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Anatomical analysis of periapical bone of maxillary posterior teeth: a cone beam computed tomography study

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Abstract

Objectives: To investigate the periapical bone thicknesses of maxillary posterior teeth at the preferred level for root resection (3 mm apical to the root end) and to determine vertical distances from apex to maxillary sinus floor (MSF) using cone beam computed tomography (CBCT) scans.

Methods: CBCT scans were collected from 341 subjects (2389 teeth). Associations of bone thicknesses and vertical distances with age and sex were determined by one-way analysis of variance.

Results: At the level of root-end resection, buccal bone was the thickest over the mesiobuccal roots of second molars (mean, 2.99 mm) and thinnest over the double-root first premolars (mean, 0.29 mm). In maxillary posterior teeth, thicker buccal bone was found in men than in women. The mesiobuccal roots of second molars were nearest to the MSF (mean, 1.33 mm), and were also most frequently extended into the sinus cavity (15.81%). Subjects more than 40 years of age had larger vertical distances from root apices to MSF in the molar region, compared with younger subjects.

Conclusions: Generally, periapical bone was thicker in men, and root apices were located nearer to the MSF in younger subjects. Age and sex should be considered before endodontic microsurgery.

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Keywords

Bone thickness, cone beam computed tomography, endodontic microsurgery, maxillary posterior teeth, maxillary sinus floor, bicuspid, tooth root, molar

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Introduction

Endodontic microsurgery comprises treatment for periapical pathology that is unresolved by nonsurgical endodontic treatment or retreatment.[1] Maxillary posterior teeth are vested in bones surrounding the maxillary sinus. The posterior vestibule has restricted space, limiting operative vision and movements.[1] To facilitate endodontic microsurgery, a comprehensive understanding is needed regarding bony architecture around these teeth and their relationships with the maxillary sinus.

The maxillary sinus cavity is bounded by zygomatic bone, alveolar process, and inferior orbital surface of the maxilla.[2] The maxillary sinus floor (MSF) extends from the maxillary first premolar to the maxillary tuberosity, and may extend to the canine. The maxillary sinus may extend between adjacent teeth or between individual roots of maxillary posterior teeth. Maxillary posterior tooth roots might exhibit close relationships with the MSF,[3] such that odontogenic infections or foreign materials in the roots or periapical region can spread into the maxillary sinus, causing maxillary sinusitis and oroantral communication during endodontic treatment. During retrograde microsurgery, buccal and palatal periapical bone thicknesses can affect visualization and surgical access.[4,5] Minimal osteotomy during endodontic microsurgery is recommended, while ensuring surgical goals are achieved.[6] Thus, anatomical knowledge of overlying tissues can aid in avoiding unnecessary tissue removal or collateral damage during surgery.

Cone beam computed tomography (CBCT) can avoid some disadvantages of plain radiography[7–9] and provide detailed information regarding the region of interest in endodontic microsurgery.[10–13] Of lesions identified on CBCT images, 34% were reportedly undetected by periapical radiography in maxillary posterior teeth. CBCT can also reveal missed root canals, sinus membrane thickening, lesion expansion into the maxillary sinus, and the presence of apicomarginal defects.[14]

At least 3 mm of the root end must be resected to diminish 98% of apical ramifications and 93% of lateral canals.[15] Assessment of bone thicknesses at the surgical resection level is valuable in treatment planning for endodontic microsurgery.[5] Bone thicknesses have been evaluated over the root apices of maxillary posterior teeth;[4,16–19] however, at the root resection level (3 mm apical to the root end), the relationships of periapical bone thicknesses with age and sex remain unknown.[5] The present study investigated buccal and palatal bone thicknesses of maxillary posterior teeth at the optimal level of root-end resection in a large sample of patients from the Mongoloid population; the study also investigated vertical distances from the root apices of maxillary posterior teeth to the MSF, and assessed the relationships of buccal and palatal bone thicknesses and vertical distances with age and sex.

