ORIGINAL ARTICLE

Buccal cortical bone thickness for mini-implant placement

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Introduction: The thickness of cortical bone is an important factor in mini-implant stability. In this study, we investigated the buccal cortical bone thickness of every interdental area as an aid in planning mini-implant placement. **Methods:** From the cone-beam computed tomography scans of 30 dry skulls, 2-dimensional slices through every interdental area were generated. On these, cortical bone thickness was measured at 2, 4, and 6 mm from the alveolar crest. Intraclass correlation was used to determine intrarater reliability, and analysis of variance (ANOVA) was used to test for differences in cortical bone thickness. **Results:** Buccal cortical bone thickness was greater in the mandible than in the maxilla. Whereas this thickness increased with increasing distance from the alveolar crest in the mandible and in the maxillary anterior sextant, it behaved differently in the maxillary buccal sextants; it was thinnest at the 4-mm level. **Conclusions:** Interdental buccal cortical bone thicknes varies in the jaws. There appears to be a distinct pattern. Knowledge of this pattern and the mean values for thickness can aid in mini-implant site selection and preparation. (Am J Orthod Dentofacial Orthop 2009;136:230-5)

Absolute anchorage has been a long sought after, but rarely achieved, treatment ideal. Therefore, orthodontic mini-implants, which can provide this desired form of anchorage, are more popular than ever. This is also reflected in the increasing number of studies in the orthodontic literature. However, despite the recent surge in scientific articles, plenty is still unknown about this topic.[1]

The literature is rich in case reports illustrating the successful use of mini-implants for various indications. Mini-implants are placed in many anatomic sites, depending on the indication and the biomechanics used.[2-5] Popular implant sites appear to be the palate, the lingual aspect of the maxillary alveolar process, the retromolar area in the mandible, and the buccal cortical plate in the maxilla and the mandible.[2-7] The latter has proven to be a versatile placement site and has thus been the subject of several investigations.[8-10] Many local anatomic factors must be considered; no single factor can be isolated to mark the ideal placement site. Among the more important factors for placement in the buccal cortex are soft-tissue anatomy, interradicular distance, sinus morphology, nerve location, and buccolingual bone depth.[11,12]

More recently, an interest in cortical bone thickness and quality has developed in conjunction with orthodontic skeletal anchorage systems.[9,13-15] The influence of bone quality on the long-term success of oral implants is undisputed and has been known for over a decade.[16] Bone quality can be expressed as the ratio of cortical to trabecular bone. In 1985, Lekholm and Zarb[17] suggested a classification system to categorize bone into 4 classes of bone quality. This ultimately became the standard classification in implant dentistry: (1) almost the entire jaw is homogenous compact bone, (2) a thick layer of compact bone surrounds a core of dense trabecular bone, (3) a thin layer of cortical bone surrounds a core of dense trabecular bone, and (4) a thin layer of cortical bone surrounds a core of low-density trabecular bone.

However, further investigations showed that it is not primarily the ratio of cortical bone to trabecular bone that influences implant stability as much as the absolute amount of dense cortical bone. Cortical bone has a higher modulus of elasticity than trabecular bone, is stronger and more resistant to deformation, and will bear more load in clinical situations than trabecular bone.[18] What applies to traditional dental implants also applies to orthodontic mini-implants: thicker cortical bone provides greater primary stability.[19-21]

Knowledge of the buccal cortical bone thickness in various areas can guide clinicians in selecting the

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The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.
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Submitted, June 2007; revised and accepted, October 2007.
0889-5406/$36.00

doi:10.1016/j.ajodo.2007.10.045

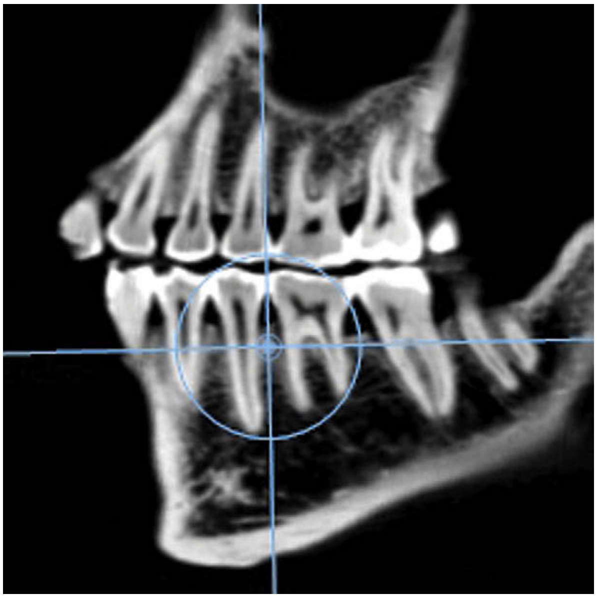

Fig 1. Two-dimensional sagittal view showing the orientation of the interdental slice on which measurements were made.

