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Microplastics in Dentistry: A Review of Health and Environmental Risks

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Abstract

Objectives: This narrative review investigated the sources, mechanisms of release, and health implications of microplastics within the dental profession.

Methods: A systematic literature search on Databases PubMed, Scopus, Web of Science and Google Scholar found eight key studies that examined various combinations of terms, including "microplastics" and "nanoplastics" related to "dental materials" and "oral healthcare," as well as their impact on the environment impact accordingly to inclusion/exclusion criteria. Detection techniques such as scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), and gas chromatography-mass spectrometry (GC-MS) were commonly applied to characterize the morphology and composition of microplastics.

Results: The main findings indicate that microplastics originate from different sources, including mechanical wear, chemical degradation, and thermal stress, with occupational exposure posing risks to dental professionals, primarily through inhalation of airborne particles. Systemic exposure, resulting from ingestion or mucosal absorption of microplastics, has been linked to immune suppression, oxidative stress, and systemic toxicity. Environmentally, microplastics from dental sources infiltrate wastewater and contribute to aquatic pollution.

Conclusions: This review underscores the importance of adopting sustainable practices, including the use of biodegradable materials and enhanced waste management. Future research should focus on longitudinal studies, bioremediation approaches, and the development of alternative, eco-friendly dental materials.

Keywords: biodegradable materials, dentistry, environmental pollution, health risks, microplastics, occupational exposure, oral healthcare products, oxidative stress, resin-based composites, sustainable practices, wastewater contamination

Introduction

Microplastics (MPs), defined as plastic particles measuring less than 5 mm, have become a major environmental pollutant. The presence of plastics in ecosystems is now recognized as a significant concern, mainly due to the extensive use of plastic items and inadequate waste management strategies.(1) MPs can be categorized into two types: primary MPs, which are produced specifically for industrial or consumer applications (e.g., microbeads in cosmetics and toothpaste), and secondary MPs, which result from the degradation of larger plastic products through environmental weathering processes, including ultraviolet radiation, wind, and wave action. MPs accumulate worldwide, particularly in marine ecosystems, as shown by the Great Pacific Garbage Patch.(2,3)

MPs have been detected in various habitats, ranging from coastal areas to isolated Arctic regions. They have invaded terrestrial ecosystems and been incorporated into soils through agricultural practices, including the use of sewage sludge as fertilizers. Global plastic manufacturing exceeds 460 million metric tonnes yearly, with MPs constituting a substantial portion of this total due to their durability against environmental degradation.(4)

MPs pose significant ecosystem risks, primarily threatening biodiversity and affecting aquatic organisms. Marine organisms often mistake these particles for food, leading to ingestion, bioaccumulation, and trophic transfer through food webs. Moreover, plastics serve as vectors for hazardous chemical pollutants, including persistent organic pollutants (POPs) and heavy metals. These pollutants bind to plastic surfaces and are transferred into living organisms, exacerbating toxicity risks. These interactions disrupt the reproductive and physiological processes of aquatic biota, ultimately leading to ecological consequences.(5)

MPs have garnered considerable attention in public health due to the increasing evidence of their ubiquity in air, water, food, and even human tissues.(6) Human exposure to MPs occurs through multiple routes, including oral ingestion of contaminated water and food, inhalation of airborne plastic fragments, and dermal absorption. Studies have reported MPs in drinking water supplies, seafood, and table salt, emphasizing that humans inadvertently ingest significant MPs annually.(7)

Once ingested, MPs can translocate from the gastrointestinal tract into the circulatory system and potentially accumulate in various organs, including the liver, kidneys, and lungs. Several mechanisms have been proposed for their toxicity, including physical damage (e.g., tissue inflammation, disruption of intestinal permeability), oxidative stress, genotoxicity, and immune responses. Furthermore, microplastics are often associated with plasticizers, flame retardants, and bisphenol A (BPA)—chemicals known for their potential to disrupt the endocrine system and their possible carcinogenicity.