Methods

Subjects

This study was approved by the Ethics Committee of the Guanghua School and Hospital of Stomatology, Sun Yat-sen University (ERC-2017-09); the requirement for informed consent was waived by the Ethics Committee due to the retrospective nature of the study. Eight hundred twenty-six CBCT images were randomly selected from an archive of 2000 radiographs with a field of view of 16×7 cm and a voxel size of 0.20 mm; these provided adequate resolution to display the entire region containing maxillary posterior teeth. These CBCT radiographs had been taken for diagnostic purposes before treatment at various departments, including endodontics, surgery, and orthodontics, in the Hospital of Stomatology, Sun Yat-sen University during the period between January 2013 and January 2016.

CBCT scans were included if they displayed maxillary permanent posterior teeth with complete root formation. CBCT scans were excluded if they met any of the following criteria, which were adapted from those of previously published studies:[19–21] 1) periapical lesions were present; 2) cystic or traumatic lesions were located in the maxillary region; 3) foreign matter was located in the region of interest; 4) any maxillary tooth showed resorption; 5) significant periodontal disease/bone loss was present.

Radiographic evaluations

Images were acquired using a CBCT scanner (DCTPRO, VATECH, Yongin-Si, Republic of Korea). The operating parameters were set at 90.0 kV and 9 mA, with a scanning time of 24 s. Measurements were evaluated using Ez3D 2009 software (Vatech Corporation, Hwaseong-si, Gyeonggi-do, Republic of Korea). The images were assessed by an oral radiologist (MC) and an endodontist (XH), both of whom used identical criteria (described in the next paragraph). Disagreements were resolved by consensus with another endodontist (LL). To avoid vision fatigue, each examiner was required to take a 10-minute break after assessment of three successive CBCT images.[5]

To ensure measurements were at the optimal level of root-end resection, a 3-mm line was drawn from the root apex along the longitudinal axis of the root in the CBCT coronal plane (Figure 1a).[5] The minimum (i.e., thinnest) buccal and palatal bone thicknesses were measured in the axial plane at this level, in accordance with the method of Lavasani et al. (Figure 1b).[5] The shortest vertical distance from the center of each root apex to the MSF was recorded in the coronal plane (Figure 1a). Root apices located under the MSF were defined as positive values, while root apices protruding into the MSF were defined as negative values. Vertical relationships between the root apices and MSF in the coronal plane were classified into three categories: Type V1, in which a root extended into the maxillary sinus cavity; Type V2, in which a root was oriented in a manner tangential to the MSF; and Type V3, in which a root was separate from the MSF (Figure 2).[21]Age and sex were also recorded for each patient, to assess their associations with the preceding measurements. Patients were divided into four age groups: $\leq$20 years, 21 to 40 years, 41 to 60 years, and $>$ 60 years.[20,21]

Statistical analysis

Statistical analyses were performed using SPSS software (version 20, IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) was used to compare differences between the buccal and palatal bone thicknesses (at the optimal resection level) and the vertical distances from root

