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ORIGINAL ARTICLE

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Comparison of cortical bone thickness and root proximity at maxillary and mandibular interradicular sites for orthodontic mini-implant placement

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Structured Abstract

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Objectives – To compare maxillary and mandibular cortical bone thickness and rootic proximity for optimal mini-implant placement.

Setting and Sample Population – CT images from 14 men and 14 women were used to evaluate buccal interradicular cortical bone thickness and root proximity from mesial of the central incisor to the 2nd molar. Cortical bone thickness was measured at 0°, 15°, 30°, and 45° angles relative to the root surface using three-dimensional images.

Results – For the cortical bone thickness, there was no statistically significant difference between the maxilla and the mandible in the anterior area; however, there was a significant difference in the posterior area. Cortical bone in the maxilla, mesial and distal to canine interradicular sites, was thickest while thickness in the mandible exhibited a gradual anterior to posterior increase. Cortical bone thickness in the maxilla increased as both level and angle increased, while the cortical bone thickness in the mandible was greatest at 4 mm from the alveolar crest. Root proximity mesial and distal to 2nd premolar interradicular sites was greatest.

Conclusion – Based on our results, cortical bone thickness depends on the interradicular site rather than sex or individual differences.

Key words: cortical bone thickness; inter-arch difference; root proximity

Introduction

Many studies have evaluated cortical bone thickness and bone density for placement of mini-implants because bone thickness and density are reported to be critical for stability (1–5). Cortical bone thickness has been reported to increase as the insertion angle of the mini-implant increased (1). Another study showed that in the majority of sites placement at 30° and 45° angles and at 4–6 mm from the alveolar crest appeared to increase bone to mini-implant contact significantly; however, an exception was observed at the 2 mm level apical to the alveolar crest (6). The same contact characteristics were reported for the cortical bone thickness in mandible (7). The cortical bone thickness at the 2 mm level apical to

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the alveolar crest at a 0° angle exhibited good contact because such sites near the alveolar crest have cortical bone occupying the space between buccal and lingual sides.

Root proximity is a critical factor when placing a 1.2–2.0 mm diameter mini-implant because a minimum of 3–4 mm is required between the mini-implant and the surrounding structures (8). It has been reported that there were no statistically significant differences in root proximity in the maxillary buccal interradicular sites, whereas the anterior mandibular region has shown insufficient root proximity (6, 7). In effect, buccal cortical bone thickness and root proximity appear to be critical for successful anchoring of a mini-implant (9, 10). Few studies have investigated the differences of interradicular anatomy in the maxillary and mandibular cortical bone thickness and root proximity at different insertion angles. The purpose of this study was to compare maxillary and mandibular cortical bone thickness and root proximity for optimal mini-implant placement, and to assess intra- and inter-subject variability.

Material and methods

Twenty-eight subjects (14 men and 14 women; mean age 27.3 years, range 23–35 years) volunteered to participate in this study and gave their informed consent. Patients with severe skeletal discrepancies, high mandibular plane angles, asymmetric occlusions, absence of any permanent teeth except 3rd molars, impacted teeth, severe crowding, or radiographic signs of periodontal disease were excluded. The study protocol was approved by the Ewha Womans University Mokdong Hospital Ethics Committee, Seoul, Korea.

High resolution CT images (SOMATOM Sensation, Siemens, Berlin, Germany) were obtained from each subject at 200 mm field of view, 120 kV, 200 mA, scanning rotation 0.5 s, average radiation exposure dose 31.32 CTDIvol, and slice thickness of 1.0 mm. CT images, saved as Digital Imaging and Communications in Medicine (DICOM) files, were reconstructed into 3-dimensional images using V-works 4.0™ (CyberMed, Seoul, Korea). To measure cortical bone thickness, sagittal images were prepared along a line passing through the contact point and parallel to the long axis of the teeth. Buccal cortical bone thickness in the interradicular site was measured at the 2, 4, and 6 mm levels from the alveolar crest at four different mini-implant insertion angles: 0°, *i.e.* perpendicular to the long axis of a tooth, and at 15°, 30°, and 45° angles relative to the root surface (Fig. 1).