The chronic implications of microplastic exposure remain uncertain, although long-term exposure has been associated with conditions such as respiratory dysfunction, metabolic disorders, and cancer. Investigations into MPs in placental tissues and human breast milk have raised concerns about their effects on fetal development and infant health. Therefore, their role as environmental pollutants of concern necessitates stringent regulatory and mitigation strategies. While chronic toxicity of MPs has received significant attention, emerging evidence also suggests the potential for acute effects. Experimental studies have demonstrated that high concentrations of certain polymer leachates, such as polycaprolactone (PCL), can induce immediate cytotoxic responses in both *in vitro* models and aquatic organisms, indicating that acute exposure may also present clinical and environmental risks.(8,9)

The use of polymer-based biomaterials in dentistry has inadvertently contributed to microplastic contamination in clinical environments and the oral cavity. Dental materials commonly implicated include resin-based composites (RBCs), orthodontic adhesives, dental prosthetics, and oral healthcare products like toothpaste and dental floss. MPs in dentistry can originate through mechanical wear, chemical degradation, or fragmentation of polymers under thermal and pH stress.(8-11)

Orthodontic adhesives, for example, degrade over time due to cyclic mechanical forces during mastication. These forces release microplastic particles into saliva, which can be swallowed or aerosolized during dental procedures. Moreover, polishing and finishing procedures performed on resin composites disintegrate MPs, which are washed away via dental unit waterlines, contributing to wastewater pollution.(12)

The ingestion of MPs from dental sources poses potential risks to the oral cavity, including inflammation of the gingival tissues, increased risk of periodontitis, and oxidative stress-induced damage to the oral mucosa. MPs can act as carriers for bacteria, heavy metals, and other environmental toxins, potentially exacerbating chronic periodontitis and endodontic infections. Inhalation risks are particularly concerning for dental professionals exposed to airborne MPs during routine procedures, especially in poorly ventilated environments.[13-15] Dental clinics have been shown to contain higher levels of suspended plastic particles compared to other indoor environments.[16-19]

Nanoplastics (NPs) was included to capture studies that discuss particulate matter smaller than one µm, which may be relevant given the potential for fragmentation of dental polymers NPs, defined as plastic particles smaller than 1 µm, represent a critical extension of microplastic research due to their greater mobility, higher surface-area-to-volume ratio, and enhanced potential for tissue penetration. Unlike MPs, which are typically retained in the gastrointestinal tract or excreted, MPs have demonstrated the capacity to cross cellular membranes, accumulate in secondary organs, and interact with biological systems at the molecular level.[20,21]

Given these challenges, this narrative review aims to comprehensively evaluate the role of MPs in dentistry, their mechanisms of release, associated health risks, and possible mitigation strategies. By analyzing current literature, this review aims to raise awareness among clinicians and policymakers regarding the multifaceted impacts of dental MPs, including their clinical release mechanisms, occupational and systemic health risks, and environmental consequences, while proposing sustainable mitigation strategies.

Materials and Methods

Eligibility criteria

Studies were included if they met the following criteria: (1) addressed the presence, release mechanisms, or health/environmental impacts of MPs in dentistry and oral healthcare; (2) focused on microplastics from dental materials or oral care products such as composites, adhesives, toothbrushes, and toothpaste; and (3) were peer-reviewed articles published in English. Studies from related sectors, such as general microplastic pollution or marine environmental contamination, were included only if they had relevant parallels to dentistry. Exclusion criteria included studies lacking direct relevance to MPs in the dental context, as well as non-peer-reviewed reports, editorials, and conference abstracts. Studies were grouped based on their primary focus: microplastic sources, health risks, and environmental impacts.

Information sources

The search for eligible studies was conducted using major academic databases, including PubMed, Scopus, Web of Science, and Google Scholar. Additionally, reference lists from selected articles were manually searched for relevant citations. No date restrictions were applied. The final database search was completed on 31 January 2025. The search incorporated both standardized Medical Subject Headings (MeSH) and general keywords. In dentistry, the progressive breakdown of polymer-based biomaterials may release both MPs and NPs, necessitating a comprehensive approach to evaluating their risks. However, the biological effects and environmental behavior of NPs differ markedly from MPs, and this distinction is maintained in the interpretation of results.

Search strategy

The search strategy employed Boolean operators and keywords related to MPs and dentistry. The search terms included combinations of the following: "microplastics," "nanoplastics," "dental materials," "resin-based composites," "oral healthcare," "orthodontic adhesives," "wastewater contamination," and "occupational exposure." Filters were applied to exclude non-peer-reviewed publications, and only articles in English were considered. Specific search examples include: (microplastics OR nanoplastics) AND ("dental materials" OR "oral healthcare" OR "resin-based composites"). Search strategies were iteratively refined based on initial screening outcomes.

