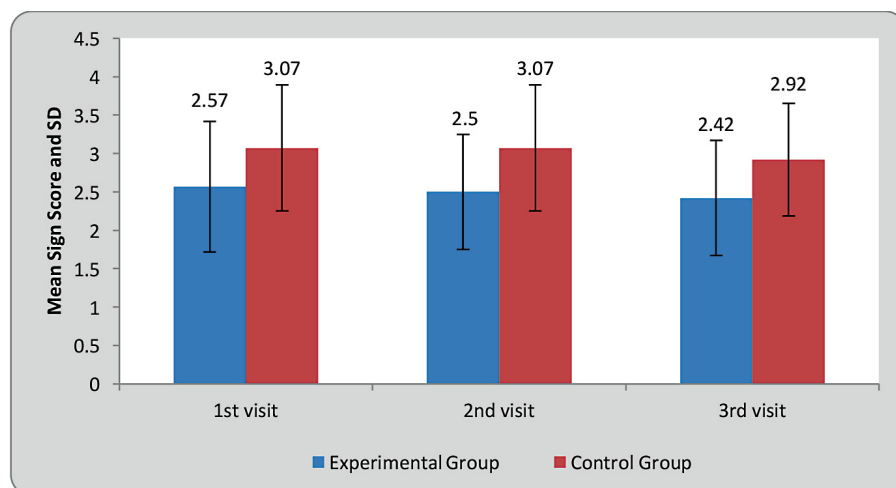
Graph 1: Comparison of mean VAS Score at 1st, 2nd and 3rd visit in experimental and control groups.

Table 3: Comparison of mean sign score at 2nd and 3rd visit with 1st visit in experimental group (Wilcoxon Signed Rank Test).

Visit	Mean±SD	Mean Difference	z-value	p-value
1 st visit	2.57±0.85	-	-	-
2 nd visit	2.50±0.75	0.07±0.26	1.00	0.33, NS
3 rd visit	2.42±0.75	0.14±0.36	1.47	0.16, NS

Table 4: Comparison of mean sign score at 1st, 2nd and 3rd visit in experimental group and control groups (Mann Whitney U Test).

Visit	Experimental Group	Control Group	z-value	p-value
1 st visit	2.57±0.85	3.07±0.82	1.48	0.13, NS
2 nd visit	2.50±0.75	3.07±0.82	1.73	0.08, NS
3 rd visit	2.42±0.75	2.92±0.73	1.68	0.09, NS

**Graph 2:** Comparison of mean sign score at 1st, 2nd and 3rd visit in experimental and control groups.**Figure 1:** OLL presenting as greyish white patch greater than 1 cm² in size with reticular striations and mild erythema (Sign Score 5).**Figure 2:** Mild white striae with marked reduction in sign score of OLL on 3rd visit treated with TPPE (Sign score 1).

the condition, either allopathic or herbal.

Discussion

OLL is an umbrella term which include multiple immune system related disorders.^(9,11) Amongst the therapeutic options, corticosteroid is a drug of choice and depending on the severity of the condition these are used either in topical or systemic forms. However, use of corticosteroid may be associated with side effects. Thus, choosing a treatment with minimal or no side effects is desirable. Natural substitutes in the form of plants constitute many medicinal properties and are side effect free too. In this regard, the utility of TPPE in the management of OLL offers a natural alternative for treatment.

Pomegranate is a commonly consumed fruit which is easily accessible for most families in the country. It plays a vital role in preventing certain diseases like hypertension, hypercholesterolemia, oxidative stress, and inflammatory activities which is mainly due to its components that control the risk factors associated with these diseases.⁽¹²⁾ Pomegranate also possess anticancer effect.⁽¹³⁾

The findings of this study revealed the efficiency of TPPE in treating OLL especially in reducing the burning sensation as significant reduction is found in VAS score in 2nd and 3rd visits as compared to 1st visit. Our findings are matchable with the study by Zakaria *et al.*,⁽¹⁾ as they reported improvement in burning of oral mucosa with the use of topical pomegranate extracts. They have used pomegranate in two forms, seed extracts and peel extracts. Both the preparations they reported to be effective in managing oral lichen planus.⁽¹⁾ Regarding pain reduction, Ghalayani *et al.*,⁽¹⁴⁾ also noticed comparable results in patients with recurrent aphthous stomatitis with the use of 10% pomegranate gel.

The explanation for reduction in burning sensation with the use of TPPE is the role of the key component punicalic acid, which is an efficient anti-inflammatory agent. It reduces pain due to its ability to inhibit secretion of prostaglandin. Pomegranate limits formation of numerous inflammatory mediators and thus control tissue damage. It controls production of interleukin-8 as well as nitric oxide. Moreover, pomegranate plays immunoregulatory role. It can reduce oxidative stress by scavenging free radicals.⁽¹⁵⁾

Similarly, there is strong evidence that PPE is abundant in polyphenols, including punicalagin that has pow-

erful anti-inflammatory activities. It reduces proinflammatory cytokines, modify MAPK signaling, and inhibit COX-2 and iNOS production, all of which provide evidence for their potential as potent anti-inflammatory compounds.⁽¹⁶⁾

With reference to sign score the present study revealed contradictory findings on comparison with previous study as the present study observed no significant difference in sign score on comparison between 2nd and 3rd visit with 1st visit in Experimental Group.⁽¹⁾ Similarly, non-significant observations are noted between present study and the previous study on comparison of Sign Score at 1st, 2nd and 3rd visits in Experimental and Control Groups.⁽¹⁾ The reason for this could be the difference in the doses. In this study, the topical application of the drugs was advised three times per day while in a study by Zakaria *et al.*,⁽¹⁾ it was four times a day. Second possible reason could be weekly recall visits in their study that could assist in improving the patient's compliance.

The presence of significant levels of polyphenols and flavonoids in PPE is responsible for wound healing. Also it is stated that using pomegranate peel strengthens granulation tissues, which aids in wound healing. Therefore, bioactive compounds from pomegranate peel show potential for wound healing by promoting wound contraction, collagen production, and expression of growth factors.^(16,17)

Pomegranate also has the capacity to reduce pathogenic bacteria in oral cavity and also enhance healing of wound by accelerating collagen formation, contraction of wound and tensile strength.⁽¹⁸⁾ A recent study by Potra Cicalău *et al.*,⁽¹⁹⁾ reported useful role of pomegranate in management of gingivitis and periodontitis. Rajan *et al.*,⁽²⁰⁾ mentioned the effectiveness of TPPE for its anti-fungal action. Likewise, the utility of TPPE is reported in candidiasis associated denture stomatitis, gingivitis, periodontitis, caries prevention, plaque control etc.^(14,21-23) Pomegranate have extensive benefits in the management of pre-malignant lesions due to its capability of effecting various signalling pathways which may include inflammation, hyperproliferation, cellular alteration, commencement of tumour formation, formation of new blood vessels and thus suppressing tumor formation and its metastasis.⁽²⁴⁾ They can also be potentially used as an adjuvant in the treatment of oral malignancy due to its anti-angiogenic, anti-proliferative and apoptotic property.⁽²⁴⁾

The observations of the study revealed efficacy of TPPE in relieving the oral burning that reduces oral discomfort. This finding suggests its use on regular basis for improving the symptoms of OLL. Furthermore, PPE is a natural remedy, economical, having negligible adverse effects.

Last but not the least, irrespective of the medication used for treating the condition, might be allopathic or ayurvedic, professional monitoring is required for OLL considering their malignant potential.⁽²⁵⁾ Vital point is deviation from the classic presentation of OLL should be alarmed for thought of biopsy to evaluate for presence of dysplasia or malignancy.

Limitations of the study

The limitations of the study are small sample size, minimal recall visits, follow up for short duration. However, there is a scope to conduct a similar study with larger sample size and the duration would be at least 3 months. Also there is scope to have more valid information about efficacy of the drugs by investigating inflammatory cytokines in saliva

Conclusions

The present study demonstrated that a novel intervention TPPE alone is effective enough to reduce the burning sensation of OLL which is usually the major concern of the patients.

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Conflict of Interest

The authors declare no conflict of interest.

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Customized Ocular Prosthesis with Eyewear-Assisted Iris Positioning: A Case Report

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Abstract

This case report describes a modified technique for iris positioning in a customized ocular prosthesis by utilizing eyewear as a reference guide. A 35-year-old male patient with an anophthalmic socket resulting from trauma presented for rehabilitation with a custom ocular prosthesis. Due to socket irregularities and the patient's expectation for a natural and symmetrical appearance, a modified method incorporating high-quality eyewear was employed to aid in accurate iris alignment. This approach proved to be practical, cost-effective, and user-friendly, significantly reducing the likelihood of asymmetry, minimizing chairside adjustments, and enhancing overall patient satisfaction. The case highlights the importance of individualized and creative techniques in achieving optimal aesthetic outcomes in ocular prosthetics.

Keywords: customized prosthesis, eyewear, iris positioning, ocular prosthesis

Introduction

Partial or complete loss of vision in an individual affects not only visual function but also self-esteem and social interactions.⁽¹⁾ Patients who have undergone enucleation or evisceration frequently seek rehabilitation with an ocular prosthesis. Broadly, ocular prostheses made from acrylic resin fall into three categories: I) Stock (pre-fabricated) prostheses, II) Custom-fitted prostheses fabricated from an impression of the socket, and III) Modified stock prostheses using various techniques.⁽²⁾

Using a custom-made ocular prosthesis enhances a person's psychological well-being, self-confidence, and social acceptance.⁽³⁾ Compared with stock prostheses, custom-made prostheses provide better socket fit, better aesthetic outcomes, and reduced long-term discomfort for the patient.⁽⁴⁾

To achieve symmetry and a life-like appearance, the fabrication of an ocular prosthesis is a technique-sensitive process requiring precise replication of the natural eye's color, size, shape, and orientation. The construction involves multiple clinical and laboratory stages, with particular emphasis on creative and individualized strategies to ensure successful prosthetic outcomes.