To measure root proximity, the reconstructed CT images were bisected along a line parallel to the occlusal plane at 2, 4, and 6 mm levels from the alveolar crest. Buccal, central, and vertical interradicular spaces were measured to evaluate root proximity at each level. The buccal interradicular space was the distance between intersecting points made by two tangent lines, one tangent to the proximal root surface and the other tangent to the buccal root surface. The central interradicular space was the shortest distance between tangent lines to the proximal root surfaces and parallel to the long axis of the roots. The horizontal interradicular space was the distance between the buccal and central interradicular spaces (Fig. 2).

Statistical analysis

A multilevel linear mixed model was applied because of the presence of multiple correlations among tooth position, jaw position and individual subject in the data. Statistical analyses were carried out using PROC MIXED (SAS 9.1, SAS Institute, Cary, NC, USA). The Bonferroni adjustment was used when comparing

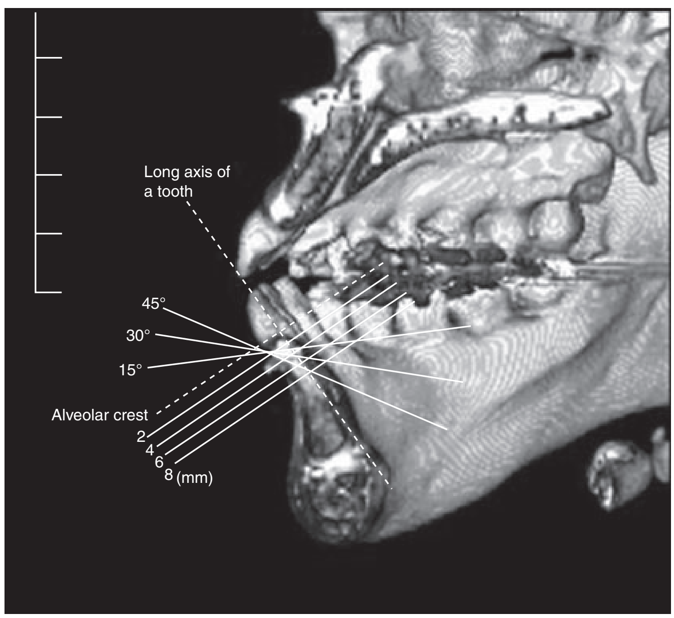

Fig. 1. Cortical bone thickness was measured at 2, 4, and 6 mm from the alveolar crest and at four different angles of 0°, 15°, 30°, and 45°.

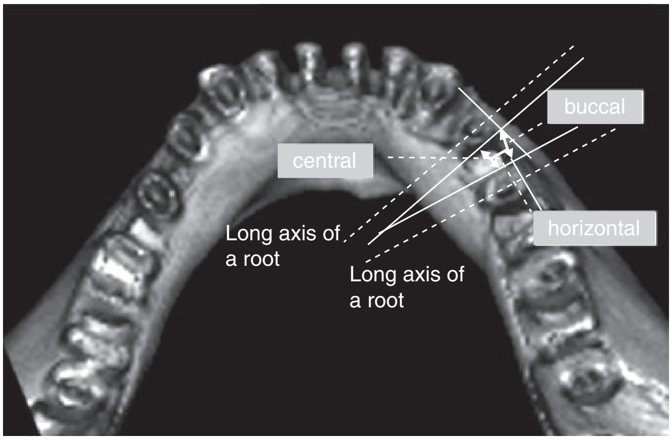

Fig. 2. For root proximity, three values were evaluated. The buccal interradicular space is the distance between the intersecting points made by two tangent lines, one tangent to the proximal root surface and the other tangent to the buccal root surface. The central interradicular space is the closest distance between tangent lines to proximal root surfaces and parallel to the long axis of the roots. The horizontal interradicular space is the distance between the buccal and central interradicular spaces.

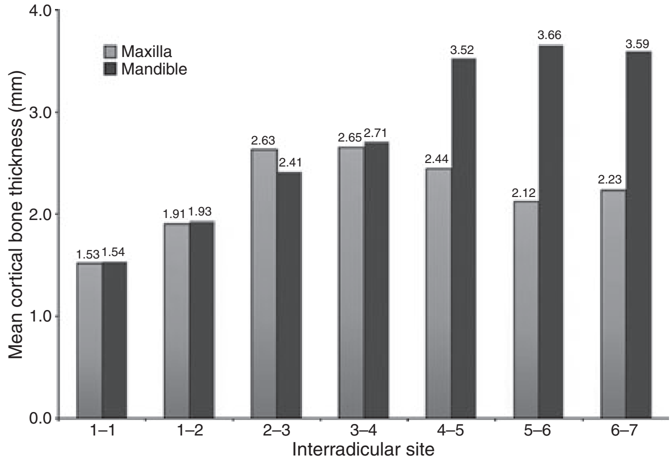

Fig. 3. Mean values of the cortical bone thickness; comparisons between maxillary and mandibular interradicular sites (1) central incisor, (2) lateral incisor, (3) canine, (4) 1st premolar, (5) 2nd premolar, (6) 1st molar, and (7) 2nd molar.

multiple mean differences. All values were considered significant when $p < 0.05$.