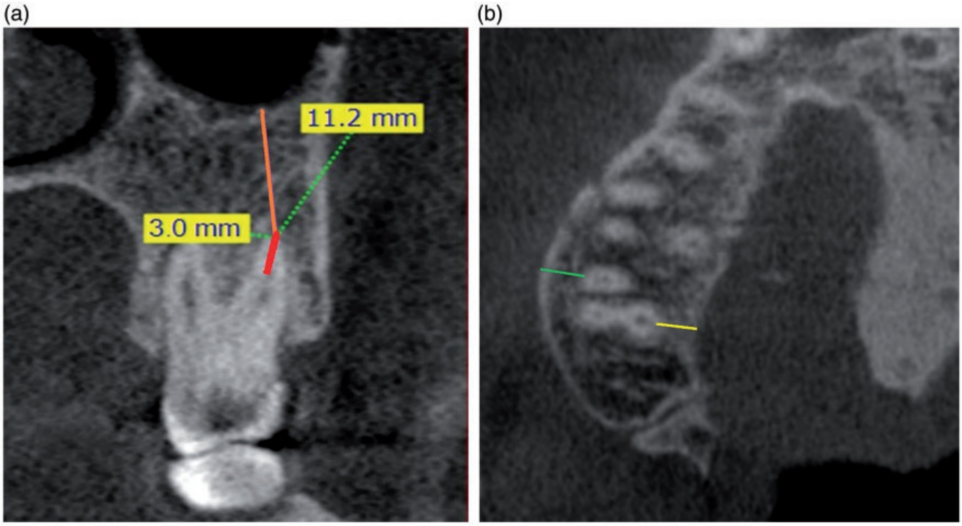

Figure 1. Measurements of vertical distances and buccal and palatal bone thicknesses of the maxillary posterior teeth in accordance with the method of Lavasani et al.[5] (a) Measurements in the coronal plane. The orange line indicates the shortest vertical distance from the root apex to the maxillary sinus floor; the red line (length = 3 mm) was drawn from the root apex along the longitudinal axis of the root of the maxillary posterior teeth. (b) Measurements in the axial plane. The green line indicates the thinnest buccal bone over the buccal root; the yellow line indicates the thinnest palatal bone over the palatal root.

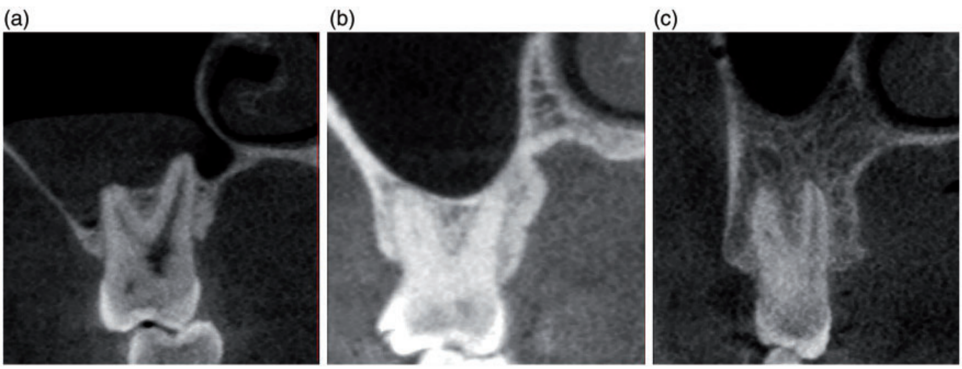

Figure 2. Coronal cone beam computed tomography images of three types of vertical relationships between the root apices of maxillary posterior teeth and the maxillary sinus floor. (a) Type V1, in which a root extends into the maxillary sinus cavity. (b) Type V2, in which a root is oriented tangentially to the maxillary sinus floor. (c) Type V3, in which a root is separate from the maxillary sinus floor.[17]

apices to MSF, based on either age or sex. The Bonferroni test was used for multiple comparisons among age groups. P values < 0.05 were considered to be statistically significant.

Results

Of the randomly selected 826 CBCT images, 341 met the above-described inclusion and exclusion criteria for inclusion in the study. The resulting study population consisted of 134 men and 207 women, with a mean age of 37.5 years (range, 15–75 years). The distributions of maxillary posterior teeth in this study are shown in Table 1. Based on the limited sample size of double-root second molar ($n = 32$), the data could not be effectively pooled for analysis of associations with sex and age; thus, only descriptive results are reported for double-root second molars (Table 2).

Buccal and palatal bone thicknesses at the optimal resection level

The mesiobuccal (MB) roots of second molars exhibited the greatest buccal bone thickness (mean, 2.99 mm), while the buccal roots of double-root first premolars exhibited the least buccal bone thickness (mean, 0.29 mm). The greatest palatal bone thickness was observed over single-root first premolars (mean, 4.31 mm), whereas the least palatal bone thickness was observed over palatal roots of first molars (mean, 1.82 mm). The buccal and palatal bone thickness of maxillary posterior teeth, stratified according to sex, are presented in Figures 3 and 4. Men had thicker buccal bone than women ($P < 0.05$), with the exception of that over the buccal roots of double-root second premolars (Figure 3). Men also had greater palatal bone thickness than women ($P < 0.05$), with the exception of that over the palatal side of single-root first premolars and over the palatal roots of double-root first premolars (Figure 4). Buccal bone in the molar region tended to become thinner with age. Palatal bone over single-root first premolars in subjects > 40 years of age showed a significant reduction in thickness, compared with that in subjects ≤ 20 years of age ($P < 0.05$).

Table 1. Distributions of maxillary posterior teeth included in this study.