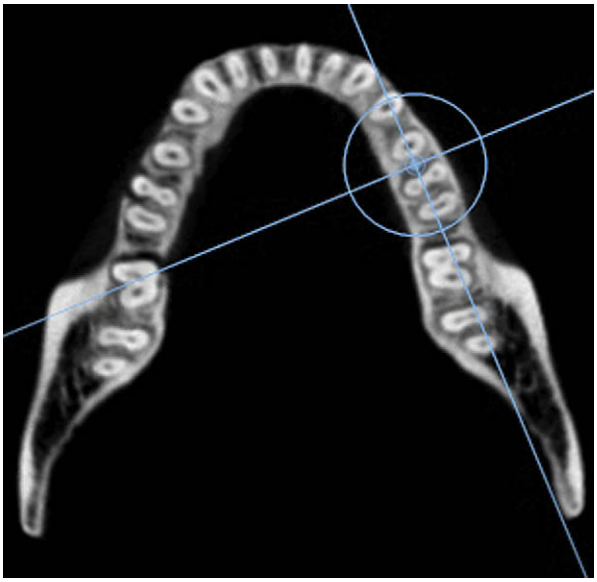

Fig 2. Two-dimensional horizontal view showing the orientation of the interdental slice on which measurements were made.

placement site and the proper placement protocol. The purpose of this study was to investigate buccal cortical bone thickness in every interdental site in both jaws to provide a guideline for implant site selection and placement.

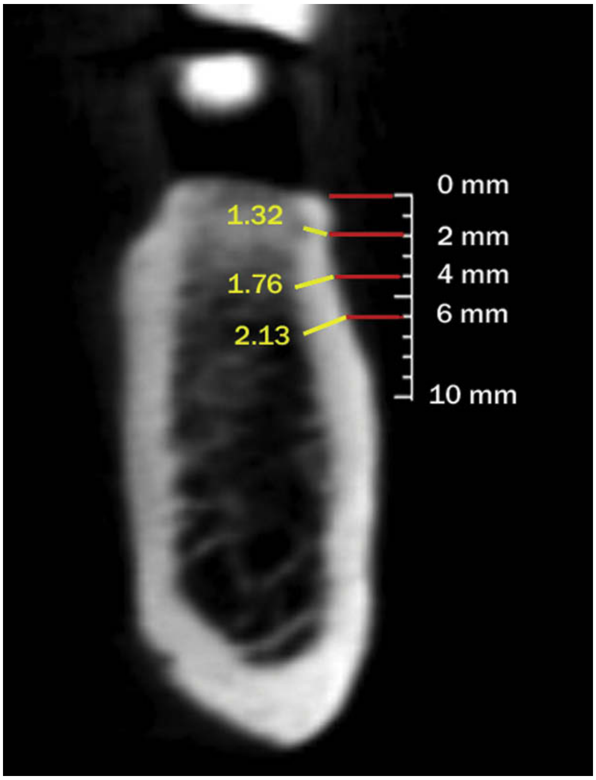

Fig 3. Two-dimensional interdental slice, showing cortical (*white*) and trabecular (*gray*) bone with measurements of buccal cortical bone thickness.

MATERIAL AND METHODS

The sample consisted of 30 adult dry skulls. Inclusion criteria were no more than 2 missing teeth per arch excluding third molars. Of these skulls, 9 had 1 missing tooth, and 3 had 2 missing teeth. All teeth, however, were lost postmortem, as shwon by the sockets.

The skulls were imaged in maximum intercuspation with cone-beam computerized tomography (CBCT) with the Hitachi CB Mercuray CBCT Unit (Hitachi Medical, Tokyo, Japan) at a 9-in field of view, 100 kVp, and 10 mA. Two-dimensional slices, 0.28 mm thick, through each contact area were created, bisecting the interradicular distance (Fig 1) and oriented perpendicular to the bone surface (Fig 2) by using Accurex software (CyberMed, Seoul, Korea). This gave a clear image of cortical and cancellous bone (Fig 3).