Selection process

The studies were selected following a systematic screening process. The author reviewed the titles and abstracts of the retrieved articles to determine their relevance. Then, full-text articles were evaluated based on the inclusion criteria. No automation tools were used during the screening process. Two authors independently screened the articles and performed data extraction using a standardized form. Discrepancies were resolved through consensus. No third-party adjudicator was required.

Data collection process

The author extracted data using a standardized data collection form. For each included study, information was extracted on study objectives, materials examined, investigative techniques, key findings, and associated health and environmental outcomes. This information was cross-checked, and discrepancies were resolved through consensus. No direct contact with study investigators was necessary, as all data were publicly available.

Data items

Primary outcomes: Data on the sources, release mechanisms, and health and environmental risks of MPs in the dental profession were sought. Findings related to microplastic ingestion, inhalation, cytotoxicity, and ecological pathways were prioritized for further examination.

Secondary variables: Study characteristics, such as the type of dental materials evaluated (e.g., resin composites, adhesives), microplastic detection methods (e.g., Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy), and exposure pathways (e.g., occupational, patient-based), were collected. Funding sources and potential conflicts of interest were noted where available to provide context for the study findings.

Synthesis methods

A narrative synthesis was employed to summarize and integrate the findings across the included studies. Key themes were identified by grouping studies into categories based on their focus, including sources of MPs, health effects, and environmental impact. Data were tabulated where applicable to highlight consistent or divergent findings. Due to the heterogeneity of study designs and outcomes, no meta-analysis or quantitative synthesis was performed. Figures and tables were used to present the significant findings visually.

Certainty assessment

As this is a narrative review, no formal assessment of certainty (e.g., GRADE) was performed. However, the strength of the evidence was evaluated qualitatively, considering the consistency of findings across studies, the robustness of the methods used, and their relevance to dental practice.

Results

Overview of literature search and selected studies

A thorough literature search was conducted across major scientific databases to identify relevant studies on microplastics in dentistry, oral healthcare, and the associated health risks. Out of numerous initial results, eight studies were deemed appropriate due to their specific focus on dental biomaterials, microplastic release mechanisms, health impacts, and mitigation measures. Our initial research obtained 10 results; only eight were selected and included in this review. The rationale for excluding two initially identified studies is explained under 'Limitations of Existing Research. The following subsections detail the primary findings of each selected study, and Tables 1 and 2 provide comprehensive summaries.

Table 1: Summary of main outcomes in studies investigating microplastic contamination in dentistry.

Study	Main Outcomes
Saha *et al.*[20]	Immune suppression, tissue fibrosis, systemic toxicity, microplastic release mechanisms through wear, pH, and thermal fluctuations.
Akhtar *et al.*[21]	Increased inhalation risk for dental professionals, higher microplastic pollution in teaching clinics, polyethylene terephthalate and polyethylene dominance.
James *et al.*[22]	Acute toxicity from polycaprolactone microplastic leachates, oxidative stress in mammalian cells, nuclear receptor activation, oligomers identified as key toxic agents.
Divakar *et al.*[23]	Wastewater contamination from orthodontic adhesives, microplastic forms identified as fibers and pellets through mechanical degradation.
Protyusha *et al.*[24]	Significant contribution of toothbrushes and toothpaste to microplastic release, polyethylene and polyamide polymers, exposure quantified through daily and annual estimates.
Odintsov *et al.*[25]	Partial biodegradation of polytetrafluoroethylene and acrylic fluorinated copolymers in marine organisms, persistence and bioaccumulation concerns.
Wang *et al.*[26]	Development of biodegradable alternatives, reduction in microplastic release through plant-based material use.
Mulligan *et al.*[27]	Persistent surface changes in resin-based composite microplastics, monomer elution, long-term environmental persistence in wastewater.

Table 2: Summary of main results.

