Quantitative investigation of palatal bone depth and cortical bone thickness for mini-implant placement in adults

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Introduction: Cortical bone thickness and overall bone depth are important factors to consider when placing an orthodontic mini-implant. The purpose of this study was to investigate both variables in the palate quantitatively to aid clinicians in planning successful mini-implant placements. **Methods:** Thirty dry skulls were imaged with cone-beam computed tomography technology. Coronal slices were generated on which overall bone depth and cortical bone thickness were measured at 4 levels and 34 palatal placement sites. One-way analysis of variance (ANOVA) was used for data analysis. **Results:** Overall bone depth decreased with increasing distance from the midsagittal plane and from the anterior to the posterior palatal regions. Cortical bone thickness decreased from anterior to posterior, but no differences were detectable within measurement levels. **Conclusions:** Bone depth and cortical bone thickness of the palate were most favorable for temporary anchorage device placement at the level of the first and second premolars. This information could aid clinicians in choosing suitable palatal placement sites for orthodontic mini-implants. (Am J Orthod Dentofacial Orthop 2009;136:104-8)

The palate is a widely used placement site for orthodontic mini-implants. Many case reports and studies have described numerous indications.[1-6] When placing mini-implants, there must be sufficient bone at the placement site. Recently, studies have investigated the overall bone depth (BD) of the palate, and specific sites have been identified that, on average, can provide adequate BD for orthodontic mini-implants.[7,8]

There is sufficient evidence that cortical bone thickness (CBT) can have a strong impact on primary stability and overall success rates of implants.[9,10] As a consequence, CBT for other placement sites—eg, the buccal alveolar process—has been investigated.[11-15] Generally, it ranges from 0.5 to 2.5 mm at any buccal placement site. This information has not yet been generated for palatal placement sites.

Therefore, the purpose of this study was to investigate palatal CBT and overall BD by using cone-beam computed tomography technology.

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MATERIAL AND METHODS

The sample consisted of 30 dry skulls of white people from The Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History, Cleveland, Ohio (26 male, 4 female; average age, 31.2 ± 10.6 years; minimum age, 19 years; maximum age, 50 years). The inclusion criteria were intact maxillary jaws with no more than 3 teeth missing and no evidence of preexisting craniofacial dysmorphology (determined by inspection or listed in the health history on file, if present).

The skulls were imaged with a state-of-the-art cone-beam computed tomography unit (Hitachi CB Mercuray, Hitachi Medical, Tokyo, Japan) at a 9-in field of view, 100 kVp, and 10 mA. The resulting voxel size was 0.28 mm.

To survey and measure the entire palate and ensure clinical applicability, an occlusal grid was projected onto the palate by using intraoral anatomic landmarks (Fig 1). Transverse lines were drawn perpendicular to the sagittal plane through the mesial and distal anatomic contact points of the maxillary first and second premolars and first molar of the right side, creating 4 measurement levels (MLs). If at least 1 landmark tooth was missing on the right side, the corresponding teeth on the contralateral side were used as the landmark. Sagittal grid lines were drawn parallel to the midsagittal plane at 2 mm intervals. With Accurex software (CyberMed, Seoul, Korea), slices were reconstructed

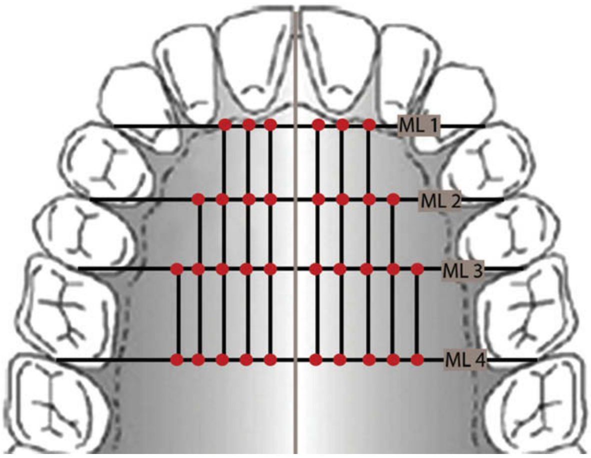

Fig 1. Occlusal grid showing measurement sites (*red dots*).

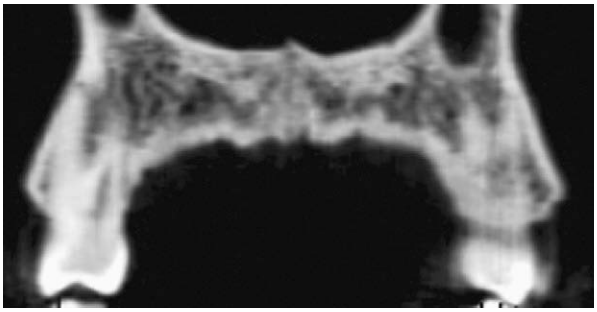

Fig 2. Transverse slice of palate along ML 2 on which measurements were made.

along the transverse grid lines (Fig 2), and measurements were made at the intersections of the sagittal and transverse grid lines, perpendicular to the bone surface. The demarcations between bone and air, and between cortical bone and cancellous bone, were drawn by visual gray-white discrimination. The intersections along the midsagittal plane were excluded from data collection because of extremely great anatomic variability of the palatal suture.[16-18] At every measurement site, CBT and the overall BD were measured. For the reliability assessment of the CBT and total BD measurements, 10 measurements were repeated twice at 3 sites 2 weeks later.