Fabrication of ocular prosthesis poses numerous challenges, one of the most critical being the accurate positioning of the iris. An improperly positioned iris can result in an undesirable squinting effect.⁽⁵⁾ The literature describes various techniques for iris placement, including pupillometers⁽⁶⁾, visual assessments, facial landmarks⁽⁷⁾, and grid systems.

Correct iris placement, shade selection, and contouring are key components of aesthetics. Cicatricial retraction is the prosthodontist's biggest obstacle while creating an ocular prosthesis in the anophthalmia sockets.⁽⁸⁾ This occurs because atrophy under these circumstances causes the prosthesis's size to be reduced to achieve a precise contour and give the artificial iris a realistic, symmetrical, and natural-looking appearance.⁽⁸⁾

This case report details the design, positioning of iris-assisted with eyewear, fabrication, and fitting of a custom ocular prosthesis tailored to a patient's individual needs. Through careful clinical and laboratory protocols, the final prosthesis achieved an ideal balance of esthetics, comfort, and patient satisfaction.

Case Report

A 35-year-old male patient visited the Department of Prosthodontics seeking a prosthesis for his right eye. His medical history indicated that the right eye had been enucleated 10 years ago following a traumatic injury. On examination, the anophthalmic socket was found to be fully healed, with preserved activity of the surrounding muscles (Figure 1). The patient had been wearing a stock artificial eye shell for 10 years. Owing to discoloration and ill-fitting of the prosthesis, the patient opted for a new prosthesis. A custom-made ocular prosthesis was planned for the patient.



Figure 1: Pre-treatment photograph.

Impression making

- Before beginning the impression patient was seated in an upright position with a straight head posture. The patient was asked to relax the facial muscles to avoid involuntary blinking or eyelid movement, which could interfere with the uniform distribution of impression material.
- A thin layer of sterile glycerine was applied to the inner lining of the anophthalmic socket and the eyelashes using a sterile cotton swab. To reduce friction between the impression material and delicate mucosal tissues of the socket.
- For the primary impression, an irreversible hydrocolloid (alginate) such as Dentsply Zelgan Advanced was chosen. Alginate provides good surface

detail for preliminary recording.

- The mixed alginate was loaded into a 5 mL disposable syringe (Dispovan). The syringe allows controlled and directed placement of material into the socket, minimizing overflow. The material was dispensed slowly and steadily to prevent air entrapment and excessive pressure on the delicate tissues. Overfilling is avoided, as it can cause distension of eyelids, discomfort, and distorted records.

- After injecting the impression material, the patient was instructed to move the eye in different directions—right, left, upward, downward, and circular movements.

- After the impression material had set, it was removed with care. The lower eyelid was gently pulled down and away from the nasal side to release the vacuum effect. The impression was then disengaged in an arc-like motion beneath the upper eyelid.

- The impression was rinsed with lens cleaning solution and saline. Lens solution contains mild disinfectants that remove debris without damaging impression surface details.

- The cleaned impression was poured immediately using dental die stone (2GM Dental Orange Die Stone).

- A custom impression tray was fabricated on the primary cast using clear cold-cure acrylic resin (DPI RR Cold Cure). The transparency of the tray allows visualization of the material flow and positioning within the socket. It provides an accurate base for making a detailed secondary impression.

- The nozzle end of a disposable syringe was attached to the central opening of the custom tray using cyanoacrylate adhesive. This modification allows precise injection of low-viscosity material into the socket while the tray stabilizes over the surrounding tissues.

- The final impression was made using light-body silicone elastomeric impression material (Prime Dental Ad-Sil Acura). The patient was instructed to look straight ahead during the procedure to ensure a centered gaze position of the prosthesis. (Figure 2)

Pouring an ocular impression into a two-piece die stone model

- The impression was poured into a piece model with die stone. An appropriately sized paper cup or similar container to hold the ocular impression was chosen.

- Die stone was mixed and poured the first layer

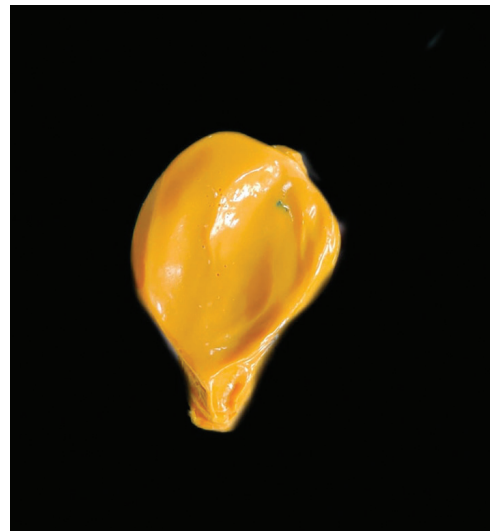


Figure 2: Final impression made with light body elastomeric impression material.

into the container, filling only enough to cover the lower portion of the impression. The ocular impression was positioned in this first pour, so it is stable and correctly oriented.

- Before the first pour sets completely, 3-4 equidistant keying notches were made on the surface using a wax knife.

- These notches helped in reorienting the two pieces during reassembly.

- Once the first pour is fully set, a thin layer of separating medium is applied over the exposed surface to prevent bonding of the two pours.

- The second layer was poured over the first pour, completely covering the impression and filling the container.

- The impression was carefully removed from the die stone and separated into two halves (2GM Dental orange die stone Giriraj Products, Mumbai, India) (Figure 3).

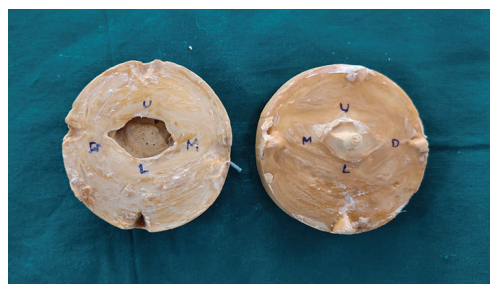


Figure 3: Two-piece stone model poured in the die stone.

Fabrication of the scleral wax pattern

- After the impression was retrieved, modelling wax (MAARC DENTAL, Palghar, Maharashtra, India) was poured.
- The wax conformer's anterior surface was designed to resemble the traits of the contralateral natural eye.
- The try-on of the wax conformer was completed and examined for eyelid support, comfort, size, appearance, and eye movement simulation. The contralateral normal eye's iris and pupil diameters were measured via a Vernier caliper.
- A stock ocular eye shell that was identical to the contralateral native eye in terms of size and color was selected (Figure 4).



Figure 4: Original stock eye shell.

Iris positioning

- Appropriate eyewear that covers the patient's eye from all sides was selected.
- To create a transparent graph grid, a paper graph grid was photocopied onto a transparent sheet.
- Once the sheet has been cut into two equal pieces, modelling wax is used to adhere it to the eyeglasses.

• The patient is requested to maintain the eye posture with a typical conversational gaze while facing forward (Figure 5). The medial, distal, superior, and inferior ends of the iris are traced using an indelible ink marker.

• Using the mirror image of the contralateral eye's grid cutout, an image is drawn on the afflicted side's grid cutout.

• After the stock eye shell's iris color was selected, the iris was meticulously cut and placed onto the wax design, where its location was marked using an eyeglass grid. All eye movements were used to verify and examine the iris position again.



Figure 5: Iris positioning assisted with eyewear.

Flasking and curing

- The type III dental stone (Kalabhai Ultrastone, Karson Pvt Ltd, Mumbai, India) was used for flasking. Before flasking, the hub portion of the needle was cut and attached to the center of the iris with cyanoacrylate. This prevented the movement of the iris within the flask during acrylic packing. The complete wax pattern was invested in a flask, and flasking was carried out according to standard procedures.
- After that, dewaxing was carried out for 20 minutes in a water bath. Following dewaxing, the flask was unsealed and filled with Tooth Coloured Heat Cure Material (DPI, Dental Products of India, Mumbai, Maharashtra,

India).

- As directed by the manufacturer, the powder and liquid were combined. To replicate precise shade matching and vasculature, brown colour heat-cure pigment (Milestone Healthcare, Raipur, Chhattisgarh) was mixed with a minimal amount of clear monomer-polymer mix and was painted in the distal end to mimic the pigmentation.

- Rayon thread fibrils were added around the iris and the mesial end with the monomer-polymer mix. This would mimic the vasculature. Following the manufacturer's instructions, the PMMA was packed into the flask's dewaxed section and cured. Following processing, the prosthesis was removed from the flask for polishing and finishing.

Insertion and post-care

After the ocular prosthesis was placed in the eye socket, its fit, support, appearance, and synchronization with the contralateral eye were evaluated (Figure 6). It was recommended that the patient clean the prosthesis with water and soap once a day and wipe the tissue bed once a day with a piece of moist gauze. The use of 0.5% carboxymethylcellulose sodium was recommended for the patient. It is recommended mainly because it acts as a lubricating and moisturizing agent for the ocular surface. On days one, two, and seven after the prosthesis was inserted, the patient was examined. A six-month follow-up was conducted to assess the prosthesis.

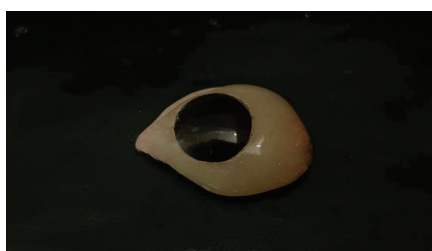


Figure 6: Post-treatment photograph.

Discussion and Conclusions

Because the prosthesis is fabricated using the patient's current anatomy, the custom-made ocular prosthesis fits the socket precisely, providing the advantages of greater adaptability, eyeball movement, and an iris position that precisely matches that of the adjacent natural eye.⁽⁹⁾

The described technique is a simple, practical, and time-efficient method for fabricating a customized ocular prosthesis.