Type of tooth	n
First premolar	
Single-root	297
Double-root	281
Second premolar	
Single-root	504
Double-root	96
First molar	
Triple-root	616
Second molar	
Double-root	32
Triple-root	563
All teeth	2389

Vertical distances and relationships between root apices of maxillary posterior teeth and the MSF

MB roots of maxillary second molars were located nearest to the MSF (mean distance, 1.33 mm). The greatest vertical distance was observed at the buccal roots of double-root first premolars (mean distance, 7.41 mm). The Type V1 relationship was most frequently found in the MB roots of second molars (15.81%), followed by the palatal roots of double-root second premolars (11.46%), distobuccal roots of second

Table 2. Characteristics of 32 double-root second molars included in this study.

Root	Mean buccal bone thickness (mm)	Mean palatal bone thickness (mm)	Mean vertical distance (mm)	Vertical relationship		
				V1	V2	V3
Buccal	3.51	–	2.05	4	5	23
Palatal	–	2.35	3.17	2	5	25

Vertical distance, distance from buccal or palatal apex to maxillary sinus floor.

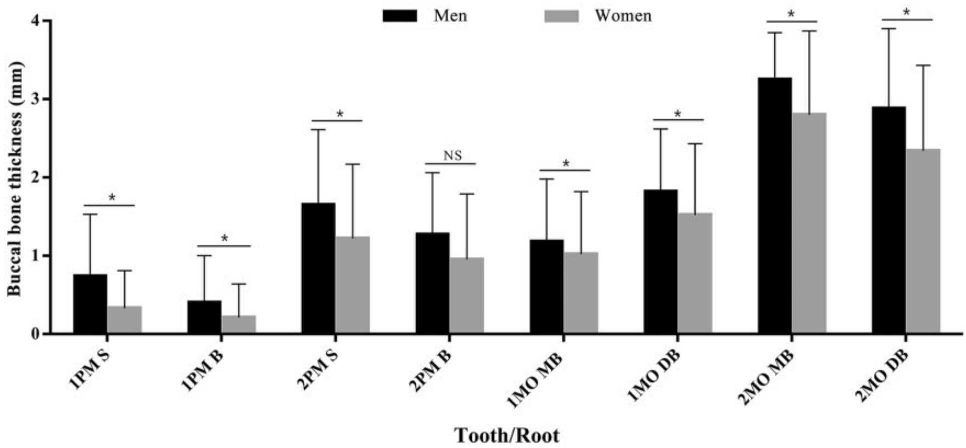

Figure 3. Buccal bone thicknesses (mm) of maxillary posterior teeth at the optimal level of root-end resection, according to sex.
1PM S, first premolar single root; 1PM B, first premolar buccal root; 2PM S, second premolar single root; 2PM B, second premolar buccal root; 1MO MB, first molar mesiobuccal root; 1MO DB, first molar distobuccal root; 2MO MB, second molar mesiobuccal root; 2MO DB, second molar distobuccal root.
*$P < 0.05$. NS, not significant (one-way analysis of variance).