All data analysis was carried out by using SPSS software (version 16.0, SPSS, Chicago, Ill). The significance level for all tests was set at $P \leq 0.05$. Preliminary data analysis showed normal frequency distribution of the sample (Shapiro-Wilk test) and equality of variances (Levene test). The paired Student *t* test was used to test for differences between measurements on the left and right sides. No statistically significant differences were found, and, for all future analyses, data from the left and right sides were pooled. Both intraclass correlation and the paired Student *t* test were used to test intrarater reliability, and 1-way analysis of variance (ANOVA) was used to test for differences in CBT and total BD.

RESULTS

Intraclass correlation ($r = 0.96$ for BD; $r = 0.99$ for CBT) and the paired Student *t* test ($P = 0.68$ for BD; $P = 0.27$ for CBT) suggested high reliability for both the BD and the CBT measurements.

The amount of total BD to anchor an orthodontic mini-implant when placed perpendicular to the bone surface generally decreased with increasing distance from the midsagittal plane. However, the most peripheral measurements at MLs 2, 3, and 4 showed marginal increases. The overall bone depth was greatest at ML 2, followed closely by ML 1, ML 3, and ML 4. These findings were statistically significant at MLs 1, 3, and 4 (Table I).

Although palatal CBT behaved differently at every ML, the results were not statistically significant. However, once the data were pooled, it became evident that CBT decreased from the anterior ML to the posterior ML. Differences in CBT between MLs were statistically significant (Table II).

DISCUSSION

The decision on where to place an orthodontic mini-implant is usually based on several factors such as intended tooth movement, biomechanics (direct or indirect anchorage), and local anatomy. Local anatomy is usually subject to considerable individual variation, and the only way to gain information on the osseous anatomic relationships in a patient is 3-dimensional imaging. Without 3-dimensional imaging, a valid option is to use averages from imaging studies to identify sites that have adequate anatomic parameters for the successful placement of an orthodontic mini-implant.

The aim of this study was to assess overall BD and CBT in the palate. To date, only 2 studies have investigated BD in the palate.[7,8] However, neither attempted a comprehensive investigation of both BD and CBT of the palate.

Knowledge of overall BD can avoid nasal perforation during placement of a palatal temporary anchorage device (TAD) and aid in selecting the proper mini-implant length. This study suggests that some regions of the palate might be superior to other regions for a TAD; this agrees with the studies by Kang et al[7] and King et al.[8]

Table I. Total bone depth (mm)

	Distance from midsagittal plane																				
	2 mm				*4 mm*				*6 mm*				*8 mm*				*10 mm*				
ML	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Sig*
1	8.70	2.30	5.5	14.4	7.65	2.07	3.12	12.71	7.32	1.71	3.4	11.34	—	—	—	—	—	—	—	—	†
2	8.68	3.77	3.68	16.02	8.03	3.37	3.96	14.04	7.54	3.01	3.69	12.29	8.19	3.02	3.45	13.52	—	—	—	—	NS
3	4.26	3.24	0.38	14.32	3.91	2.65	0.43	12.48	3.66	2.51	0.4	12.2	4.07	2.89	0.41	12.00	5.25	3.49	0.3	13.08	*
4	2.71	1.40	0.47	8.36	1.99	1.46	0.42	6.53	1.59	1.14	0.31	4.87	1.62	1.07	0.26	3.77	2.40	1.41	0.40	5.02	†

ML 1, Anatomic contact point of canine and first premolar; *ML 2,* anatomic contact point of first and second premolars; *ML 3,* anatomic contact point of second premolar and first molar; *ML 4,* anatomic contact point of first and second molars.
Max, Maximum; *Min,* minimum; *Sig,* significance; *NS,* not significant.
**P* ≤0.05; †*P* ≤0.001.

Table II. Overall palatal cortical bone thickness (mm)

ML	*Mean*	*SD*	*Min*	*Max*	*Sig*
1	1.49	1.16	0.65	2.43	*
2	1.14	0.35	0.13	1.97	*
3	1.04	0.40	0.1	2.78	*
4	1.00	0.40	0.3	2.04	*

ML 1, Anatomic contact point of canine and first premolar; *ML 2,* anatomic contact point of first and second premolars; *ML 3,* anatomic contact point of second premolar and first molar; *ML 4,* anatomic contact point of first and second molars.
Max, Maximum; *Min,* minimum; *Sig,* significance.
**P* ≤0.001.