Various techniques have been proposed to determine the size and position of the iris through visual assessment.⁽¹⁰⁾ In 1969, Roberts developed a device called a pupillometer for iris positioning in prosthetic eyes. It uses the pupil as a fixation point and rests on two plastic rotatable discs with scale marks on the nasal bridge.⁽¹¹⁾ For iris centering, McArthur employed the ocular locator. He placed an Ocular locator on the patient's face, overlaying the marks on the patient's face with the horizontal lines and the designated midline to outline the anatomy of the eye.⁽¹²⁾ Guttal *et al.*, precisely positioned the iris using a grid template. In regards to iris location, using a transparent graph grid is a straightforward and trustworthy technique as opposed to ocular evaluation. However, the graph must be held by an assistant using this approach, which is prone to inter-observer error.⁽¹³⁾ Owing to the above-mentioned drawback, this case report highlights the use of eyewear with a graph grid attached to its glass lens.

Meena *et al.*,⁽⁵⁾ described the attachment of a transparent grid to the spectacle frame using cyanoacrylate adhesive; however, once bonded, the grid becomes permanently fixed and cannot be repositioned, and its removal often results in damage to either the eyewear or the grid sheet. In contrast, the use of modeling wax for the attachment of grid allows easy detachment of the grid without causing any damage to the eyewear or grid sheet, making it reusable for multiple patients or repeated trials.

The versatility that eyewear provides throughout the fabrication process is one of its main benefits when it comes to iris location. The ability to wear eyeglasses during the fitting allows for real-time alignment monitoring of the prosthesis and allows for corrections to be made without requiring many visits. Additionally, it allows for a more customized fit because the eyewear may be adjusted to the patient's eye's natural position, taking into account any differences in the structure of their socket.

From a clinical perspective, this method enhances the patient's comfort and confidence. Prostheses that are closely aligned with the patient's natural eye position reduce the psychological burden that often accompanies ocular prosthetics. The use of eyewear as a temporary positioning guide can improve the patient's satisfaction, as they can see the potential final look during the trial phase,

allowing for collaborative decision-making in the fitting process.

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Conflict of Interest

The authors declare no conflict of interest.

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Selective Root Canal Retreatment as an Alternative Option in Patient at Risk of MRONJ: A Case Report

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Abstract

Aims: This case report aims to demonstrate an alternative treatment approach of a failed endodontically treated tooth (ETT) in a patient at risk of medication-related osteonecrosis of the jaw (MRONJ), in which conventional retreatment of all canals had limited access and surgical interventions possessed osteonecrotic risk.

Methods and Results: A 65-year-old female presented with discomfort at the upper right posterior region, where a sinus tract opening was observed adjacent to maxillary right first molar. She had osteoporosis and had been taking oral Alendronate for more than five years, placing her at a higher risk of MRONJ. A preoperative radiograph of maxillary right first molar revealed prefabricated fibre posts in the palatal and distobuccal canals, and an absence of root canal filling material in the mesiobuccal root canal. The diagnosis of maxillary right first molar was previously treated with chronic apical abscess. Selective root canal retreatment was performed as one of the plans following comprehensive, patient-centred consideration. After a 1.5-year follow-up period, the patient remained asymptomatic, and both clinical and radiographic evaluations demonstrated favourable healing.

Conclusions: Selective root canal retreatment may serve as a viable and effective alternative treatment for managing failed ETTs when conventional and surgical approaches pose increased risks. Successful outcomes depend on prudent case selection, prognosis assessment, and thorough informed consent.

Keywords: endodontic retreatment, medication-related osteonecrosis of the jaw, minimal invasive approach, root canal retreatment, selective root canal retreatment, special care dentistry

Introduction

Primary root canal treatment (RCT) generally demonstrates favourable success rates, ranging from 93% after the first decade to 85% at the twentieth year, and 81% at 37 years.⁽¹⁾ The primary RCT may fail due to various factors, including persistent bacterial or fungal infections, untreated/missed canals, inadequate or overextended root canal fillings, suboptimal coronal seals, iatrogenic procedural errors, and other complications during instrumentation.^(2,3) Furthermore, clinical signs and symptoms of infection, increased size of periapical radiolucency, and root resorption are considered indicators of failure.⁽⁴⁾ A period of four years is commonly used as a cut-off point to evaluate the size of a periapical lesion, whether it has persisted or not healed.⁽⁴⁻⁷⁾ Still, asymptomatic periapical lesions may take over ten years to resolve.⁽⁸⁾ To manage failed endodontically treated tooth (ETT), relevant factors include clinical and radiographic findings, causes of failure, accessibility to root canals, anatomical difficulties, quality of root canal obturation, and the need for prosthetic restoration.⁽⁹⁻¹¹⁾ Established management options include follow-up, conventional endodontic retreatment, surgical endodontic retreatment, intentional replantation, root section or hemisection, and extraction.⁽¹¹⁻¹³⁾

Not all teeth with suboptimal quality of root canal filling require intervention. Nonetheless, conventional retreatment is often performed when root canal access is feasible.⁽¹¹⁾ With this approach, it is advised to remove existing restorations and obturating materials entirely.⁽¹⁴⁾ However, this may weaken the tooth structure through excessive dentine removal, iatrogenic errors, and heat generation during post removal, potentially causing surrounding tissue necrosis.^(14,15) On the other hand, surgical retreatment targets only the diseased root(s) through root-end resection and root-end filling, thereby avoiding disturbance of the existing restoration or intraradicular post.⁽¹⁴⁾ Tooth extraction should be reserved only for cases of root fracture or lack of restorability, as tooth loss may contribute to malocclusion and temporomandibular disorders.⁽¹⁶⁾ Moreover, tooth loss is associated with oral impairment, resulting in poor oral health-related quality of life⁽¹⁷⁾, decreased chewing efficiency^(18,19), and a decline in cognitive function.⁽²⁰⁾

The formulation of a tentative plan should incorporate patient-related considerations guided by the shared-decision-making concept⁽²¹⁾, along with the treatment-related

factors, such as advantages and disadvantages, feasibility, and costs of each option. Some options may pose significant risks in certain situations. For example, tooth extraction may raise concerns in patients treated with anti-resorptive and anti-angiogenic medications because of medication-related osteonecrosis of the jaw (MRONJ).⁽²²⁾ Clinically, MRONJ is defined by exposed necrotic bone persisting for more than eight weeks.⁽²³⁾ Many hypotheses of pathophysiology have been proposed, including bone remodelling inhibition, oral inflammation or infection, angiogenesis inhibition, immune dysfunction, and genetic predisposition.^(23,24) The risk of MRONJ following tooth extraction in patients treated for osteoporosis and cancer was 0.15% and 3.2%, respectively.⁽²⁵⁾ It could be as high as 15% in certain situations.⁽²³⁾ Intravenous administration of bisphosphonates carries a higher incidence of MRONJ compared to oral administration, as it has a more potent effect.⁽²⁶⁾ Apart from exodontia, other dental comorbidities, such as periodontal disease, acute dental infections, trauma, bony exostosis, and poor oral hygiene, can also increase the MRONJ risks.⁽²⁷⁾ However, the risks of MRONJ associated with implant surgery, endodontics, or periodontics intervention remain uncertain.^(23,27) Several MRONJ cases have been reported following dental implant surgery in patients taking oral bisphosphonates.⁽²⁸⁾ Thus, a more conservative and less invasive approach should be to minimise the risk of osteonecrosis.^(22,29)

Interestingly, an alternative option for the failed ETT has recently been proposed, known as selective root canal retreatment (sRCT).⁽¹⁴⁾ The procedure targets only the root with a periapical lesion, while leaving other disease-free roots untouched. It is advantageous as it preserves tooth structure with a more conservative access cavity directed to the diseased root, diminishes the risks of iatrogenic errors associated with attempting to remove existing intraradicular posts, and reduces the cost to the patient. In contrast, risks of re-infection or inflammation of the untouched roots could be a drawback.⁽³⁰⁾ An experienced and skilful operator is generally suggested, and it may require additional equipment, such as ultrasonic tips and a dental operating microscope. A previous study demonstrated a favourable outcome of nearly 90% when follow-up was conducted over a period of up to four years. Conversely, only 3.5% of untouched roots showed radiographic signs of failure.⁽³⁰⁾ Therefore, sRCT could be a

promising option in a multi-rooted tooth when only a canal or some canals show signs of unsuccessful RCT.

This case report presents a conservative alternative treatment approach for managing a failed ETT in a patient at high risk of MRONJ, where conventional retreatment of all canals had limited access, and tooth extraction could provoke alveolar complications. Indications and contraindications for sRCT are also proposed.

Case Description

A 65-year-old female, living with osteoporosis, presented with discomfort in the upper right posterior region. Since she had been taking oral Alendronate 70 mg weekly for more than five years, her condition was considered to have a higher risk of MRONJ.⁽²²⁾ At examination, a sinus tract opening was observed at buccal gingiva between the maxillary right first and second molars (Figure 1A). The distopalatal part maxillary right first molar was fractured (Figure 1B), with tenderness to percussion and palpation. The patient reported an RCT completed over four years ago. A preoperative radiograph (Figure 1C) showed that the palatal and distobuccal canals contained prefabricated fibre posts without periapical lesions. In contrast, root canal filling material at the mesiobuccal root canal was absent, with an existing periapical radiolucency. The cause of failure was therefore diagnosed as a missed canal. Evidently, gutta-percha tracing confirmed that the sinus tract originated from the apex of the mesiobuccal root (Figure 1D). Periodontal probing depths were ≤ 3 mm, except for 6 mm mesiopalatally and 4 mm mesiobuccally. These non-deep, non-narrow pockets

helped exclude a potential root fracture. Conclusively, the diagnosis was maxillary right first molar, previously treated with chronic apical abscess.⁽³¹⁾

Treatment options, their associated fees, and potential risks and benefits were discussed comprehensively with the patient. Options provided included tooth extraction with implant placement, conventional RCT, sRCT, and no treatment with regular reviews. The patient was explicitly informed of an increased MRONJ risk associated with invasive dental procedures.⁽²²⁾ Following discussions, sRCT was agreed upon as a tentative treatment, and informed consent was obtained prior to the procedure.