Study	Materials Studied	Release Mechanisms	Polymers Identified	Health/Environmental Risks
Saha *et al.*[22]	Toothpaste, orthodontic implants	Friction, pH/thermal fluctuations	Polyethylene, thermoplastic polyurethane	Immune suppression, tissue fibrosis, systemic toxicity
Akhtar *et al.*[23]	Clinical and teaching dental units	Aerosolized particles during use	polyethylene terephthalate, polyethylene	Inhalation risks, higher exposure among female workers
James *et al.*[24]	Polycaprolactone, thermoplastic polyurethane plastics	Leaching of oligomers, degradation	polycaprolactone, thermoplastic polyurethane	Acute toxicity, oxidative stress, receptor activation
Divakar *et al.*[25]	Orthodontic adhesives	Mechanical degradation	Polyamide, ester	Environmental pollution via wastewater
Protyusha *et al.*[26]	Toothbrushes, toothpaste, floss	Mechanical abrasion during use	Polyethylene, polyamide, polyethylene terephthalate	High annual microplastic exposure, polymer risk levels
Odintsov *et al.*[27]	polytetrafluoroethylene and acrylic copolymers	Biodegradation in marine organisms	polytetrafluoroethylene, fluorinated copolymers	Potential bioremediation paths, persistence concerns
Wang *et al.*[28]	Biodegradable plant-based materials	Microplastic degradation mechanism	Biodegradable fibers	Sustainable alternatives to plastic dental products
Mulligan *et al.*[29]	Resin-based composites	Grinding, clinical wear	Monomers, methacrylates	Environmental leaching, persistent surface alterations

Detailed results from selected studies

Saha *et al.*,[22] explored the impact of MPs generated by oral care products and dental materials, including toothpaste and orthodontic appliances, on human health. They highlighted mechanical friction, pH variations, and thermal changes as primary factors contributing to the generation of MPs in the oral environment. Released particles were shown to induce immune suppression, tissue fibrosis, and systemic toxicities. The authors emphasized the need for advanced analytical tools to detect MPs more accurately and sustainable strategies to mitigate their environmental release.

Akhtar *et al.*,[23] investigated MPs' abundance and morphological characteristics in dental healthcare units, distinguishing between teaching hospitals and private dental clinics. Their study revealed higher levels of microplastic pollution in teaching environments, with polyethylene terephthalate (PET) being the most common polymer. The average annual inhalation rate of MPs was found to be higher among female dental professionals. This study also calculated the polymer hazard index (PHI), revealing varying risk levels associated with different types of MPs.

James *et al.*,[24] focused on PCL and thermoplastic polyurethane (TPU) plastics, commonly used in dental modeling and prosthetics. Their experiments demonstrated that aqueous leachates from PCL exhibited acute toxicity in zebrafish models and activated nuclear receptors in mammalian cells responsible for oxidative stress. The study suggested that oligomeric compounds and NPs released from PCL were accountable for the observed toxicity, emphasizing the need to reconsider assumptions regarding the inertness of these materials.

Divakar *et al.*,[25] investigated the generation of MPs from orthodontic adhesives using scanning electron microscopy and Fourier-transform infrared spectroscopy (FTIR). The predominant microplastic types identified included fibers, fragments, and pellets, with polymeric signatures such as polyamides and esters. The study acknowledged that although the quantity of microplastic release was minimal compared to other industries, its environmental impact should not be overlooked, especially in clinical wastewater.

Protyusha *et al.*,[26] conducted a comprehensive risk assessment of MPs found in commercially available oral healthcare products, such as toothbrushes, toothpaste, mouthwash, and dental floss. Their results showed that toothbrushes were the most significant contributors to microplastic pollution, primarily polyethylene and polyamide particles. The risk of microplastic exposure was quantified through daily and annual estimates, with toothbrushes contributing approximately 48,910 particles per individual annually.

Odintsov *et al.,*[27] investigated the biodegradation of polytetrafluoroethylene (PTFE) and acrylic fluorinated copolymers, commonly used in dental applications, within the digestive tracts of marine gastropods. The study demonstrated that specific biological processes facilitate the partial degradation of these plastics, suggesting possible avenues for bioremediation efforts to reduce microplastic waste in aquatic ecosystems.

Wang *et al.,*[28] explored biodegradable alternatives to plastic-based dental materials by developing a biodegradable respirator made of plant fibers and recycled dental floss silk. The study demonstrated that incorporating microplastic degradation mechanisms within the design of new materials could reduce environmental impact.

Mulligan *et al.,*[29] focused on RBCs, highlighting the significant elution of monomers and other microparticulate waste from these materials during clinical procedures. Surface area analyses and FTIR confirmed the persistence of these particles over time, with the potential leaching of harmful compounds into surrounding environments.