Results

To evaluate intra-examiner reproducibility, five randomly selected sites were re-measured by the same examiner after a 4-week interval. There was no significant difference in measurements between the two time-points. Furthermore, there were generally no significant differences between male and female subjects in cortical bone thickness ($p > 0.05$). Individual variability for the cortical bone thickness at a specific interradicular site was five times as large as the variability between subjects (data not shown).

Regarding maxilla and mandible cortical bone thickness, there was no statistically significant difference in the anterior area while a significant difference was found in the posterior area (Fig. 3). The cortical bone thickness in the mandibular posterior area was significantly greater compared to that in the maxillary posterior area. In the maxilla, the areas mesial and distal to the canine interradicular sites had the thickest cortical bone while the thinnest cortical bone was found in the central/central incisors and central/lateral incisors interradicular site. The maxillary 1st/2nd premolars, 2nd premolar/1st molar and 1st/2nd molars interradicular sites showed similar cortical bone thickness, with the measurements within the previously observed range. In the mandible, cortical bone thickness showed a gradual increase from the anterior to posterior areas.

The maxilla and mandible at different alveolar levels and insertion angles, showed thickness differences. The cortical bone thickness was greatest at the 2 mm level and 0° angle (Fig. 4). Cortical bone thickness in the maxilla increased as both level and angle increased, while the cortical bone thickness in the mandible was greatest at 4 mm from the alveolar crest.

There were generally no significant differences between male and female subjects in root proximity ($p > 0.05$), and none detected between the maxilla and the mandible ($p > 0.05$). With regard to root proximity, the buccal and central interradicular spaces increased

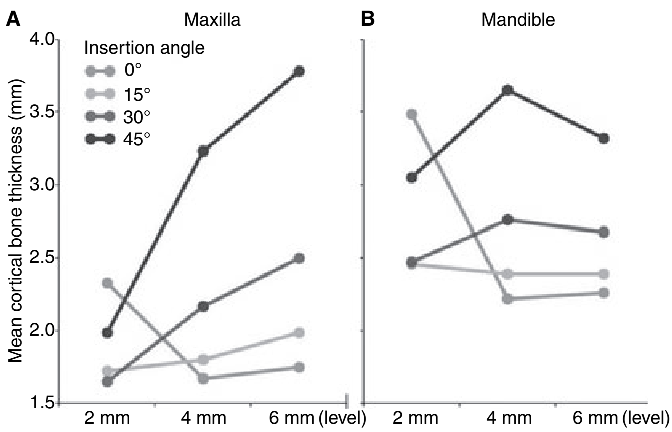

Fig. 4. Mean values of the cortical bone thickness in the maxilla (A) and mandible (B); comparisons at 2, 4, and 6 mm from the alveolar crest with four different insertion angles.

as the level from the alveolar crest increased while the horizontal interradicular spaces decreased with increasing level (Fig. 5).

For root proximity, the central/central incisor and the central/lateral incisor buccal interradicular spaces showed the smallest values while the 1st/2nd premolars and 2nd premolar/1st molar buccal interradicular spaces showed the greatest value. The lateral incisor/canine, canine/1st premolar and 1st/2nd molar buccal interradicular spaces had values within those extremes (Fig. 6).

