การเปรียบเทียบพื้นที่ผิวรากฟันของผู้ป่วยไทยที่มีความสัมพันธ์ ของกระดูกขากรรไกรแบบที่ 1 (Class I) และ แบบที่ 2 (Class II) โดยใช้ภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟฟี Comparison of Maxillary Root Surface Areas in Thai Patients with Class I and Class II Skeletal Patterns Using Cone-beam Computed Tomography

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บทคัดย่อ

วัตถุประสงค์: เพื่อเปรียบเทียบพื้นที่ผิวรากฟันของ ฟันแท้ในขากรรไกรบนในผู้ป่วยไทยที่มีรูปแบบความ สัมพันธ์ของกระดูกขากรรไกรแบบที่ 1 (Class I) และ แบบที่ 2 (Class II) โดยใช้ภาพรังสีโคนบีมคอมพิวเตดโท โมกราฟฟี (Cone-beam computed tomography)

วัสดุและวิธีการ: คัดเลือกภาพภาพรังสีโคนบีมคอมพิว เตดโทโมกราฟฟี ก่อนการจัดฟันของผู้ป่วยไทยที่มีรูปแบบ ความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 1 และแบบที่ 2 จำนวน 30 คน ฟันในขากรรไกรบนจากฟันตัดซี่กลางถึง ฟันกรามซี่ที่สองทั้งสองข้างถูกเลือกเพื่อระบุขอบเขตและ

Abstract

Purpose: To compare root surface areas of maxillary permanent teeth in Thai patients with Class I and Class II skeletal patterns using cone-beam computed tomography.

Materials and Methods: Pretreatment cone-beam computed tomography images of 30 Thai orthodontic patients with Class I and Class II skeletal patterns were selected. Maxillary teeth from central incisor to second molar on both sides were chosen for investigation with 3-D dental

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สร้างโครงร่างของตัวฟันและรากฟันทั้ง 3 มิติ มีการระบุและทำเครื่องหมายบริเวณรอยต่อเคลือบฟันและเคลือบรากฟัน (cement-enamel junction) พื้นที่ที่อยู่ใต้รอยต่อเคลือบฟันและเคลือบรากฟันไปจนถึงปลายรากฟันจะถูกวัดเป็นพื้นที่ผิวรากฟัน ข้อมูลที่ได้ถูกนำไปวิเคราะห์ด้วยสถิติเชิงพรรณนา

ผลการศึกษา: พื้นที่ผิวรากฟันโดยเฉลี่ยของฟันแท้ในขากรรไกรบนแต่ละซี่จากฟันตัดซี่กลางถึงฟันกรามซี่ที่สองในผู้ป่วยที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 1 เท่ากับ 208.51, 193.87, 275.54, 258.70, 233.35, 447.41 และ 386.26 ตารางมิลลิเมตรตามลำดับ และ 203.55, 191.16, 262.44, 236.47, 227.91, 408.38 และ 351.70 ตารางมิลลิเมตรตามลำดับในผู้ป่วยที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 2

สรุป: จากภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟฟีพื้นที่ผิวรากฟันของฟันกรามน้อยบนซี่ที่หนึ่ง ฟันกรามบนซี่ที่หนึ่ง และฟันกรามบนซี่ที่สอง ในผู้ป่วยที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 2 มีค่าน้อยกว่าอย่างมีนัยสำคัญเมื่อเทียบกับกลุ่มที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 1

คำสำคัญ: มนุษย์ รากฟัน โคนบีมคอมพิวเตดโทโมกราฟฟี ขากรรไกรบน

crown and root construction. The cemento-enamel junction was identified and labeled; the area apical to the cemento-enamel junction was measured as the root surface area. Descriptive statistical analyses were performed.

Results: Mean root surface areas of maxillary permanent teeth from central incisor to second molar in patients with Class I skeletal pattern were 208.51, 193.87, 275.54, 258.70, 233.35, 447.41 and 386.26 mm^2, respectively, and 203.55, 191.16, 262.44, 236.47, 227.91, 408.38 and 351.70 mm^2, respectively in those with Class II skeletal pattern. Root surface areas of first premolar, first molars and second molars in patients with Class II skeletal pattern were significantly smaller than those with Class I skeletal pattern.

Conclusions: Root surface areas of maxillary first premolars, first molars and second molars in patients with Class II skeletal pattern were smaller than those with Class I skeletal pattern.