Summary of findings

Table 2 summarizes the key characteristics, microplastic sources, and associated risks reported in each included study.

Investigative techniques for microplastic detection

The selected studies' detection and characterization of MPs relied on advanced microscopy, spectroscopy, and chemical analysis techniques. Scanning electron microscopy (SEM) was one of the most commonly used techniques to provide high-resolution images and evaluate the MPs' surface morphology and particle size, as seen in studies like Divakar *et al.,*[25] Mulligan *et al.,*[29] FTIR was frequently employed to identify the detected MPs' chemical composition and polymer types. FTIR works by detecting the vibrational signatures of molecular bonds, allowing precise polymer identification even in complex environments.

In studies where airborne or environmental MPs were of concern, techniques such as attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) were utilized to analyze microplastic particles directly on the sampling surface without extensive preparation. Protyusha *et al.,*[26] employed this method to assess oral healthcare products, while Akhtar *et al.,*[23] used it to characterize particles in dental clinic environments. Gas chromatography coupled with mass spectrometry (GC-MS) and high-resolution two-dimensional gas chromatography (GC×GC-HRT) were used by James *et al.*[24] to identify polymer fragments, additives, and oligomers within aqueous leachates of PCL plastics.

Additionally, Mulligan *et al.,*[29] conducted potentiometric titration techniques and zeta potential analyses to assess the surface charge properties of RBC microparticles. This contributed to understanding their environmental behavior and interaction with the surrounding ecosystems. Combining these techniques provided robust data on particle morphology, size distribution, polymeric content, and the potential biological and ecological impacts. It is essential to note that several studies[24-26] have detected nanoscale polymer fragments, underscoring the need for detection techniques with high resolution, such as GC-MS and zeta potential analysis. These findings emphasize the co-occurrence of micro- and nanoplastics in dental environments. Odintsov *et al.,*[27] employed digestive tract analysis of marine gastropods combined with fluorescence microscopy to evaluate the degradation capacity of polymer particles, focusing on surface erosion and fragmentation patterns. Wang *et al.,*[28] employed scanning electron microscopy and tensile strength testing to evaluate the structure and biodegradability of plant-fiber-based respirator components made from recycled dental floss.

Sources of dental microplastics

MPs originate from commonly used dental materials, including resin-based composites, orthodontic adhesives, dental prostheses, and oral care products. Mechanical processes such as polishing and mastication contribute to fragmentation. Divakar *et al.,*[25] and Protyusha *et al.,*[26] identified polyethylene and polyamide particles as frequent contaminants derived from toothbrushes, toothpaste, and adhesives.

Mechanisms of microplastic release

Microplastic release within dental settings is facilitated by a range of physicochemical and mechanical processes that affect polymer stability. Mechanical abrasion during finishing, polishing, mastication, and ultrasonic scaling procedures can induce the fragmentation of polymer-based materials, such as resin composites and orthodontic adhesives. Divakar *et al.,*[25] demonstrated that repetitive mechanical forces applied to adhesives produce fibers and pellets, which may be dispersed via aerosols or effluents.

Thermal stress is another prominent factor contributing to polymer degradation. Temperature fluctuations during restorative procedures, particularly when using curing lamps and rotary instruments, promote the breakdown of polymer chains. Saha *et al.,*[30] reported that thermal changes and intraoral pH variations weaken polymer integrity, thereby accelerating microplastic generation. These phenomena are further exacerbated in materials with low cross-linking densities or inadequate polymerization. Chemical degradation, particularly hydrolysis and oxidative stress, also contributes to the formation of MPs. The oral environment, characterized by enzymatic activity, fluctuating pH levels, and constant exposure to saliva, creates favorable conditions for the gradual degradation of polymeric dental materials. Studies such as those by Mulligan *et al.,*[29] have observed that composite materials may elute monomers and micro-debris into saliva and rinse water, indicating a progressive degradation pathway that contributes to both patient exposure and environmental contamination.

Discussion

This section critically synthesizes the results, contextualizing the findings within current knowledge and discussing their clinical implications. Redundancies with the results section have been minimized to offer a more evaluative discussion.