Discussion

The present study evaluated the difference between maxillary and mandibular cortical bone thickness and root proximity at three levels apical to the alveolar crest and at four insertion angles. These levels and angles were relevant screening sites for optimal mini-implant placement. Significant differences in cortical bone thickness in the maxilla and mandible were detected in the posterior areas. On the other hand, there were no statistically significant differences between maxilla and mandible in anterior areas. Cortical bone thickness in the maxilla and mandible were different depending on the interradicular sites of specific teeth. The cortical bone thickness in the maxilla was greatest in the canine area while that in the mandible exhibited a gradual increase from anterior to posterior areas. Furthermore, variability of cortical bone thickness in a specific interradicular site was much larger than the variation between subjects. Thus, cortical bone thickness depends on the

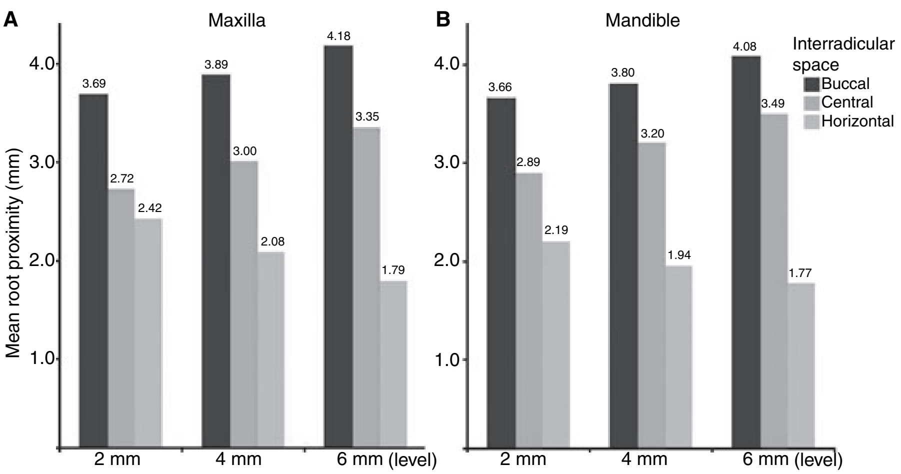

Fig. 5. Mean values of the root proximity in the maxilla and mandible.

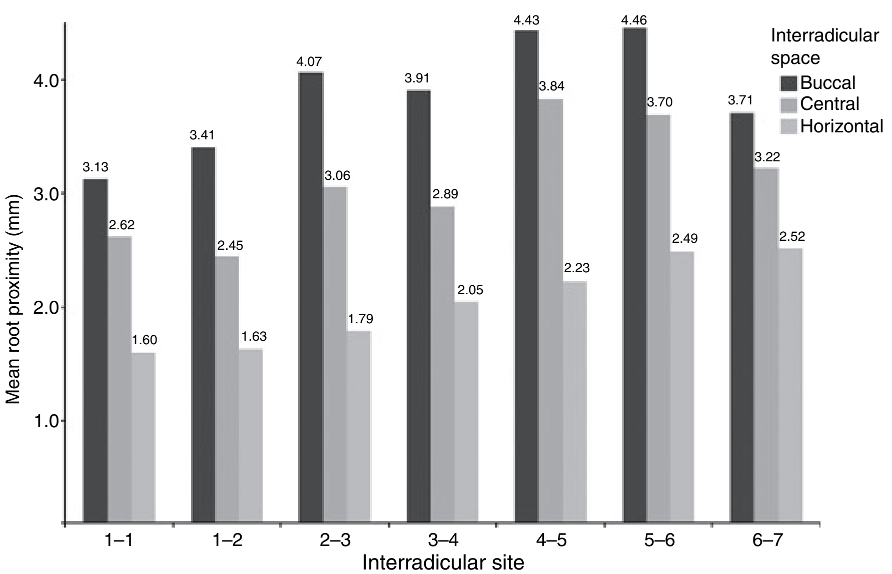

Fig. 6. Mean values of the root proximity; comparisons between interradicular sites (1) central incisor, (2) lateral incisor, (3) canine, (4) 1st premolar, (5) 2nd premolar, (6) 1st molar, and (7) 2nd molar.

interradicular site rather than sex or individual differences.

When considering the alveolar level and insertion angle, a 2 mm level from the alveolar crest with a 0° insertion angle were associated with greater cortical bone thickness in both the maxilla and mandible. However, placement of a mini-implant in most sites at a 2 mm level from the alveolar crest is not always possible due to an insufficient space between roots and because a mini-implant site may need to be adjusted. In the maxilla, placement of a mini-implant in an interradicular site 6 mm from the alveolar crest with an increased insertion angle provides a greater bone to mini-implant contact area, while a mini-implant in the mandible would be better placed with an increased insertion angle in an interradicular site 4 mm from the alveolar crest for better bone to mini-implant contact. Moreover, the attached gingiva, in addition to cortical bone thickness and root proximity, should be considered to minimize inflammation when placing a mini-implant (8, 10, 11). The attached gingiva in the maxilla is reported to range between 4.3 mm and 5.4 mm while that in the mandible is 3.3–4.6 mm (12, 13). When an interradicular site with insufficient attached gingiva is selected for mini-implant placement, insertion angle needs be increased for better bone to mini-implant contact.