Keywords: humans, tooth root, cone-beam computed tomography, maxilla

Introduction

Since the forces required for orthodontic tooth movement are related to root surface area,[1] optimum force magnitude to initiate orthodontic movement for a particular tooth should be individualized based on the root surface area. Especially for distal movement of maxillary teeth in patients with a large overjet or crowding in the anterior region, this mechanical variation is quite common in patients with Class I or Class II skeletal patterns, but the suggested or proper orthodontic force for distalization was not clear. Because many studies have found some differences between patients with Class I and those with Class II skeletal patterns, for

example, differences in mastication force or bite force,[2] interradicular distance or buccal cortical bone thickness,[3,4] there might also be some differences in root surface area. Several studies have reported root surface areas in subjects from various races and age groups;[5-14] however, different root surface measuring methods were utilized in those studies and no skeletal classifications included. Since root surface area in Thai subjects has not yet been investigated, and because the combination of cone beam computed tomography (CBCT) and computer software programs should lead to both increased accuracy of measurement and a conservative way to assess data regarding living patients, this study was

aimed to measure and compare the root surface area of non-extracted, maxillary permanent teeth in Thai patients with Class I and those with Class II skeletal patterns.

Materials and Methods

This study was approved by the Human Experimentation Committee, Faculty of Dentistry, Chiang Mai University, Thailand (No.23/2558). Informed consent was obtained from all patients before CBCT images were acquired.

Pretreatment CBCT images of 15 Thai orthodontic patients with Class I skeletal relationship (ANB = 2 ± 2 degrees), and 15 with Class II skeletal relationship (ANB > 4 degrees) were selected. |Sample size was calculated with difference between two independent means (two groups), an effect size of 0.95 at a significance level of $\alpha = 0.05$ and power of test of 1-β = 0.8, using G*Power[15]. The calculation yielded at least 15 samples for each group. The inclusion criteria included: 1) patients had all permanent teeth with complete root formation (except for the third molars), 2) patient's age was between 15 and 25 years, 3) teeth should have no deviation in form, 4) no history of previous orthodontic treatment, 5) no severe craniofacial disorders or any systemic disease, and 6) no radiographic sign of periapical or bone lesions. All CBCT images were obtained using a Promax 3D (Planmeca OY, Helsinki, Finland) CBCT machine, at 8 cm x 8 cm field of view, 84 kVp, and 9 mA, and voxel size of 0.16 mm, in the Division of Oral and Maxillofacial Radiology, Department of Oral Biology and Diagnostic Sciences, Faculty of Dentistry, Chiang Mai University. Each patient was positioned in the radiographic device, sitting and keeping the occlusal plane horizontal.

Each CBCT image was converted from a Digital Imaging and Communications in Medicine (DICOM) file to a Stereolithography (STL) file, using the Mimics software (version 15.01, Materialise, Leuven, Belgium) with functions that allow for the production of 3-D models. All crowns and roots of the maxillary teeth were isolated from the rest of the skull using thresholding and region growing tools (Figure 1). By thresholding, the image is overlayed with a mask that contains only those pixels of the image with a value equal to or higher than the thresholding value. The pixels of the supporting structures with a similar value to the thresholding value were removed manually in each slice in all (sagittal, coronal and axial) views (Figure 2). Once each tooth was isolated, intentional extension spine markings were added manually to clearly identify the CEJ after 3-D dental reconstruction (Figure 3). Each 3-D dental reconstruction was saved and then exported to 3-Matic software (version 7.01, Materialise, Leuven, Belgium). Before root surface area measurement, the CEJ of each tooth was labeled, following the intentional extension spine marking in the 3-D dental reconstruction. The surface area apical to the CEJ was measured as the root surface area of each tooth (Figure 4). These methods were repeated twice for each selected tooth; then the average root surface area of each tooth was used.