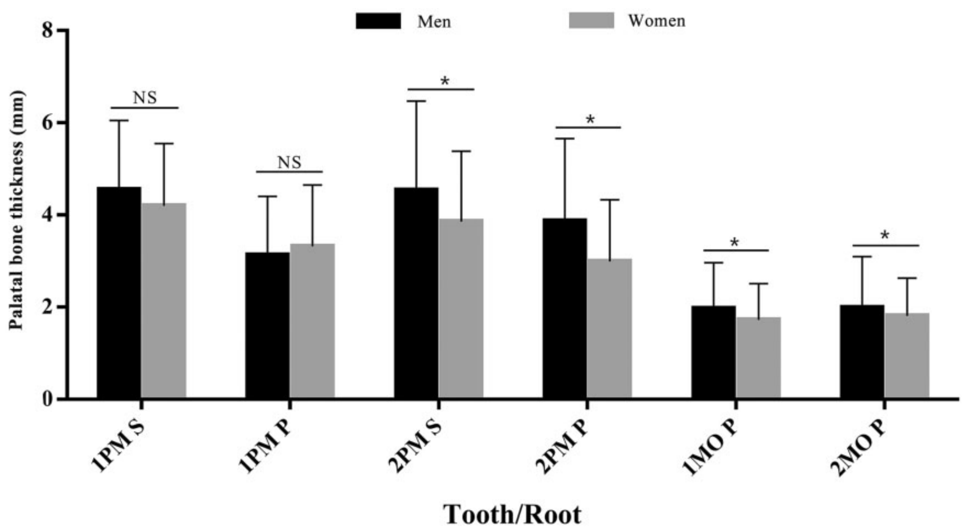

Figure 4. Palatal bone thicknesses (mm) of maxillary posterior teeth at the optimal level of root-end resection, according to sex.
1PM S, first premolar single root; 1PM P, first premolar palatal root; 2PM S, second premolar single root; 2PM P, second premolar palatal root; 1MO P, first molar palatal root; 2MO P, second molar palatal root.
*$P < 0.05$. NS, not significant (one-way analysis of variance).

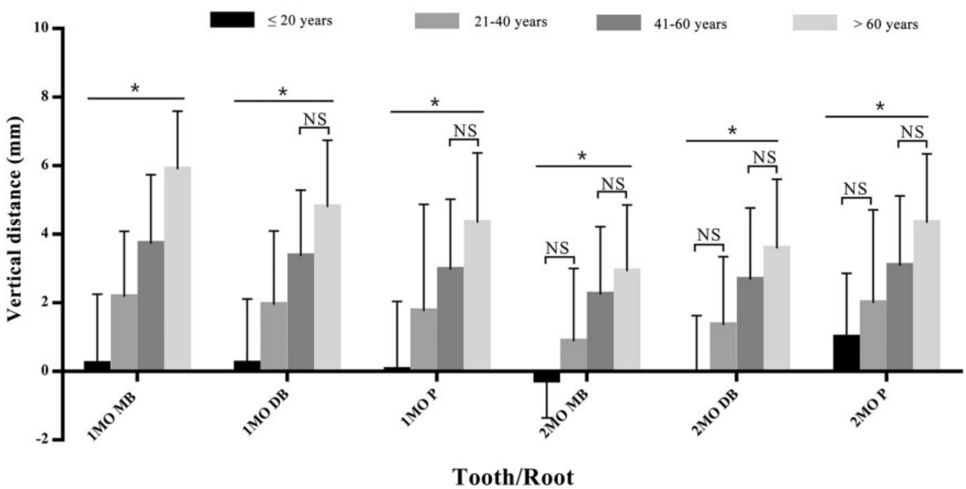

Figure 5. Vertical distances (mm) from the root apices of maxillary molars to the maxillary sinus floor, according to age. Comparisons among groups were performed by one-way analysis of variance, followed by Bonferroni's post hoc test. $^{*}P < 0.05$. NS, not significant.

molars (11.19%), and palatal roots of first molars (10.88%). The vertical distances between root apices of molars and the MSF, stratified according to age, are presented in Figure 5. In the premolar region, vertical distances from root apices to the MSF tended to increase with age. In the molar region, vertical distances from root apices to the MSF were greater in subjects > 40 years of age than in younger subjects ($P < 0.05$) (Figure 5). With respect to sex, root apices tended to be closer to the MSF in men than in women. Vertical distances from double-root first premolars and second molars to the MSF were significantly different between men and women ($P < 0.01$).

Discussion

With regard to the literature describing buccal and palatal bone thicknesses over maxillary posterior teeth,[4,5,16–19] only Lavasani et al.[5] measured these thicknesses at the optimal resection level (3.0–3.6 mm apical to the root end); however, this measurement was performed in a population within the United States. In our study, the thinnest buccal bone at the optimal resection level was found over the buccal roots of double-root first premolars, whereas the thickest buccal bone at the optimal resection level was found over the MB roots of the second molars. These findings were in agreement with those of previous reports.[5] Regarding the mean thicknesses of bone, our study showed that all buccal bone over the MB and distobuccal roots of molars, as well as palatal bone over the roots of maxillary posterior teeth, were thicker than those reported by Lavasani et al.; however, the buccal bone thicknesses over single-root and double-root second premolars were similar between these two studies.[5] Overall, our findings showed that relative buccal and palatal bone thicknesses at the resection level of molar roots were higher in the Mongoloid population, which suggests that endodontic microsurgery in maxillary molars may be more challenging in Mongoloid patients than in Caucasian patients. Compared with the findings of another report based on an Asian population,[19] the present study demonstrated thinner periapical bone. This difference might be due to differences in the levels chosen for assessment (root apex vs. resection level). Lavasani et al.[5] also suggested that the bone at root apices was considerably thicker than that at the optimal resection level.