Clinically, most mini-implants have been placed in the premolar areas (14). From our data, premolar areas such as the areas mesial and distal to 2nd premolar interradicular sites showed the greatest value for root proximity. This may be a factor in the frequency of placement of mini-implants in premolar areas. Root proximity increased as the interradicular sites moved away from the alveolar crest, which can be related to the general morphology of roots.

Intra-subject variability of cortical bone thickness between the maxilla and mandible was small, indicating that a subject's maxilla and mandible have similar features. However, inter-subject variability in cortical bone thickness at a specific interradicular site was larger than that for root proximity. Root proximity appears to vary less than the cortical bone thickness among individuals, which can be partly explained by the assumption that root anatomy showed analogies between individuals.

The linear mixed model used for analysis had some statistical advantages (15–17). The model did not require observations to be independent and with equal variance, and it is able to test the random effects of individual variability. Additionally, missing measurements do not cause all data for an individual to be ignored. The linear mixed model equation used was $Y_{ijklm} = \mu + \alpha_i + \beta_1 Sex_i + \beta_2 max_i\mathrm{la}_j + Wk_{(ij)} + p_k + \beta_3 level_{ijkl} + \beta_4 angle_{ijklm} + e_{ijklm}$ where: μ, total mean; β_1, sex effect; β_2, either maxilla or mandible; p_k tooth position effect; β_3, alveolar bone level; β_4, insertion angle fixed effects along with three level nested random effects by $\alpha_i (i = 1,2,....,28)$, individual subjects; $\gamma_{j(i)}$ $(j = 1,2)$, jaw position; and $W_{k(ij)}$ $(k = 1, 2,..., 7)$, tooth position.

Cortical bone thickness based on our sex, arch, specific tooth, alveolar bone level, and insertion angle data was cortical bone thickness = 2.44 + 0.17 × 0 (if male = 1) −0.44 × 0 (if maxilla = 1) − 1.20 × 0 (if incisor region = 1) − 0.33 × 0 (if canine region = 1) + 0.05 × alveolar bone level (mm) + 0.02 × insertion angle (°). For example, if a mini-implant is placed in a female with a 0° angle in the mandibular molar area, the cortical bone thickness would be 2.44 mm (2.44 + 0.17 × 0–0.44 × 0–1.20 × 0 − 0.33 × 0 + 0.05 × 0 + 0.02 × 0). If a mini-implant is placed in a male with a 0° insertion angle in the maxillary molar area, the cortical bone thickness would be 2.61 mm (2.44 + 0.17 × 1 − 0.44 × 0 − 1.20 × 0 − 0.33 × 0 + 0.05 × 0 + 0.02 × 0).

Measurement of the cortical bone thickness and root proximity in interradicular sites depending on levels from the alveolar crest and insertion angles can provide valuable information that may be useful during clinical implant placement as well as provision of an anatomical map for use during implant placement planning. With regard to root proximity, placement of a mini-implant 2 mm from the alveolar crest may not be clinically applicable because the space between roots and a mini-implant may be insufficient. Based on our study, placing a mini-implant in the maxilla at the 6 mm level apical to the alveolar crest and with an increased insertion angle would provide better cortical bone to mini-implant contact without root damage. In the mandible, such an implant can be placed at the 4 mm level from the alveolar crest and with an increased insertion angle to ensure better cortical bone to mini-implant contact. In addition, the range of attached gingiva should be taken into consideration when placing mini-implants for orthodontic anchorage.

Conclusions

Within the limits of this study, the observations suggest that cortical bone thickness depends on the interradicular site rather than sex or individual differences. Root proximity mesial and distal to the maxillary and mandibular 2nd premolar showed the greatest value.

Clinical relevance

The present study on cortical bone thickness and root proximity for orthodontic mini-implant placement suggests that mini-implants for orthodontic anchorage may be effective when placed at 4–6 mm from the alveolar crest with increased insertion angle. The frequently used area for mini-implants, mesial and distal to the maxillary and mandibular 2nd premolar showed the greatest value in root proximity.

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