The demarcation between the 2 bone qualities was drawn manually by visual gray-white discrimination; gray was cancellous bone, and white was cortical bone. Each measurement area was coded with a number, beginning in the maxillary right quadrant, distal to the second molar with number 1 and ending in the

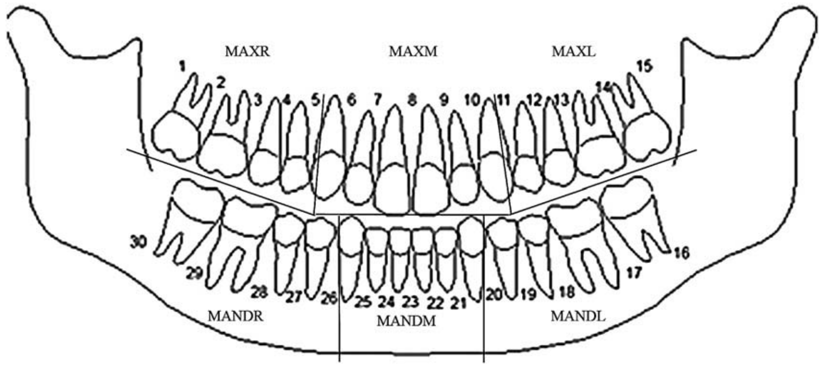

Fig 4. Schematic of interdental area coding and definition of sextants.

Table I. Buccal cortical bone thickness at different measurement levels by sextants

	2 mm	*SD*	*4 mm*	*SD*	*6 mm*	*SD*	*Mean*	*Sig*
MaxR	1.15	0.27	1.03	0.22	1.28	0.28	1.16	*
MaxM	0.85	0.23	0.94	0.18	1.11	0.24	0.97	*
MaxL	1.11	0.25	1.00	0.22	1.29	0.26	1.14	*
MandR	1.48	0.47	1.89	0.51	2.22	0.6	1.87	NS
MandM	0.85	0.15	0.99	0.21	1.15	0.26	1.00	*
MandL	1.60	0.53	2.03	0.56	2.32	0.59	1.98	NS

*$P \leq 0.001$; *NS,* not significant; *Sig,* significance.

mandibular right quadrant distal to the second molar with number 30. For analysis, these measurement areas were also grouped into sextants (Fig 4). Three measurement points were then defined at 2, 4, and 6 mm from the alveolar crest in each measurement area. From these, measurements were made perpendicular to the bone surface by using the function "ruler" in the Accurex software (Fig 3). Data were entered into an Excel 2003 spreadsheet (Microsoft, Redmond, Wash). On 10 randomly selected skulls, all measurements were made twice to assess intrarater reliability, 2 weeks apart.

Statistical analysis

SPSS software (version 15.0, SPSS, Chicago, Ill) was used for all statistical calculations. Preliminary data analysis indicated normal frequency distribution of the sample and equality of variances. Intraclass correlation was used to determine intrarater reliability, and analysis of variance (ANOVA) was used to test for differences in cortical bone thickness. The level of significance was set at $P \leq 0.05$.

RESULTS

Intrarater reliability was high ($r = 0.91$), and the measurements proved to be reproducible.

Statistical analysis showed that, on average, buccal cortical bone was thicker in the mandible than in the maxilla, and that the buccal sextants of both jaws (maxilla left [MaxL], maxilla right [MaxR], mandible left [MandL], and mandible right [MandR]) had greater cortical bone thickness than the anterior sextants (maxilla middle [MaxM] and mandible middle [MandM]). When the means of the measurement levels (2, 4, and 6 mm) were compared in each sextant, the differences were significant in the entire maxilla (MaxL, MaxM, and MaxR) and the anterior mandibular sextant (MandM), but not in the mandibular buccal sextants (MandR and MandL). In the maxillary buccal sextants (MaxL and MaxR), cortical bone thickness was thickest at the 6-mm level and thinnest at the 4-mm level. In the maxillary anterior sextant (MaxM), thickness increased progressively with increasing distance to the alveolar crest and was thickest at the 6-mm level. The mandibular anterior sextant (MandM) was similar to its maxillary counterpart; cortical bone thickness increased away from the alveolar crest. In the mandibular buccal sextants (MandR and MandL), the same trend was observed (Table I). Further analysis showed that, overall, each contact differed significantly from the rest. Cortical bone thickness increased in both jaws with increasing distance from the midsagittal plane except distally to the maxillary second molars, where it decreased (Table II).