Local anaesthesia was administered using 2% mepivacaine with epinephrine 1:100,000 (Scandonest 2% special, Septodont). Rubber dam isolation was achieved according to endodontic standard.⁽⁴⁾ A conservative yet adequate access cavity was prepared directly to the mesiobuccal root using a round-end tapered diamond bur (Figure 2). Exploration for a second mesiobuccal canal was attempted, but its absence was confirmed.



Figure 2: Conservative endodontic access of maxillary right first molar.

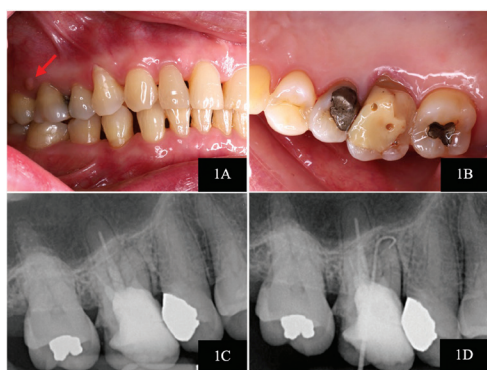


Figure 1: Preoperative assessment. (1A) A red arrow pointing sinus tract opening at the buccal gingiva; (1B) Intraoral photograph showing the fracture of the distopalatal part of maxillary right first molar; (1C) Preoperative periapical radiograph; (1D) Preoperative periapical radiograph with gutta-percha tracing.

Coronal flaring of the mesiobuccal root canal was performed. Working length (15 mm) was determined using an electronic apex locator (root ZX, J Morita Co.) and verified radiographically. Cleaning and shaping were completed using rotary files (Protaper Gold, Dentsply) with a crown-down technique. Intracanal irrigation with 2.5% sodium hypochlorite (NaOCl) and intracanal medication with calcium hydroxide paste (Ultracal XS, Ultradent) were then performed. At the end of the visit, the access cavity was temporarily sealed using Cavit (Cavit, 3M) and intermediate restoration material (IRM, Dentsply) following a double-seal technique.⁽³²⁾

At the three-week review, the patient was asymptomatic, and the sinus tract opening had resolved. A size-35 gutta-percha master cone (Gutta-percha point, Dentsply) was fitted and confirmed radiographically. Irrigation was repeated using 2.5% NaOCl for a minute, 17% Ethylenediamine tetraacetic acid (EDTA) for a minute, and 2.5% NaOCl for 30 seconds.⁽³³⁾ The root canal was dried with paper points and obturated by lateral condensation with an epoxy resin-based root sealer (AH Plus, Dentsply). The access cavity was then restored with resin composite (Filtek Z350XT, 3M), and a postoperative radiograph was taken (Figure 3A). A zirconia crown was subsequently placed for a full-coverage restoration (Figure 3B). Comprehensive dental care, including fluoride treatment, oral hygiene advice, non-surgical periodontal therapy, and restorative procedures, was also provided to complete all dental work for the patient.

At the 1-year follow-up visit, the patient remained asymptomatic. Clinical examination revealed an intact coronal restoration, normal soft tissue, and no tenderness to percussion and palpation. Periodontal probing depths were ≤ 3 mm with healthy gingival tissue. The periapical radiograph showed mild periodontal ligament (PDL) space widening at the mesiobuccal root but no periapical

lesions (Figure 4A). At 1.5 years, the tooth remained symptoms-free, with radiographically normal PDL space and no periapical pathology, indicating complete healing with a periapical index (PAI) score of 1^(34,35) (Figure 4B).

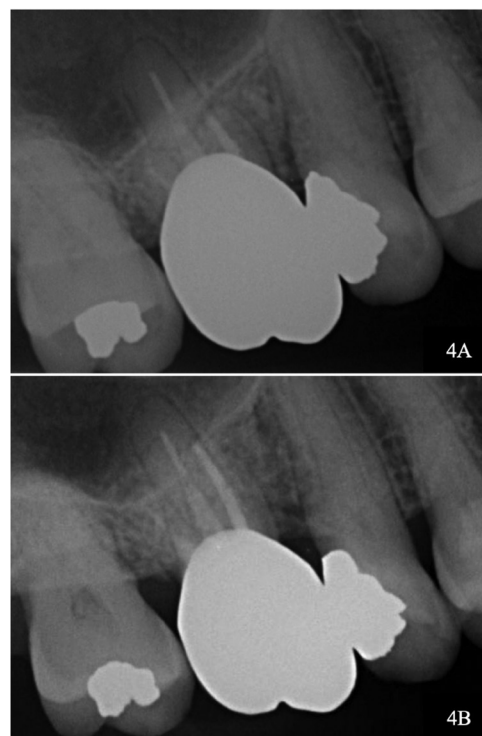


Figure 4: Follow-up periapical radiographs. (4A) At 1-year; (4B) At 1.5-year.

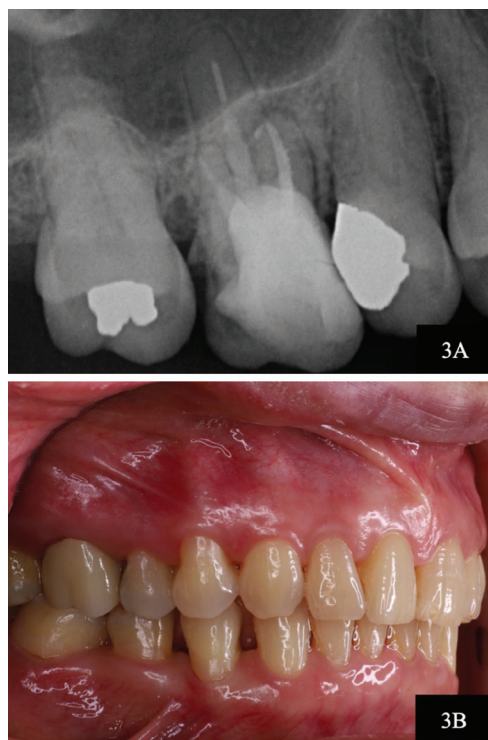


Figure 3: Postoperative outcomes. (3A) Post-obturation periapical radiograph; (3B) Intraoral photograph following coronal restoration.

Discussion

This case report demonstrates a successful outcome of sRCT as a conservative alternative option for a multirooted tooth in a patient at elevated risk of MRONJ. The technique is less invasive and can be performed more rapidly and with greater precision than full retreatment or surgical interventions. Understandingly, while extraction is not absolutely contraindicated, a conservative strategy is preferable in patients at increased MRONJ risk.⁽²²⁾ In instances of pulpal involvement, endodontic therapy is often preferred because it generally does not trigger MRONJ, except when procedural complications occur.⁽²⁹⁾ In this situation, conventional full retreatment was challenging due to prefabricated fibre posts occupying the distobuccal and palatal canals. Given that surgical options such as extraction or apical surgery carry a potential risk of MRONJ in susceptible patients⁽²³⁾, sRCT was chosen to minimise possible complications.

By addressing only the affected root, sRCT helps

preserve structural integrity and fracture resistance of the previously failed ETT. Laboratory and *ex vivo* evidence suggests that limithing access preserves tooth fracture resistance compare with complete conventional retreatment.⁽³⁶⁾ Moreover, sRCT reduces the risk of iatrogenic errors, such as root perforation during post-removal, which can occur if post-removal is required. Attempts to remove intraradicular posts may further compromise the remaining tooth structure and increase the possibilities of perforation and fracture.⁽³⁷⁾ It is reasonable to assume that sRCT requires less clinical time than full conventional retreatment due to the smaller number of canals to manage. According to the Markov simulation model, sRCT was both less costly and more effective than complete retreatment for ETT with persistent apical periodontitis.⁽³⁸⁾ Additionally, the literature suggested that nonsurgical retreatment often yields more favourable long-term outcomes than surgical retreatment.⁽³⁹⁾ In line with this, sRCT - as a form of nonsurgical management - has reported favourable outcomes in 86.7% of cases and a survival rate of 91.5% over follow-up periods ranging from 12 to 48 months.⁽³⁰⁾

In contrast, un-retreated roots remain at risk of developing new periapical lesions. In a retrospective study, only 3.5% of untouched roots developed radiographic signs of emerging periapical lesions.⁽³⁰⁾ In the present case, the remaining canals did not show radiographic periapical changes after 1.5 years. If new disease emerges, it typically becomes apparent within one year following the endodontic intervention.⁽⁴⁰⁾ Currently, sRCT is still not universally accepted and was not included in a recent review of management strategies for secondary endodontic disease, which can complicate preoperative discussions between patients and influence future guideline recommendations.⁽¹³⁾

Cone-beam computed tomography (CBCT) has become an important diagnostic adjunct in endodontics as it provides three-dimensional visualisation of root and periapical anatomy. Studies reported superior sensitivity and specificity of CBCT in detection of periapical

lesions and complex canal morphology, compared with two-dimensional radiography.^(14,41) CBCT is therefore valuable for detecting periapical pathology, evaluating obturation quality, identifying complex canal morphology, and assessing persistent endodontic disease.⁽⁴²⁾ In this case, a conventional radiograph revealed a straightforward anatomy at the mesiobuccal root; together with patient's financial constraints, CBCT was not deemed necessary at baseline. Instead, CBCT was reserved for use only if persistent signs or symptoms warranted further three-dimensional assessment.

The pretreatment periodontal examination revealed pocket depths of 6 mm and 4 mm at the mesiopalatal and mesiobuccal sites, respectively. A root fracture must be ruled out prior to the retreatment since the prognosis would become hopeless if the fracture is present. In our case, these pockets were not narrow and deep, making a root fracture unlikely. sRCT was performed in conjunction with non-surgical periodontal therapy and oral hygiene advice, which may have contributed to pocket resolution at follow-up. We therefore consider root fracture a potential contraindication for sRCT.