In the present study, buccal bone tended to be thicker in men than in women, with the exception of bone over the buccal roots of double-root second premolars; this was similar to the finding of Jang et al.[19] This difference between men and women could result from the difference in their general skeletal sizes. To plan surgical access and estimate the depth of resection for endodontic microsurgery, clinicians should consider sex differences among patients. In the present study, the longest vertical distance from the maxillary posterior teeth to the MSF was observed in the buccal roots of double-root first premolars, whereas the shortest vertical distance from the maxillary posterior teeth to the MSF was observed in the MB roots of second molars; these findings were consistent with those of previous reports.[5,17,19,21–23] We found that, in the premolar and molar regions, vertical distances from root apices to the MSF tended to increase with age; a similar tendency was reported by Jang et al.[19] Given the shorter vertical distances in younger subjects, meticulous surgery is essential to avoid unnecessary tissue removal and damage in endodontic surgery. During orthograde root canal treatment, error tolerance was further reduced with respect to length estimation of the palatal roots of double-root premolars and buccal roots of the second molars, as the apices were located nearly within the MSF for subjects $\leq$20 years of age.

Regarding vertical relationships between the root apices of maxillary posterior teeth and the MSF, we found that the Type V1 relationship was most frequently present in the MB roots of second molars (15.81%); this was consistent with the vertical distance findings, which showed that the MB roots of the second molars were located nearest to the MSF. Moreover, from anterior to posterior, the Type V1 relationship was observed with increasing frequency in the buccal roots of maxillary posterior teeth. Tian et al.[21] reported that subjects <40 years of age showed a greater likelihood of maxillary root location above/inside the MSF. Similarly, we found that subjects <40 years of age had shorter vertical distances in the present study. Thus, to avoid sinus perforation and odontogenic sinusitis, clinicians should closely monitor the treatment of maxillary posterior teeth in younger patients. When comparing the specific values of the root apices in relation to the MSF, the results from the present study slightly differed from those of previous studies in Korean, Turkish, and Brazilian populations.[13,17,19,20,24–26] These discrepancies might be due to ethnic differences. Individuals of different ethnic backgrounds exhibit variation in genetic characteristics, which might result in distinctive topographical and anatomical relationships.[23]

Some additional aspects should be considered when interpreting the findings of this study. Interestingly, although our study population was generated by random selection from image archives, significantly more CBCT images were obtained from women, compared with those from men. A similar trend was reported in previous studies.[5,21,23,25] This might suggest that there is greater awareness of oral care needs in women than in men. In statistical analysis, two-way ANOVA was initially used to analyze two effects (age and sex) on dependent variables (bone thickness and vertical distance); this showed that the interaction of the main effects was statistically significant in only a few root apices ($P<0.05$). Nevertheless, the interaction of the main effects showed a weak impact on dependent variables in further analysis.

This indicated that the relationship of factor one (sex) and the response (the collected data) was not significantly influenced by the presence of factor two (age). Thus, for a concise presentation of the data, one-way ANOVA was performed to compare the data according to either age or sex. In addition, vertical distances were measured by CBCT radiographs in this research; therefore, patients who previously had undergone maxillary sinus lifting or orthodontic treatment could not be excluded by radiographs, which might have influenced the results. Further studies should be conducted that include clinical information and medical history of the analyzed patients.

Conclusion

Our study evaluated buccal and palatal bone thicknesses at the optimal level of root-end resection, as well as vertical distances from the apex to the MSF in a Mongoloid population, and investigated the relationships of these parameters with age and sex. We found that, at the preferred level for root resection (3 mm apical to the root end), buccal bone was thinnest over the buccal roots of double-root first premolars, whereas it was thickest over the MB roots of second molars. In addition, the MB roots of maxillary second molars were located nearest to the MSF and most frequently extended inside the maxillary sinus cavity. Finally, subjects > 40 years of age tended to have larger vertical distances than younger subjects; generally, men had thicker buccal and palatal bone than women.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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