Microplastic contamination in dentistry

Microplastic contamination in dentistry reflects a microcosm of the broader global plastic pollution crisis. Several studies, including those analyzed in this review, demonstrate how standard dental procedures and products, ranging from orthodontic adhesives to resin-based composites, contribute to the release of MPs. The fragmentation of plastics during clinical operations, combined with aerosolization and mechanical degradation, highlights dentistry as a significant but overlooked contributor to indoor and environmental plastic pollution.[20]

Studies like those conducted by Protyusha *et al.,*[26] and Saha *et al.,*[22] reveal the multifactorial mechanisms of microplastic release, including frictional forces, thermal stress, and pH fluctuations. These mechanisms illustrate how polymers commonly used in dental materials undergo chemical breakdown, shedding micro- and nanoplastics intraorally and into the surrounding environment. The potential for these particles to be inhaled or ingested during dental treatments raises questions about occupational exposure risks, especially for dental professionals who spend prolonged periods in clinical settings, as demonstrated by Akhtar *et al.*[23]

While dentistry may not match the microplastic output of larger sectors, such as textiles or fisheries, as indicated by Divakar *et al.,*[25] the clinical and localized nature of dental pollution magnifies its impact on specific populations, particularly patients and practitioners. This finding is significant because it highlights the potential for cumulative exposure and underscores the urgent need to explore mitigative measures in this field. The evidence suggests that the health effects of MPs extend beyond localized oral tissues, necessitating a broader interdisciplinary understanding of their biological behavior.

Health implications of dental microplastic exposure

This review highlights one key concern: the health impact of oral and systemic microplastic exposure resulting from dental procedures. Saha *et al.,*[22] reported adverse effects from MPs originating in dental materials, including systemic toxicity and immune suppression. The authors documented immune suppression, tissue fibrosis, and systemic toxicity as critical outcomes of microplastic exposure.

These health risks primarily arise from two factors: the physical properties of MPs (size, shape, and surface area) and their chemical composition, including associated contaminants such as monomers, stabilizers, and plasticizers. Studies like Mulligan *et al.,*[29] and James *et al.,*[24] further reinforce the role of additives and leachates from dental materials as primary drivers of cytotoxicity and oxidative stress—the study by James *et al.,*[24] for example, demonstrated how oligomeric compounds leached from PCL plastics triggered nuclear receptor activation, which is closely linked to inflammatory and metabolic disturbances.

Furthermore, the oral cavity serves as a direct interface for the systemic absorption of MPs. The combination of mechanical friction, salivary flow, and mucosal permeability creates an environment conducive to the translocation of MPs into deeper tissues. Recent studies have identified MPs in human feces, placental tissues, and even breast milk, suggesting that exposure from multiple routes, including oral pathways, may contribute to cumulative systemic effects[30,31] (Figure 1). While most toxicity data pertain to MPs, NPs have shown unique biological effects, including mitochondrial damage, oxidative DNA damage, and endocrine disruption at lower concentrations.[20,30] Their small size facilitates cellular uptake and translocation to organs such as the brain and placenta, making their impact more insidious and potentially more severe.

Occupational risks for dental professionals

The occupational exposure of dental professionals is a significant yet underexplored issue, as indicated by Akhtar *et al.,*[23] who found a higher prevalence of inhaled MPs among dental workers, particularly in teaching hospitals, compared to private clinics. The increased exposure risk in teaching settings may be attributed to frequent training procedures, higher patient turnover rates, and the extended use of polymer-based materials in restorative and orthodontic treatments.

This observation has important implications for female dental professionals, who, as reported, exhibit slightly higher inhalation rates of airborne MPs due to occupational factors and possibly hormonal differences affecting pulmonary clearance mechanisms. Long-term exposure can lead to respiratory complications, airway inflammation, and systemic absorption of inhaled particles. Thus, there is an urgent need for improved ventilation systems and non-plastic-based protective barriers to mitigate these risks[31] (Figure 1).

Environmental and ecosystem impacts of dental microplastics

MPs generated within dental clinics are not confined to the clinical environment; wastewater discharge systems act as vectors for their release into larger ecosystems. Studies by Divakar *et al.,*[25] and Protyusha *et al.,*[26] have demonstrated how MPs from dental adhesives, toothbrushes, and resin-based composites enter wastewater treatment plants and sub-sequently infiltrate aquatic ecosystems.

Once introduced into the environment, MPs can persist for extended periods, affecting marine and terrestrial organisms. The biodegradation of fluorinated copolymers and PTFE, as examined by Odintsov *et al.,*[27] demonstrated partial degradation in the digestive tract of marine gastropods. Although this finding suggests potential for bioremediation, it also highlights the persistent nature of these materials and their likelihood of bioaccumulation.