Appropriate case selection is critical for sRCT success. Before initiating the treatment, the aetiology of failure and the expected prognosis must be carefully evaluated. In the present case, a missed mesiobuccal canal was the aetiology, which is a common reason recognised in many failed ETTs. Missed canals have been reported as one of the frequent causes of endodontic failure; for example, one study identified missed canals in 42% of over a thousand failed ETTs.⁽⁴³⁾ For conventional retreatment, three important predictors are the quality of the previous root filling, the presence of perforation, and the existence of apical periodontitis.^(44,45) Although the concept of sRCT has been described for about a decade⁽¹⁴⁾, formal selection criteria remain undeveloped. To address this gap, we propose preliminary indications and contraindications for sRCT (Table 1).

Limitations of this report include the single-case design and the relatively short follow-up (1.5 years) for

Table 1: Proposed indications and contraindications for sRCT.

Indications	Contraindications
1. Failed multi-rooted ETT in which at least one root has no periapical lesion	1. Unidentified aetiology of failure
2. The diseased root is able to accessed for conventional retreatment	2. Signs or symptoms of root fracture
3. The non-diseased root and diseased root must be isolated in separate environments	3. Unrestorable tooth

establishing long-term prognosis. Although the clinical and radiographic outcome at 1.5 years is favourable, longer-term follow-up in larger cohorts is strongly suggested to confirm the durability of sRCT outcomes. Future research should include prospective trials and longer observational studies comparing sRCT with other modalities, or explore novel procedural techniques or materials for sRCT.

Conclusions

Selective root canal retreatment represents a viable option for managing failed endodontic cases in which surgical intervention carries higher risks or complete conventional retreatment is impractical. This approach should be considered when full access to all canals is limited or when surgical procedures may predispose the patient to complications, such as MRONJ. Successful outcomes rely on careful case selection, accurate identification of the failure cause, comprehensive informed consent, and consistent postoperative monitoring.

Conflict of Interest

The authors declare no conflict of interest.

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Oral Leiomyomatous Hamartoma of the Midline Maxillary Gingiva: A Case Report and Review of the Literature

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Abstract

Oral leiomyomatous hamartoma (OLH) is a rare lesion characterized by abnormal growth, with smooth muscle tissue as the predominant component. It mainly presents on the midline region of both the dorsal tongue and the maxillary alveolar ridge. This article reported a case of OLH in a 7-year-old Thai girl. The lesion presented as a pedunculated, normal-colored, soft tissue nodule located on the palatal gingiva at the midline between the maxillary deciduous central incisors. Panoramic radiograph showed no bony changes associated with the lesion. The clinical differential diagnoses included irritation fibroma, congenital epulis and non-angiomatic hamartoma. Complete excision was performed under local anesthesia. Microscopically, it revealed soft tissue mass surfaced by parakeratinized stratified squamous epithelium with mild acanthosis. Proliferative smooth-muscle fascicles were dispersed in the loose fibrous connective tissue stroma. The diagnosis of OLH was supported by positive immunohistochemical reactivity of smooth-muscle actin and desmin with no reactivity for S-100 protein. Postoperative wound healing was uneventful, and no recurrence was found during the 10 months follow-up period.

The focus on OLH in the anterior maxilla, epidemiological data, pathogenesis, clinical and histopathological features, and differential diagnosis are discussed herein.

Keywords: anterior maxilla, differential diagnosis, midline, midline maxillary gingiva, oral leiomyomatous hamartoma

Introduction

Hamartoma derives from the Greek word “hamartanein” which means “to fail”. Hamartoma is a benign tumor-like malformation manifested as a mass of an abnormal mixture of tissues indigenous to the site involved.⁽¹⁾ By definition, there is usually a relative overgrowth of one element of the tissue, but without the tendency towards progressive growth found in benign neoplasm.⁽²⁾ A hamartoma is histopathologically classified by its main composite elements. In oral regions, lymphangiomas and hemangiomas are hamartomas of a vascular origin, which are commonly found.⁽²⁾ However, oral hamartoma of other tissues is rare.⁽³⁾ Oral leiomyomatous hamartoma (OLH) corresponds to a disorganized, abnormal mass with a predominance of smooth muscle tissue first reported by Stamm and Tauber in 1945.⁽⁴⁾ It typically presents early in life as a soft tissue nodule on the anterior maxillary alveolar tissues or the tongue. Due to its nonspecific symptoms, diagnosis remains a challenge.⁽⁵⁾ Thus far, only 28 cases of OLH of the anterior maxilla region have been reported in the English-language literature.

This case report described a case of OLH occurring in a healthy 7-year-old Thai girl treated successfully by excision under local anesthesia. Clinical, histological and immunohistochemical features are presented, along with a review of the literature.

Case Report

A healthy 7-year-old Thai girl was referred to the Oral Surgery Clinic, Dental Division, Phramongkutklao Hospital for evaluation of a painless nodular soft tissue mass on the palatal gingiva at the midline between maxillary deciduous central incisors. The patient complained of a slow-growing mass that had been present for three years, with the lower anterior teeth occluding on it. The right maxillary deciduous central incisor had exfoliated the previous week. Her medical history was non-contributory, and no family history of any importance pertaining to the lesion was reported.

Intraoral examination revealed a pedunculated soft tissue mass measuring 15 mm x 12 mm x 5 mm, with a smooth, normal-colored, and intact mucosal surface (Figure 1). The lesion was firm in consistency. Panoramic radiograph revealed no calcifications within the soft tissue nodule and no bony changes associated with the lesion

(Figure 2). Based on the clinical presentation, a provisional diagnoses of irritation fibroma, congenital epulis and non-angiomatous hamartomas were made.

An excisional biopsy was performed under local anesthesia. Microscopically, the specimen was a mucosal mass of fibrovascular fibrous tissue intermixed with numerous randomly oriented fascicles of smooth muscle cells (Figure 3). The lesional tissue was unencapsulated and covered by intact parakeratinized stratified squamous epithelium with mild acanthosis. Immunohistochemical staining revealed that the spindle cells were positive for smooth muscle actin (SMA) and desmin, but negative for S-100 protein, confirming their muscular differentiation (Figure 4). Based on the clinical histopathological findings, a final diagnosis of OLH was established. The post-operative wound healing was uneventful. No recurrence was found during the 10-month follow-up period.

Discussion

Leiomyomatous hamartoma is defined as a hamartoma composed primarily of smooth muscles. Leiomyomatous hamartomas are commonly found in the lungs, liver, spleen, or kidneys but are rarely found in the oral

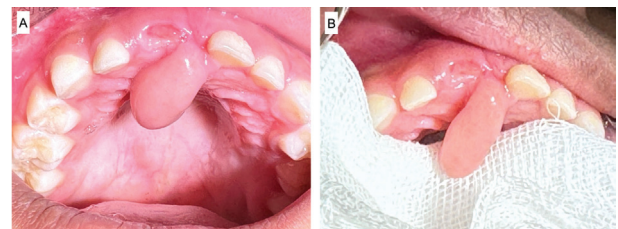


Figure 1: (A and B): Clinical presentation of the lesion showing a pedunculated, soft tissue mass covered by smooth, normal-colored mucosa located at the midline of the maxillary alveolar ridge. Note the recent exfoliation of the right maxillary deciduous central incisor.

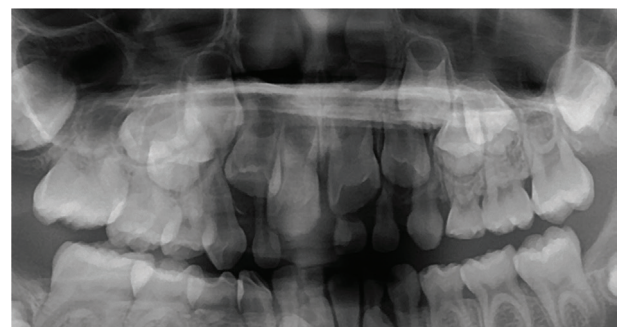


Figure 2: Cropped panoramic radiograph revealing no bony changes associated with the lesion.

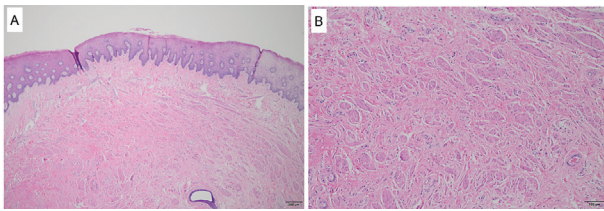


Figure 3: Histopathological features of oral leiomyomatous hamartoma. (A) The lesion composed of a subepithelial non-encapsulated proliferation of eosinophilic smooth muscle tissues fascicles intermixed with small blood vessels (H&E, 40x magnification); (B) Proliferation of delicate smooth muscle fascicles arranged in an irregular pattern with occasional blood vessels (H&E, 100x magnification).

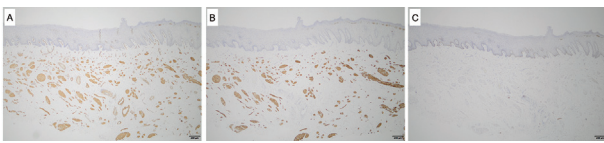


Figure 4: Immunohistochemical features of oral leiomyomatous hamartoma. (A, B) Smooth muscle bundles showed strong positivity for smooth muscle actin (SMA) and desmin, respectively (40x magnification); (C) The lesion exhibited negative immunoreactivity for S-100 protein (40x magnification)

cavity.⁽⁶⁾ Systematic review of Alarcón-Sánchez *et al.*,⁽⁷⁾ reported 66 OLH cases, with a mean age at presentation of 6 years and no sex predilection. Most lesions presented normal-colored color (24.24%), pedunculated base (31.81%), and firm consistency (22.72%), with an average size of 1.20 cm. The most commonly found location was the tongue (49.98%), followed by the anterior maxillary alveolar ridge (37.87%).