Statistical analysis

The errors of the method and the reliability of the measurements were tested. The CBCT images of 30 maxillary jaws were randomly selected and re-measured by the same examiner after a four-week interval. The intra-examiner variation was assessed using an intraclass correlation coefficient (ICC). There was excellent reliability between the first and the second root surface area measurements by the same examiner as calculated by intraclass correlation coefficient (ICC > 0.98). The data were analyzed by descriptive analysis to obtain the mean and standard deviation of all measurements using SPSS version 16.0 for Windows (SPSS Inc., Chicago, Illinois,
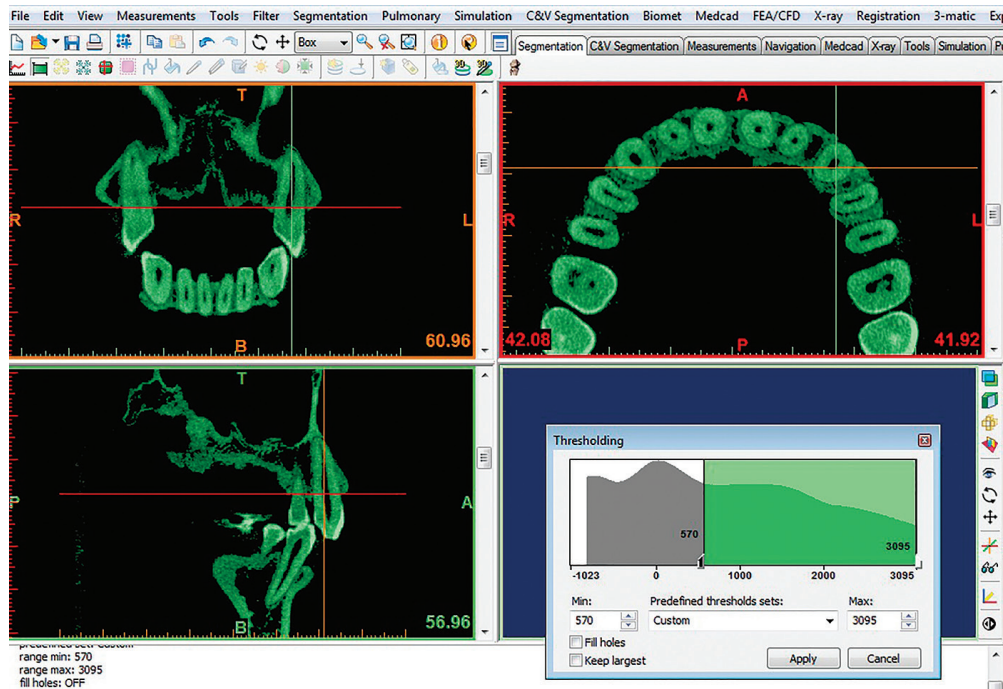
รูปที่ 1　　การจับภาพหน้าจอแสดงการเลือกขอบเขตพื้นที่ทำงานสำหรับตัวฟันและรากฟันในขากรรไกรบนทั้งหมด

Figure 1　　*Screen capture showing the threshold selected for the working area to present crowns and roots of all maxillary teeth.*
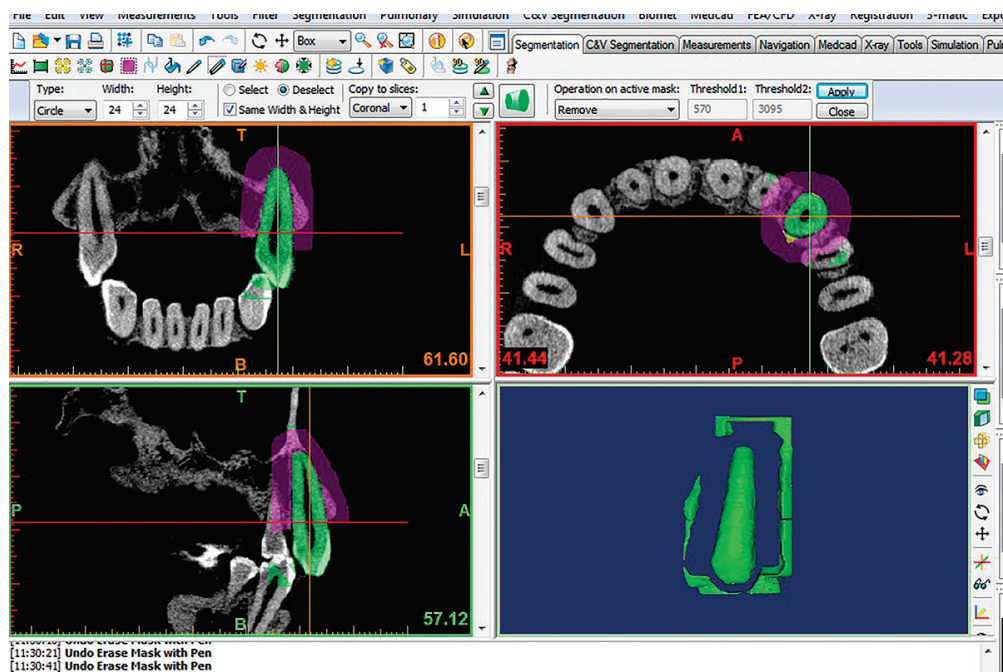