Moreover, the ability of microplastics to adsorb environmental toxins, such as POPs and heavy metals, exacerbates their ecological impact. Contaminated MPs can transfer harmful substances through the food chain, posing risks to both aquatic life and human populations that consume seafood contaminated with MPs. The combination of direct and indirect exposure pathways necessitates an integrated approach to mitigating the environmental footprint of dental MPs[32] (Figure 1).

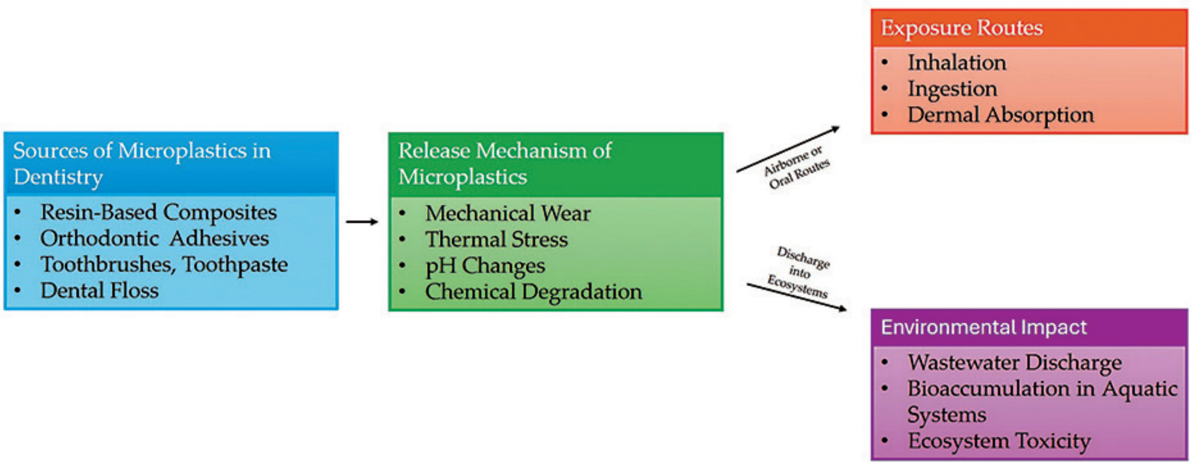

Figure 1: Schematic overview of microplastic generation, exposure pathways, and health/environmental impacts in dentistry.

Emerging solutions and mitigation strategies

The need for sustainable practices within dentistry has been a recurring theme throughout this review. Wang *et al.,*[28] offer an innovative perspective by exploring biodegradable alternatives, such as plant-based respirators incorporating microplastic degradation mechanisms. This study emphasizes the importance of rethinking material design to reduce plastic waste at its source.

Additional strategies include developing non-plastic alternatives for dental materials, improving wastewater filtration systems, and implementing recovery mechanisms for microplastic-contaminated effluents. Advanced filtration technologies such as membrane bioreactors (MBRs) and activated carbon filters have shown promise in capturing MPs before they enter natural water bodies.

Furthermore, policies restricting the use of high-risk polymers (e.g., polyethylene and polyamide) in dental products and mandating sustainability certifications for dental clinics could drive the adoption of environmentally friendly materials. Public awareness campaigns targeting dental professionals and patients are equally essential to promoting eco-friendly practices, such as using biodegradable toothbrushes and non-plastic dental floss. In recent years, dental materials research has witnessed significant advancements in developing biodegradable materials to reduce environmental impact and enhance patient outcomes. These materials are designed to degrade naturally within the body, eliminating the need for removal and minimizing long-term complications. A multicenter randomized controlled trial[33] compared biodegradable plates and screws to traditional titanium counterparts in maxillofacial surgeries. The study found that while 21% of patients in the biodegradable group required an intraoperative switch to titanium due to concerns about stability, biodegradable devices were effective and safe when used appropriately. This suggests a potential application in specific clinical scenarios, with the added benefit of eliminating the need for a second surgery to remove hardware.

Research into magnesium (Mg)- based biodegradable metals[34] has shown promise for oral and maxillofacial applications. These materials offer advantages such as biocompatibility and mechanical properties comparable to those of bone. However, challenges like rapid degradation and gas formation have limited their clinical translation. Recent studies focus on alloying and surface modifications to overcome these limitations, aiming to develop viable biodegradable metal options for dental use.