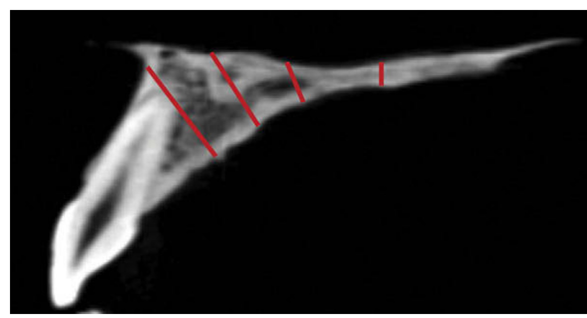

Fig 3. Sagittal slice through maxilla, indicating MLs 1 to 4.

Just as could be expected from the triangular sagittal cross section of the palate, overall BD was greatest in the anterior portions (MLs 1 and 2) and decreased gradually in the posterior direction (MLs 3 and 4) (Fig 3). It was interesting that, if perforation into the nose was to be avoided, there was sufficient BD for placement of the shortest currently available TAD (6 mm) on average only at MLs 1 and 2.[19] In the MLs, BD was greatest close to the suture and farthest from the suture, at the transition to the alveolar process. At MLs 3 and 4, BD was so drastically reduced that perforation into the nasal cavity was likely if an implant 6 mm or longer was to be completely seated.

Although these findings suggest that the posterior palate is a less ideal placement site, individual variations, shown by the standard deviations, were relatively high in this region. Therefore, in an individual patient, there may also be ample BD in the posterior region, as shown from the ranges in Table I. The imaging study of Kang et al[7] also points out the possibility of sufficient BD at the first molar level in the midsagittal plane. As a result, the posterior palate should not be ruled out entirely as a valid placement site, especially because it can be biomechanically favorable. However, diligent diagnosis and evaluation of the osseous and general anatomic relationships are necessary to prevent complications. Among the general anatomic relationships to consider in the posterior palate are the increased soft-tissue thickness composed mainly of adipose tissue and minor salivary glands, and the pathways of the greater palatine arteries, veins, and nerves.[20]

The risks of perforation increase with a longer implant, a perpendicular placement angle, and complete insertion of the implant. A TAD does not necessarily need to be seated completely. To date, there is no conclusive evidence about how much bone needs to surround a TAD to ensure maximum stability and success. Therefore, another option is to avoid seating the TAD completely in the far posterior regions, or to place it at an angle, which would increase the available BD.

Although nasal perforation is a risk factor when placing palatal TADs, this is usually not detrimental. Under normal circumstances, small oro-antral perforations heal quickly and without complications. In rare cases, there is a risk of mucocele creation or nasal bleeding.[21] Local anatomy can also aid in avoiding perforation of the nasal cavity. The nasal cortical plate is considerably thick and dense, so that haptic feedback will alert the clinician when the implant has reached that critical depth if a slow and sensible placement technique is used.

CBT is an important factor in obtaining sufficient primary stability for the TAD.[22] Motoyoshi et al[10] demonstrated that CBT should be greater than 1 mm for adequate primary stability and acceptable clinical success rates. It correlates directly with placement torque, which can in turn influence success rates.[9,22] Baumgaertel[23] suggested that CBT should play a role when determining the protocol for implant site preparation. Therefore, it appears that knowledge of CBT can be beneficial when selecting placement sites and performing the placement.

This investigation of palatal CBT showed that it behaved similarly to the overall BD. It also showed that the greatest thickness is located in the anterior regions of the palate (MLs 1 and 2) and less in the posterior regions (MLs 3 and 4). Within the MLs, the differences were not statistically significant. With regards to CBT, this means that, clinically, it should make no difference where the TADs are placed within a specific ML; especially since CBT was on average sufficient at all placement sites. However, individual variations were so great that deviations from the norm should be expected in any patient.

On average, it can be expected that the most favorable overall anatomic relationships for palatal orthodontic mini-implant placement are at the level of the first and second premolars. This site is also clinically accessible, which facilitates TAD placement. However, with placement at the MLs 1 and 2, it is important to consider the potential proximity to the incisive canal. Although the incisive foramen is topographically closely related to the incisive papilla, the actual canal extends superiorly and posteriorly, again with marked individual variations, potentially all the way to the level of the premolars. To stay clear of this sensitive structure, only parasagittal placement can be recommended at these sites as the canal is located in the sagittal plane. Also, anesthesia with the biofeedback method is recommended, since it aids in preventing damage to sensitive structures.[19]

CONCLUSIONS

Osseous dimensions of the palate can differ greatly depending on the measurement site, and individual variations were great. BD and CBT of the palate were most favorable for TAD placement at the level of the first and second premolars. This information may aid clinicians in choosing suitable palatal insertion sites for orthodontic mini-implants.

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