รูปที่ 2　　การจับภาพหน้าจอที่ระดับความสูงหนึ่ง แสดงการเลือกลบกระดูกรองรับรากฟันบริเวณฟันเขี้ยวบนด้านซ้าย (ตัวอย่าง) : ในมุมมอง
ระนาบแบ่งฟันหน้าหลัง, ระนาบแบ่งฟันซ้ายขวา และระนาบแบ่งฟันบนล่าง

Figure 2　　*Screen capture of one slice showing the supporting structures around the left maxillary canine (for example) manually
removed: in sagittal, coronal and axial views.*
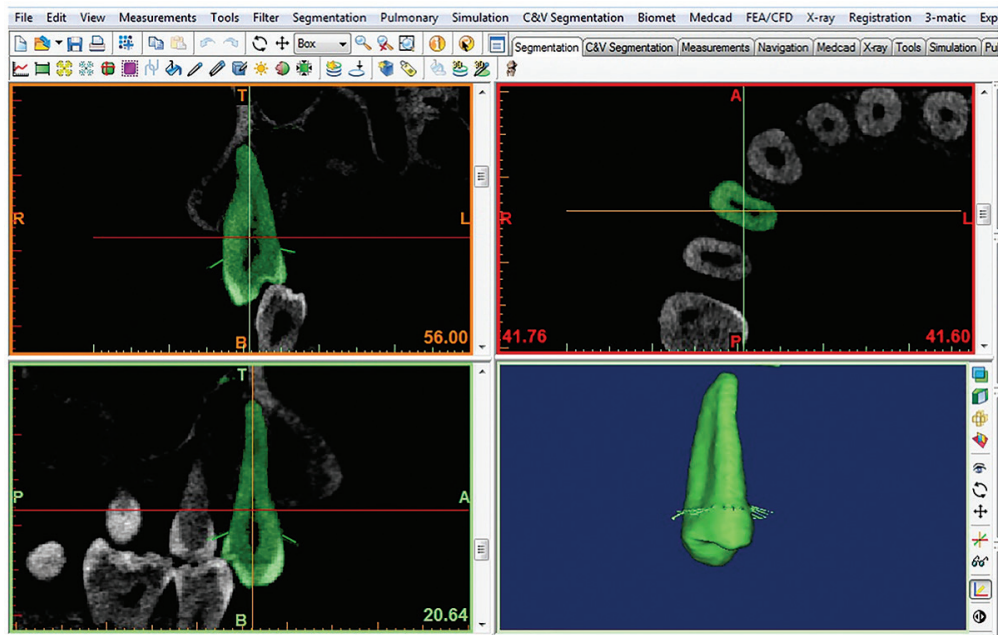
รูปที่ 3   การจับภาพหน้าจอแสดงการทำสัญลักษณ์บริเวณรอยต่อเคลือบฟันและเคลือบรากฟัน (เส้นสีเขียว) ในมุมมองระนาบแบ่งฟันหน้า หลังและระนาบแบ่งฟันซ้ายขวา เพื่อง่ายต่อการระบุตำแหน่งของรอยต่อเคลือบฟันและเคลือบรากฟันหลังการสร้างภาพฟันสามมิติ