OLHs are frequently located in the midline region of both the dorsal tongue and the maxillary alveolar ridge. In the anterior maxilla region, especially at the midline, their occurrence could result from embryogenic errors during the fusion of processes and prominences in the developing embryo. The primary palate and palatine crests meet to form the nasopalatine foramen where nerves and blood vessels emerge. These developmental processes are complex and susceptible to errors. Dysgenic events of smooth muscle cell differentiation around the arteries could lead to the formation of leiomyomatous hamartoma.⁽⁸⁾

Thus far, only 28 OLH cases of the anterior maxilla region have been reported in the English-language literature. The clinical features of OLH at the anterior maxilla from the previous case reports and case series, including the present case are summarized and illustrated

in Table 1.^(2,3,6,8-29) The mean age of patients in this current review is 44.79 months (3.74 years), ranging from 1 month to 20 years, with female predominance (60.71%). Most patients are Japanese. The majority of lesions present with normal-colored (68.41%), smooth surface (100.00%), pedunculated base (76.47%) and firm consistency (100.00%). The average size is 8.97 mm, ranging from 3 mm to 2.5 cm. A unilobed nodular mass is observed in 93.10% of cases. Most OLH (93.10%) manifest as a single lesion; however, two Japanese patients presented with multiple OLHs with no associated syndrome. One was a 2 years 7-month-old boy who had three lesions at the incisive papilla and two isolated lesions on the dorsal tongue.⁽⁶⁾ The other was a 3-year-old boy with two lesions on the tongue and the midline of the upper gingiva.⁽¹²⁾ No OLH cases have been associated with any syndromes and they occurred in otherwise healthy individuals.⁽⁶⁾ Nevertheless, Falci *et al.*,⁽²²⁾ showed an incipient lip cleft corresponding to an OLH in the anterior maxilla. Although hamartomas are congenital lesions, they may only be detected at later developmental stages. Their growth is slow and self-limited. In addition, these lesions are asymptomatic and may develop over several years.^(7,8)

This present case is the first case report of OLH found in a Thai patient. This soft tissue mass at midline maxillary gingiva has occurred since she was 4 years old. The lesion's size is slowly increasing until she came for a treatment 3 years later. The maxilla generally completes its growth by the age of 14 years in female.⁽³⁰⁾ Therefore, this present lesion may be associated with proliferation of smooth muscle cells' remnants from this region during the incomplete maxilla growth period. In addition, this mass was 15 mm in maximum dimension which is relatively larger than overall OLH (12 mm in average) and OLH case of anterior maxilla region (8.97 mm in average). This may be associated with a history of slow and prolonged lesion growth.

According to the clinical characteristics of the present case, including its appearance, anterior location, absence of pain, long duration and slow growth, the clinical differential diagnoses include benign lesions such as irritation fibroma, congenital epulis, and non-angiomatous hamartoma. First, irritation fibroma (traumatic fibroma or focal fibrous hyperplasia) is commonly detected among pediatric reactive lesions and associated

with fibrous tumor-like growths caused by trauma or local irritation.⁽³¹⁾ Lesions in the anterior region may have the same clinical appearance and can be triggered by chronic irritation such as digit sucking or bottle feeding.⁽⁶⁾ However, the patient reported no history of exposure to irritant factors. Second, congenital epulis, also called granular cells congenital epulis, is a benign lesion frequently found on the anterior alveolar ridge of the maxilla and is among the most common congenital oral lesions.^(18,31) Histologically, the lesion is characterized by sheets or nests of polygonal cells with eosinophilic granular cytoplasm.⁽³²⁾ Lastly, oral hamartomas are more frequently detected in children and young adults. Typically, non-angiomatic hamartomas show normal-colored, slow-growing soft tissue masses without bleeding and or pulsatile.⁽³³⁾ Therefore, non-angiomatic hamartoma must be considered in the differential diagnosis.

Microscopically, OLH is characterized by a soft tissue mass containing a diffuse proliferation of fascicles and bundles of eosinophilic spindle cells of varying size, oriented in longitudinal and/or transverse patterns. These fascicles are composed of spindle cells compatible with mature smooth muscle cells, exhibiting indistinct borders, elongated blunt-ended (cigar-shaped) nuclei. The presence of a fibrous capsule is unclear.^(1-3,5-8,14-29) In addition, some authors described a non-inflammatory Grenz zone.⁽³⁾ These fascicles are irregularly scattered and mixed up with various sizes other tissue elements, such as lymphatic vessels, blood vessels, and nerve fibers. The presence and distribution of multiple tissues types are characteristics of hamartomatous lesions. In contrast, in OLH, the predominant element is the smooth muscle tissue.⁽⁷⁾ Occasionally, adipose tissues and minor salivary glands may be seen in the OLH.⁽⁶⁾

Although histopathological entities consisting of fusiform cells vary widely,⁽³⁴⁾ OLH should be differentiated histopathologically from oral spindle cell neoplasms including solid leiomyoma, benign mesenchymoma, irritation fibroma and other benign neural tumors. First, solid leiomyoma is primarily diagnosed in middle-aged adults although it can be found at any age.^(14,35) Histologically, it is well-circumscribed with or without capsulation and comprised intertwining bundles of spindle-shaped or smooth-muscle cells with elongated, blunt-ended, and pale-staining nuclei.⁽³⁶⁾ In some areas, the neoplastic smooth muscle tissue may be poorly demarcated and

embedded in scarce fibrous tissue.^(6,35) If diagnostic uncertainty remains, additional serial sections may be helpful. Second, benign mesenchymoma is an unencapsulated soft tissue tumor consisting of fibrous tissue stroma and the at least two or more benign mesenchymal components not typically associated with each other.⁽³⁷⁾ Notably no single mesenchymal tissue should predominate in benign mesenchymoma.⁽³⁷⁾ On the other hand, OLH is characterized by the predominance of smooth muscle tissue and lacks infiltration or invasion to surrounding tissue. Third, irritation fibromas infrequently contain dense collagenous tissues with occasional spindle cells which may mimic smooth muscle tissue.⁽²⁴⁾ Last, various types of benign neural tumors demonstrate spindle cells with wavy nuclei, which may be similar to smooth muscle cells.⁽³⁸⁾ The pattern of spindle-cell proliferation and immunohistochemical staining can be useful for accurate diagnosis. Summary of histopathologic differential diagnosis of OLH and immunohistochemical staining is presented in Table 2.^(1-8,14-29,34-38)

Immunohistochemical staining is highly beneficial for confirming a diagnosis of OLH. SMA, desmin, muscle-specific actin, caldesmon, CD34, collagen IV and calponin are among common markers showing positive reactivity for smooth muscle spindle cells.^(1,7,14,16-29) In contrast, markers such as Neuron-specific enolase, laminin, melanosome, S-100 protein and CD31 are typically negative for this cell type.^(3,7,16) Notably, Zaitoun and Triantfyllou⁽³⁾ discovered positive expression of Collagen IV in the basement membrane of smooth-muscle cells and CD34+ in the interstitial cells surrounding smooth-muscle bundles. The existence of these cells could be an intrinsic component of OLH or merely represent tissue remnants from the incisive papilla region.^(3,8) These findings support the theory of underlying dysgenic events affecting blood vessel formation in the anterior midline region of the maxilla, leading to the development of OLH.⁽²¹⁾ In the present case, the lesional cells exhibit strong positivity for SMA and desmin, confirming their smooth-muscle origin and supporting the diagnosis of OLH. According to the majority of published reports, SMA and desmin are the reliable markers for confirming the smooth muscle cells of the OLH.⁽⁹⁻²⁹⁾

The recommended treatment modality for OLH is surgical excision which has an excellent prognosis. Across reported cases with follow-up period ranging from

Table 1: Summary of clinical features of oral leiomyomatous hamartoma at the anterior maxilla.^(2,3,6,8-29)

Parameter	Number of cases (n=29)	%
Sex		
Male	11	39.29
Female	17	60.71
Not reported	1	
Age (month)		
Mean ± SD	44.79±10.51	
Range	1 to 240	
Country		
Japan	10	34.48
USA	6	20.70
India	3	10.34
Brazil	3	10.34
United Kingdom	2	6.90
Others (Malaysia, Mexico, Saudi Arabia, Peru, Thai)	5	17.24
Size (mm)		
Mean±SD	8.97±2.13	
Range	3 to 25	
Color		
Normal-colored	13	68.41
Pink	4	21.06
Red	2	10.53
Not reported	10	
Surface		
Smooth	18	100.00
Not reported	11	
Base		
Pedunculated	13	76.47
Sessile	4	23.53
Not reported	12	
Consistency		
Firm	15	100.00
Not reported	14	
Uni/bi/multi-lobed nodule		
Unilobed nodule	27	93.10
Bilobed nodule	1	3.45
Multilobulated nodule	1	3.45
Single/multiple lesion(s)		
Single	27	93.10
Multiple	2	6.90

Table 2: Summary of histopathologic differential diagnosis of oral leiomyomatous hamartoma and immunohistochemical staining.^(1-8,14-29,34-38)

	Well-circumscribed lesion	Fibrous capsule	Lesional cells and pattern	Infiltrative border	Positive markers
Leiomyomatous hamartoma	No	Unclear/no	Predominant element of mature smooth muscle cells with varying size and irregularly arranged fascicles	No	SMA, desmin, muscle-specific actin, caldesmon, calponin, smooth muscle myosin heavy chain
Solid leiomyoma	Yes	Yes/No	Dense intertwining bundles or whorled pattern of cellular smooth muscle cells	No	SMA, desmin, muscle-specific actin, caldesmon, calponin, smooth muscle myosin heavy chain
Benign mesenchymoma	No	No	Fibrous connective tissue interspersed with at least two other mature mesenchymal tissues with no single dominant element	Yes	Depending on type of mesenchyme
Irritation fibroma	Yes/No	No	Dense fibrous connective tissues with collagen bundles and some blood vessels	No	Not applicable
Traumatic neuroma	Yes/No	No	Haphazard proliferation of nerve bundles within fibrous connective tissue stroma	No	S-100 protein, neurofilament
Solitary circumscribed neuroma	Yes	Yes/No	Moderately cellular interlacing fascicles of spindle neural tissues	No	S-100 protein, neurofilament
Neurofibroma	Yes	No	Interlacing bundles of neural tissues mixed with delicate collagen bundles and scattered mast cells	No	S-100 protein, CD34
Neurilemoma (Schwannoma)	Yes	Yes	Biphasic spindle cell tumor composing of Antoni A tissue (compact hypercellular areas with nuclear palisading) and Antoni B tissue (less cellular and less organized areas)	No	S-100 protein, CD56, calretinin, neurofilament

6 months to 5 years, no recurrence or malignant transformation have been reported.^(7,8)

Conclusion

OLH is an uncommon and diagnostically challenging lesion. However, when a soft tissue mass is in the anterior midline of the maxilla in children, OLH should be considered among the differential diagnoses. Its histopathological features are relatively distinctive, typically consisting of small fascicles of fusiform or spindle shaped cells, irregularly distributed in the subepithelial connective tissue. The lesion is characteristically unencapsulated. A definitive diagnosis of OLH requires histopathological

evaluation supported by immunohistochemical staining such as SMA, desmin.