Innovative approaches are exploring natural polymers such as silk fibroin for dental tissue regeneration.[35] The Instituto Murciano de Investigación y Desarrollo Agrario y Medioambiental (IMIDA) is developing a biomaterial that combines silk fibroin with graphene to stimulate the regeneration of dental and periodontal tissues. Initial *in vitro* studies have yielded promising results, and upcoming animal model studies aim to assess the potential for human applications further.

These developments underscore a growing trend toward the use of sustainable and patient-friendly materials in dentistry. While challenges remain, ongoing research and clinical trials are paving the way for the integration of biodegradable materials into routine dental practice, offering potential benefits in terms of environmental impact and patient care.

Limitations of existing research

While this review presents significant findings, several limitations in the research must be acknowledged. The variety in methodologies across studies, especially regarding the detection and measurement of MPs, makes it challenging to compare direct exposure effects with toxicity results. Furthermore, the absence of longitudinal studies examining the long-term impacts of ongoing dental microplastic exposure represents a significant gap. There is also a pressing need to standardize investigative methods, such as SEM, FTIR, and GC-MS, to enhance the reproducibility and reliability of research outcomes. Many existing studies tend to concentrate on *in vitro* models or aquatic species, which restricts the applicability of their results to human populations. Future research endeavors should focus on clinical studies involving humans and investigate potential genetic or epigenetic reactions to chronic microplastic exposure and pollution.[36-39]

Excluded literature from results

The studies by Wolfson *et al.,*[40] and Guo *et al.,*[41] were excluded from the table and primary results synthesis because they did not directly address the release of MPs or their health and environmental impacts in dentistry.

Wolfson *et al.,*[40] focused on the load-bearing capacity of alumina dental implants and the mechanical stress-induced plastic deformation in supporting bone tissue. Although this study mentions microplastic deformation in a structural context, it does not involve the generation or impact of environmental MPs.

Using electron microscopy, Guo *et al.*,[41] explored fatigue mechanisms in high-palladium dental casting alloys. The focus was on the behavior of metallic microstructures rather than polymer-based MPs, which are relevant to the current review.

Conclusions

This narrative review highlights the pervasive presence of microplastics in the dental profession, including clinical procedures, oral healthcare products, and occupational settings. Studies have shown that dental materials, such as RBCs, orthodontic adhesives, and oral hygiene products, significantly contribute to the release of MPs. Mechanisms of particle generation include mechanical wear, thermal degradation, and chemical leaching, resulting in both localized and systemic exposure risks.

MPs from dental sources can lead to localized oral inflammation, oxidative stress, and systemic effects like immune suppression. Dental professionals face additional risks from inhaling airborne particles, especially in poorly ventilated clinics. These MPs also infiltrate wastewater systems, leading to environmental pollution that affects aquatic life and may enter the human food chain. This review highlights the importance of adopting sustainable practices in dentistry to mitigate the risks associated with MPs. Dental professionals can adopt non-plastic or biodegradable alternatives to reduce the release of MPs, thereby promoting environmentally sustainable clinical practices. Policymakers should work with researchers to establish guidelines for acceptable microplastic emissions and promote sustainability in dental clinics.

Several actions are recommended, including clinically relevant precautions to minimize microplastic exposure within dental practices. More research is required, mainly longitudinal studies, to assess the long-term health effects of dental MPs. Clinical studies should measure microplastic accumulation in various tissues, and investigations of their toxic effects are essential. Developing standardized detection protocols and alternative biodegradable materials is crucial for reducing environmental impacts. Addressing microplastic pollution effectively requires the dental profession to prioritize sustainable practices and collaborate across disciplines, supporting broader sustainability goals. A summary of the recommendation is given in Table 3.

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Table 3: Precautionary guidelines for managing microplastic exposure in dentistry.

Recommendation	Description
Use biodegradable materials	Prefer materials with known bioresorption profiles to reduce polymeric waste
Enhance clinic ventilation	Reduce inhalation risks from airborne plastic microparticles
Install advanced water filtration	Capture resin and polymeric particles from dental unit effluents
Minimize use of polishing procedures	Reduce mechanical degradation of restorative materials
Educate staff and patients	Raise awareness on environmental and health impacts of dental microplastics

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