Figure 3   Screen capture showing intentional extension spine markings (green lines) at the CEJ in both sagittal and coronal views for clearly identifying the CEJ after 3-D dental reconstruction.
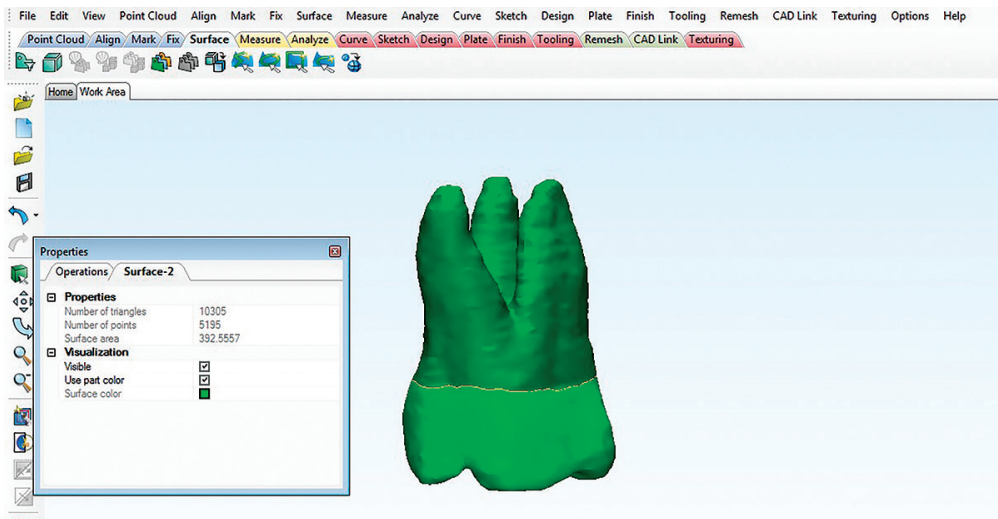
รูปที่ 4   การจับภาพหน้าจอแสดงพื้นที่ผิวรากฟันกรามบนซี่ที่หนึ่ง วัดโดยโปรแกรม 3-Matic (พื้นที่สีเขียวเข้มจากบริเวณรอยต่อเคลือบฟันและเคลือบรากฟันถึงปลายรากฟัน)

Figure 4   Screen capture showing the root surface area of maxillary first molar measured by the 3-Matic program (dark green area from CEJ to root apex).

USA). Results were considered statistically significant at $p < 0.05$. The unpaired t-test was used to analyze differences between measurements on the right and the left sides. No significant difference was found, so the measurements were pooled for analysis. An independent t-test was used to compare the mean values of all collected measurements from patients with Class I and Class II skeletal patterns.

Results

Each CBCT image included seven maxillary permanent teeth on both sides; therefore, the number of samples included 30 samples per tooth type per group (n=30/tooth/skeletal classification). The mean age of the patients with Class I skeletal pattern (12 females and 3 males) was 20.12 (15.67-28.17) years, and that of the patients with Class II skeletal pattern (10 females and 5 males) was 19.98 (15.58-27.92) years (Table 1).

The mean and standard deviation of root surface area of the maxillary teeth in patients with Class I and Class II skeletal patterns are presented in Figure 5. The mean root surface area of maxillary teeth ranged from 191.16 to 447.41 mm^2. The greatest root surface area was found in the maxillary first molars in patients with Class I (447.41±51.24 mm^2) and Class II (408.38±47.77 mm2) skeletal patterns. The smallest root surface area was found in the maxillary

lateral incisors in patients with Class I (193.87±32.16 mm^2) and Class II (191.16±25.36 mm^2) skeletal patterns. The maxillary root surface areas in Class II skeletal pattern were smaller than those in Class I skeletal pattern in all tooth types, but only those of first premolars, first molars and second molars in Class II skeletal pattern were significantly smaller than those in Class I skeletal pattern (P=0.044, P=0.003, P=0.036, respectively) (Figure 5).
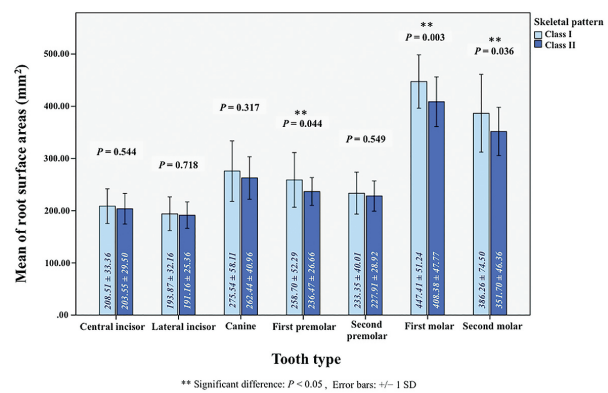
รูปที่ 5 แสดงค่าเฉลี่ยของพื้นที่ผิวรากฟันของแต่ละซี่ โดยใช้ข้อมูลจากภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟี ในผู้ป่วยที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 1 และในผู้ป่วยที่มีความสัมพันธ์ของกระดูกขากรรไกรแบบที่ 2

Figure 5 Mean root surface areas of each maxillary tooth type measured from Cone-beam computed tomography images in patients with Class I, and in those with Class II skeletal patterns.