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None

Conflict of Interest

The authors declared that they have no conflict of interest.

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Unmasking a Diagnostic Dilemma: A Rare Cartilaginous Tumor in the Maxilla

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Abstract

Tumors characterized by the production of chondroid matrix, at least focally, are grouped under cartilaginous tumors. It ranges from benign lesions to highly aggressive neoplasms. Benign cartilaginous tumors are usually asymptomatic, with overlapping histopathological features that pose diagnostic challenges for pathologists. A male patient in his late twenties presented with a painless swelling in the right palatal region for three months. The patient had a history of nasal congestion and breathing difficulties. On examination, a unilateral lesion of size 6x4x2.5 cm extended antero-posteriorly from the canine to the maxillary tuberosity and mediolaterally from the right alveolus to the mid-palatine raphe. The surface was lobulated without any ulceration and no evidence of tooth mobility. The orthopantomogram (OPG) revealed an unilocular, well-defined lesion with a sclerotic border. Computed tomography (CT) showed a lytic lesion with destruction of the maxillary sinus walls. The key differentiating feature in histopathology is the lobular arrangement of hyaline cartilage supported by a myxoid background with matrix calcification, without any evidence of tissue dysplasia. Immunohistochemistry findings were consistent with the diagnosis of Chondromyxoid Fibroma (CMF), effectively differentiating it from malignant counterparts such as chondrosarcoma. The subtotal maxillectomy (Transoral approach) was performed under general anesthesia. The current case discussed a benign cartilaginous tumor mimicking malignancy, which has an incidence of less than 1% of all bone tumors, highlighting the diagnostic complexity and importance of histopathological confirmation.

Keywords: benign cartilaginous tumor, chondroid matrix, chondromyxoid fibroma (CMF)

Introduction

Cartilaginous tumors share a common characteristic feature of the production of chondroid matrix at least at a focus, and these range from benign to highly lethal neoplasms.⁽¹⁾ It is categorized based on its neoplastic or non-neoplastic nature, composition (purely cartilaginous or not), and site of occurrence (intraosseous, juxtacortical, or soft tissue). The WHO in 2022 classified cartilaginous tumors into benign (enchondroma, osteochondroma, chondroblastoma, chondromyxoid fibroma, and synovial chondromatosis) and malignant lesions (chondrosarcoma and the chondroid variant of chordoma).^(2,3) Benign cartilaginous tumors are usually asymptomatic, slow growing, locally invasive, and the histopathological features of these lesions mimic each other. It is difficult to excise the complete lesion, and en-bloc resection is usually recommended to overcome recurrence. Malignant transformation of benign cartilaginous lesions like enchondroma and osteochondroma never develops, and only 1-5% deteriorates to chondrosarcoma. These lesions in the head and neck are rare, posing significant diagnostic challenges due to their morphological heterogeneity because of the mesenchymal cell multipotency during differentiation.⁽⁴⁾ Hereby, we present a rare case of Chondromyxoid Fibroma (CMF) in the maxilla of a young adult male to highlight the diagnostic complexity and importance of histopathological confirmation.

Case Report

A male patient in his late twenties presented with a swelling in the upper jaw present for three months. The swelling was insidious in onset, gradually increasing in size. The patient reported nasal congestion, sinusitis, and difficulty breathing. Extraordinarily, mild facial asymmetry was observed in the right maxillary region, with obliteration of the naso-jugal groove. Intraorally, a unilateral lesion measuring 6x4x2.5 cm was noted on the right palatal shelf, extending antero-posteriorly from the canine to the maxillary tuberosity and mediolaterally from the right alveolus to the mid-palatine raphe. The surface was lobulated, with no evidence of surface ulceration or tooth mobility (Figure 1). Gingival recession with root exposure was noted in the right lateral incisor and canine, without occlusal discrepancy. The lesion was firm to hard on palpation and mildly tender over the right molar area. Based on clinical features, a provisional diagnosis of

ossifying fibroma was made, with differential diagnoses including minor salivary gland neoplasm, odontogenic tumor, fibrous dysplasia, osteosarcoma, and chondrosarcoma.

The orthopantomogram (OPG) revealed a unilocular, well-defined lytic lesion (radiolucent with mild opacity), with a sclerotic border in the right maxilla extending from mesial aspect right maxillary first premolar to distal aspect of right maxillary third molar. The upper limit extended to the superior wall of the maxillary sinus. There is no evidence of cortication of bone. The root apices of first and second maxillary molars and interdental bone appeared to be resorbed (Figure 2A). The 3D reconstructed image of computed tomographic (CT) image reveals loss of trabecular pattern of alveolar bone extending from the facial aspect of right maxillary first premolar till the maxillary tuberosity. The soft tissue window contrast enhanced axial section showed focal destructive mass extending from the infra-zygomatic surface to the posterior maxilla, with nasal septum deviation and matrix calcification (Figure 2B). Radiological differential diagnoses included fibrous dysplasia, non-ossifying fibroma, and benign cartilaginous tumor.

Incisional biopsy showed a greyish-white soft tissue measuring 0.8x0.9 cm, firm to hard in consistency. Gritty consistency was noted during grossing. The cut surface showed whitish-coloured lobules with hemorrhagic areas. The histopathology revealed lobular arrangements of hyaline cartilage supported by a myxoid background. Cells were situated in lacunae, arranged singly or in clusters, with occasional multinucleation. Peripheral fibrous condensation and Basophilic stippled calcifications were noted, with no evidence of mitotic activity or necrosis (Figure 3). Based on the clinical, radiographical and histopathological features, the lesion was consistent with chondromyxoid fibroma. Immunohistochemical analysis was performed to confirm the diagnosis and rule out malignant differentials. The tumor cells showed strong cytoplasmic positivity for S-100 and SOX9, indicating chondrogenic differentiation, while diffuse vimentin positivity confirmed their mesenchymal origin. The Ki-67 proliferative index was low (<5%), supporting a benign nature, and CD34 and Bcl-2 negativity ruled out vascular or aggressive neoplasms. Additionally, p53 expression was absent, further supporting the benign histopathological profile of the lesion. These findings were consistent with

Chondromyxoid Fibroma (CMF), effectively differentiating it from potential malignant counterparts such as chondrosarcoma. The choice of treatment was under general anesthesia to avoid recurrence. The excisional specimen was consistent with the histopathological findings of the incised specimen (Figure 4). Post-operatively, there was no evidence of recurrences for the past 1 year, but the patient had issues of difficulty with mastication and aesthetic concerns that were corrected by prosthetic replacement. (Figure 5)



Figure 1: Intra-oral swelling extending mediolaterally from the right alveolus to the mid-palatine raphe.



Figure 2A: A well-defined, unilocular lytic (radiolucent with mild internal opacity) lesion with a sclerotic border is noted in the right maxilla. The lesion extends from the mesial aspect of the right maxillary first premolar to the maxillary tuberosity. Superiorly, it reaches the superior wall of the maxillary sinus. The root apices of the first and second maxillary molars, as well as the surrounding interdental bone, appear affected

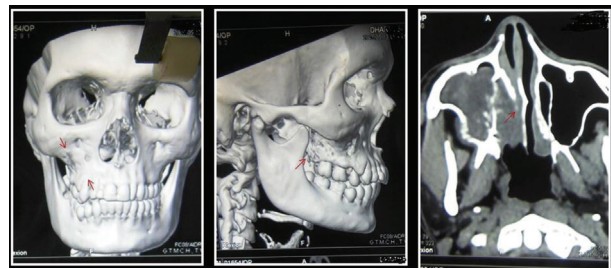


Figure 2B: 3D reconstructed CT images reveal loss of the normal trabecular pattern in the alveolar bone from the facial aspect of the right maxillary first premolar to the right maxillary third molar, suggesting involvement of a pathological lesion in this region (left). A focally destructive mass is observed extending from the infrazygomatic surface toward the posterior surface of the maxilla (middle). A diffuse lesion is also noted within the left maxillary sinus with deviation of the nasal septum (right).

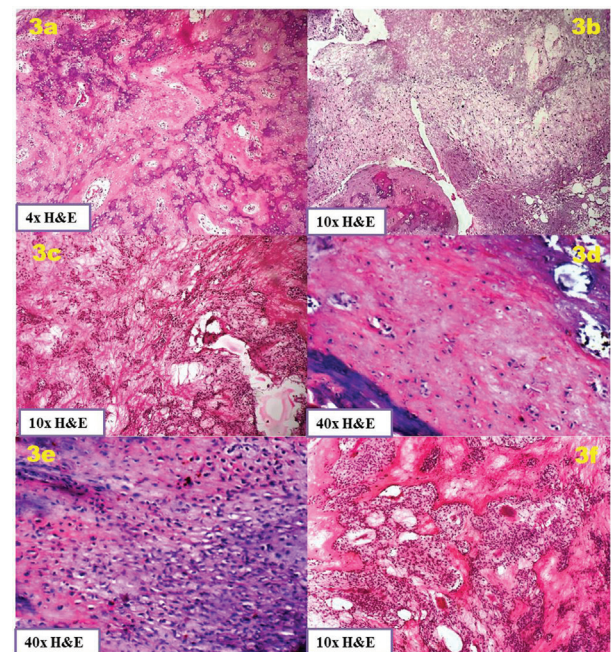


Figure 3: (3a) Photomicrograph revealed lobular pattern of arrangement of hyaline cartilage supported by a fibroid and myxoid background; (3b) predominant myxomatous areas with stellate shaped cells; (3c) exhibits fibroblastic proliferation with round to oval shaped cells. [10x objective, 10x eyepiece & H&E]; (3d) central lobular areas exhibit cartilaginous matrix with round to oval nuclei along with basophilic stippled calcifications; (3e) showing predominant areas of chondroid differentiation with well-formed lacunar spaces and chondrocytes residing in lacunae was evident [40x objective, 10x eyepiece & H&E]; (3f) revealed confluent nodular architecture with intervening collagen fibers and evident of osteoclast-like giant cells [10x objective, 10x eyepiece & H&E].

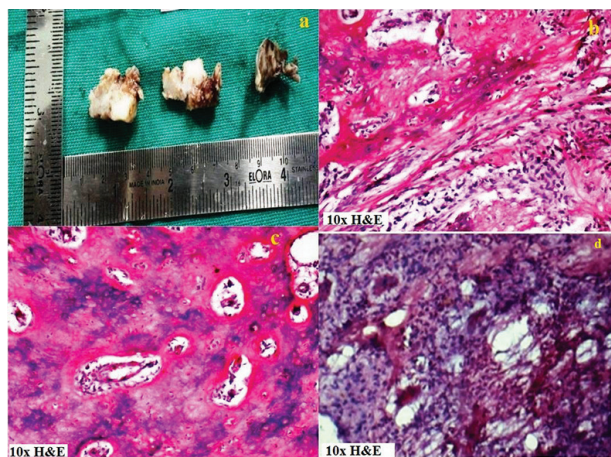


Figure 4: Grossing picture of excisional specimen. (a) and the photomicrograph showing lobular pattern of arrangement of hyaline cartilage supported by a myxoid background within this loosely arranged stellate shaped cells. Central lobular areas exhibits cartilaginous matrix showing round to oval nuclei; (b, c) The osteoclast-like giant cells are evident; (d) 10x objective, 10x eyepiece & H&E.

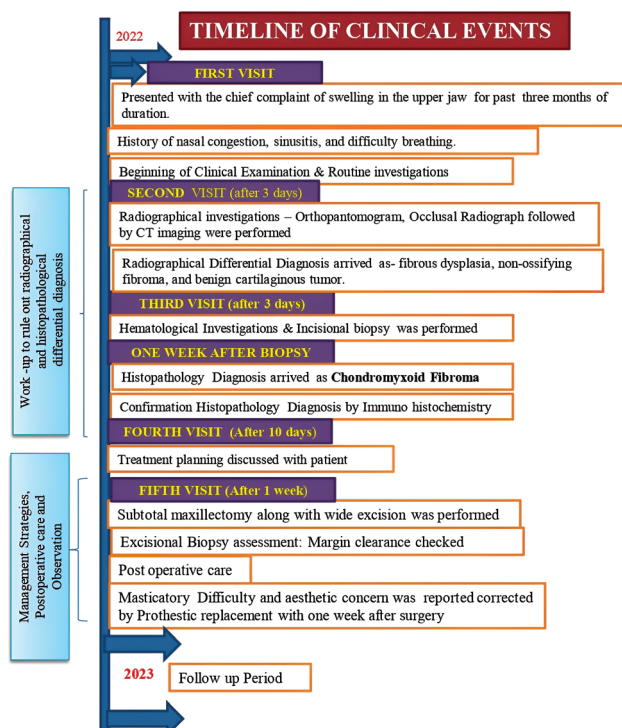


Figure 5: Clinical timeline events.

Discussion

CMF is a rare benign cartilaginous or chondrogenic tumor that predominantly affects the proximal metaphyseal region of long bones, such as the tibia, femur, and fibula, with approximately 25% occurring in flat bones.⁽³⁾ It has characteristic histological features, including a lobular architectural pattern in a chondro-myxomatous background. Initially described by Jaffe and Lichtenstein in 1948, CMF was identified as a distinct entity that which may mimic chondrosarcoma histologically.⁽⁵⁾ According to the World Health Organization (WHO), CMF is defined as a "benign tumor characterized by lobules of spindle-shaped or stellate cells proliferating within an abundant intercellular matrix that is myxoid or chondroid in nature."⁽⁶⁾ It accounts for 1-1.8% of all bone tumors and 2-5% of tumors in the craniofacial region. The first case of CMF involving the anterior mandible in a young woman was reported by Srivatsava in 1955.⁽⁷⁾ More recent literature highlights the rarity of CMF in the craniofacial region, with only 25 cases involving jawbones, 2 cases in the zygoma, 1 case in the pterygopalatine space, and 35 intracranial localizations reported.⁽³⁾

Despite its benign nature, CMF poses a diagnostic challenge due to similar lobular architecture, cellularity or calcification patterns with other cartilaginous tumors especially chondrosarcoma particularly when occurring in unusual locations. CMF primarily manifests in the second to third decade of life, with no significant sex predilection. This report underscores an exceptionally rare presentation of CMF in the maxilla of a young male, a location seldom reported in the literature. Cytogenetic analysis has revealed recurrent clonal abnormalities involving chromosome 6, particularly the rearrangement of the long arm at bands q13 and q25. These regions harbor genes such as BMP6, COL9A1, and COL10A1, along with oncogenes like FYN and ROS1, which are associated with cartilage development.^(8,9) The repeated genetic rearrangements and over expression of glutamate receptor gene GRM1 are consider as key driver in the development of CMF. The comprehensive radiographical and histomorphological assessment combined with GRM1 immunohistochemistry helps us to distinguish the CMF from other histological mimics.⁽¹⁰⁾

Clinically, CMF typically presents as a painful, slow-growing swelling over a period of 6 months to 2

years. The pain is usually mild, intermittent, and dull in nature, as seen in this case. However, in rare sites like the hands or feet, painless swelling may be the primary complaint. Occasionally, the tumor may be asymptomatic and discovered incidentally on radiographs.^(3,8) Radiologically, CMF appears as a radiolucent lesion, often eccentric, affecting the metaphyseal region with sharply demarcated and scalloped margins that aid in diagnosis and monitoring. The calcification of matrix is rare but more frequently observed in craniofacial CMF than in CMF affecting long bones.^(8,9) Advanced imaging, such as CT and Magnetic Resonance Imaging (MRI), offers detailed insights into the extent of bony destruction and adjacent tissue involvement. MRI findings typically show a lobulated pattern with hypointense signals on T1-weighted images and heterogeneously hyperintense signals on T2-weighted images.⁽¹¹⁾ In this case, the lesion extended to the maxillary sinus, causing nasal congestion and difficulty breathing, with evident matrix calcification on CT.

Histopathological examination remains the gold standard for diagnosing CMF. The lesion typically exhibits hypocellular lobules of stellate or spindle-shaped cells set in a chondro-myxomatous intercellular matrix. These lobules are separated by a highly cellular connective tissue stroma, which contains spindle-shaped cells and thick fibrous bands, along with variable numbers of multinucleated giant cells.^(3,9) Dahlin emphasized the presence of giant cells at the periphery of the chondroid lobules with plump, hyperchromatic nuclei as a characteristic feature of CMF.⁽¹²⁾ Given its histological resemblance to other entities, differential diagnoses include chondroblastoma, chondrosarcoma, enchondroma, and aneurysmal bone cyst.⁽¹¹⁾ However, the unique histological features of CMF aid in distinguishing it from these lesions. IHC is a valuable tool in identifying the specific proteins in the diagnosis and differentiating CMF from other tumours.⁽¹³⁾ In the present case, the tumor cells diffuse vimentin positivity followed by strong cytoplasmic positivity for S-100 and SOX9, indicating cartilaginous origin. The proliferative index of Ki-67 was low (<5%), supporting a benign nature of the lesion, and CD34 and Bcl-2 negativity ruled out vascular or aggressive neoplasms. These findings were consistent with Chondromyxoid Fibroma, effectively differentiating it from malignant counterparts such as chondrosarcoma.

Despite being benign, CMF can recur, particularly

after incomplete excision, with recurrence rates reported as high as 25%.⁽¹⁴⁾ The recurrence risk of CMF, depending on the treatment modalities, includes curettage, curettage with adjuvants like phenol applications and bone cementation, and surgical excision. The curettage alone showed a relatively high recurrence rate of up to 80%. The combination therapy with bone grafting reduces the recurrence rate by around 22%. The En-bloc resection with wide margins is a more aggressive approach with subsequent functional deficit and cosmetic concern, but preferred treatment of choice for a better prognosis and reduces the recurrence risk by 4%.⁽¹⁵⁾ However, in the craniofacial region, complete excision is often challenging due to anatomical complexity and proximity to vital structures.^(15,16) The additional factors tumor in younger age, tumor location, and surgical clear margins, increase the recurrence risk. In the present case, subtotal maxillectomy (Transoral approach) was performed without any complications. The absence of mitotic figures and necrosis in the excised tissue indicates a favorable prognosis. However, long-term follow-up with clinical and radiographic evaluations is essential due to the potential for recurrence.⁽¹⁶⁾

Conclusions

Diagnosing CMF in atypical locations, such as the craniofacial region, remains challenging due to its overlapping clinical and radiographic features with other benign and malignant tumors. The differential diagnosis includes ossifying fibroma, odontogenic tumors, fibrous dysplasia, or even malignancies like chondrosarcoma and osteosarcoma to be ruled out while diagnosing the lesion. Radiographically, CMF may mimic fibrous dysplasia or non-ossifying fibroma due to its well-defined, lytic appearance with a sclerotic border and mixed trabecular patterns. However, histopathology, as seen in this case, provides definitive confirmation of the diagnosis, with the absence of mitotic activity, necrosis, and dysplasia confirming its benign nature.

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or public health policy.

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Conflict of Interest

The authors declared that they have no conflict of interest.

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