ตารางที่ 1 แสดงอายุ (ปี) แจกแจงโดยความสัมพันธ์ของกระดูกขากรรไกร เพศ และจำนวนภาพรังสีโคนบีมคอมพิวเตดโทโม-กราฟี (n)

Table 1 Ages (years) distributed by skeletal pattern, sex, and number of samples (n) for Cone-beam computed tomography image selection.

Skeletal pattern	Sex	n	Age (years)			
			Minimum	Maximum	Mean	Standard deviation
Class I	Female	12	15.67	28.17	20.13	3.38
	Male	3	15.67	22.33	20.08	3.82
Class II	Female	10	15.58	26.17	20.18	3.73
	Male	5	16.17	27.92	19.57	4.88

Discussion

The CBCT images of the root surface areas in both Class I and Class II skeletal patterns indicated that, the first molars showed the largest root surface areas, and the lateral incisors the smallest. Our results concur with those reported by previous studies (Table 2).[5,6,9,12]

Although the root surface areas of all maxillary teeth in Class II skeletal pattern were smaller than those in Class I skeletal pattern, only the root surface areas of first premolars, first molars, and second molars showed significant differences. Araújo et al.[1] suggested that lower bite force might be found in subjects with Class II skeletal pattern than in Class I skeletal pattern. This lower bite force might result from the compensation of tooth inclination and angulation for Class II skeletal discrepancies, and this compensation might cause improper occlusal contact.[16-18] Other investigators[19-21] have reported that lower bite force was associated with shorter root length and smaller root surface area, especially in posterior regions. Normal occlusal loading and function is responsible for normal development of alveolar bone, dental root and associated supporting structures. Occlusal hypofunction decreases alveolar bone mass, accelerates bone resorption, causes deficient root development and leads to atrophic changes in the periodontal ligament[22-24] as reported

with short dental roots from incisors to premolars in patient with anterior open bite.[25-26] In addition, the smaller root surface area in Class II skeletal pattern may be associated with the wider interradicular distances reported by Khumsarn et al.[3] This association may need further investigation.

From the study by a group of Seon-Young Kim in 2013,[27] they reported that the dental root length of all tooth types are longer in male than female, So we tried to select the CBCT images of sample in most similar number of gender for each group as possible to reduce this influence factor.

Our CBCT measurement method was accurate and appropriate, especially for measuring non-extracted or vital teeth.[28] The measured teeth in this investigation were selected from the complete maxillary dentitions of 30 living subjects. So, the inclusion criteria of the samples were greatly improved from those of the previous root surface area investigations,[5,6,9,12] in which extracted teeth were selected from different subjects. Such selections had a chance for bias.

Conclusions

The root surface areas measured from CBCT images in Class II skeletal pattern were smaller than those in Class I skeletal pattern in all tooth types, especially those of first premolars, first molars and

ตารางที่ 2   แสดงค่าพื้นที่ผิวรากฟันที่วัดได้จากการศึกษานี้และการศึกษาอื่น ๆ[5,6,9,12]

Table 2   *Maxillary root surface areas of this study and others.*[5,6,9,12]

Research study Tooth type	This study (2016)		Yamamoto *et al.* (2006)	Hujoel *et al.* (1994)	Tylman *et al.* (1960)	Boyd *et al.* (1958)
	Class I	**Class II**				
Central incisor	208.5±33.4	203.6±29.5	200.7±25.9	200	139	204.5
Lateral incisor	193.9±32.2	191.2±25.4	202.9±25.2	180	112	177.3
Canine	275.5±58.1	262.4±41.0	291.9±38.8	290	204	266.5
First premolar	258.7±52.3	236.5±26.7	249.4±37.3	250	149	219.7
Second premolar	233.4±40.0	227.9±28.9	232.9±32.0	230	140	216.7
First molar	447.4±51.2	408.4±47.8	467.7±61.6	475	335	454.8
Second molar	386.3±74.5	351.7±46.3	368.4±52.4	405	272	416.9

second molars in Class II skeletal pattern, which were significantly smaller. These findings suggest that the sagittal skeletal pattern may be the principle factor in determining the root surface area, especially in the posterior region. So, the root surface areas might be associated with the sagittal skeletal pattern. The association between the vertical skeletal pattern and the root surface areas should also be further investigated. The reported mean root surface area may serve as a baseline for future study and for clinical decisions, such as identifying the amount of force required for orthodontic movement for each patient or for each skeletal type.

Acknowledgements

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