Table II. Buccal cortical bone thickness at the measurement levels in each interdental area (1-30)

Area	2 mm	SD	4 mm	SD	6 mm	SD	Mean	SD	Sig
1	1.00	0.31	0.98	0.21	1.17	0.27	1.05	0.28	†
2	1.23	0.23	1.10	0.19	1.39	0.27	1.24	0.26	‡
3	1.25	0.27	1.09	0.24	1.34	0.30	1.23	0.29	†
4	1.16	0.24	1.01	0.24	1.29	0.27	1.15	0.27	†
5	1.11	0.28	0.98	0.23	1.22	0.26	1.10	0.27	‡
6	0.91	0.18	0.99	0.22	1.13	0.27	1.01	0.25	‡
7	0.89	0.28	1.00	0.20	1.12	0.26	1.00	0.25	‡
8	0.75	0.18	0.85	0.21	0.99	0.24	0.86	0.23	‡
9	0.88	0.39	0.88	0.13	1.16	0.21	0.97	0.21	‡
10	0.85	0.15	1.01	0.15	1.17	0.22	1.01	0.22	‡
11	1.16	0.18	1.03	0.17	1.28	0.19	1.16	0.21	‡
12	1.14	0.24	1.03	0.20	1.32	0.25	1.16	0.26	‡
13	1.18	0.26	1.04	0.21	1.34	0.28	1.19	0.28	‡
14	1.20	0.28	1.06	0.27	1.35	0.26	1.20	0.29	‡
15	0.90	0.30	0.86	0.26	1.15	0.31	0.97	0.32	‡
16	2.28	0.79	2.86	0.72	3.05	0.76	2.73	0.82	‡
17	2.00	0.94	2.49	0.82	2.89	0.74	2.46	0.91	‡
18	1.44	0.37	1.85	0.47	2.20	0.55	1.83	0.56	‡
19	1.26	0.30	1.66	0.42	1.96	0.57	1.63	0.53	‡
20	1.01	0.23	1.28	0.29	1.49	0.32	1.26	0.34	‡
21	0.90	0.19	1.05	0.22	1.27	0.23	1.07	0.26	‡
22	0.82	0.15	0.98	0.22	1.11	0.26	0.97	0.24	‡
23	0.82	0.23	0.93	0.14	1.03	0.20	0.93	0.17	‡
24	0.85	0.17	0.96	0.24	1.10	0.32	0.97	0.27	‡
25	0.86	0.14	1.04	0.25	1.25	0.30	1.05	0.29	‡
26	0.91	0.19	1.14	0.27	1.39	0.28	1.15	0.32	‡
27	1.16	0.31	1.50	0.42	1.88	0.54	1.51	0.52	‡
28	1.32	0.41	1.74	0.51	2.13	0.65	1.73	0.62	‡
29	1.45	1.35	2.01	0.67	2.60	0.72	2.02	0.76	‡
30	2.58	1.08	3.08	0.74	3.12	0.80	2.92	0.91	*

*$P \leq 0.05$; †$P \leq 0.01$; ‡$P \leq 0.001$; *Sig,* significance.

DISCUSSION

Turkyilmaz et al[22] demonstrated that it is possible to estimate primary implant stability from presurgical computerized tomography (CT) diagnosis. Therefore, it would be desirable to image every patient with CT, but not every clinician has access to a CT or CBCT scanner and might lack some potentially important information. This investigation was intended to supply a guideline when CT imaging is not possible.

In this study, we found an interesting pattern of variation in buccal cortical bone thickness. In general, the mandible provides more buccal cortical bone than the maxilla. Friberg et al[23] found similar results in their morphometric study; they reported more compact cortical bone in the mandible than in the maxilla. In the mandible and the maxillary anterior sextant, buccal cortical bone increases in thickness as the distance of the measurement points from the alveolar crest increases. This is no surprise, since one would expect cortical bone thickness to increase from the alveolar bone to the basal bone. In the maxillary buccal sextants, however, buccal cortical bone thickness decreases at the 4-mm mark before it increases again at the 6-mm mark. This finding agrees with the study of Kim et al,[15] who found that, in the buccal interproximal areas of the maxilla that they investigated, the "cortical bone was thickest closest to and farthest from the CEJ and thinnest in the middle." This was an interesting result because it demonstrates that, to maximize cortical bone anchorage in the maxillary buccal sextants, the mini-implant should be placed more than 4 mm apically from the alveolar crest. This means that most mini-implants in the maxillary buccal sextants must be placed close to the mucogingival junction or perhaps even in mucosa.

Another interesting finding was that buccal cortical bone is thinnest in the anterior sextants of both jaws and increases progressively toward the posterior, except distally to the maxillary second molars, where the buccal cortex is on average thin. The implications for clinical purposes are that, to place the implant in a more favorable spot, biomechanics should be ideally structured so that placement is possible in the buccal sextants, except

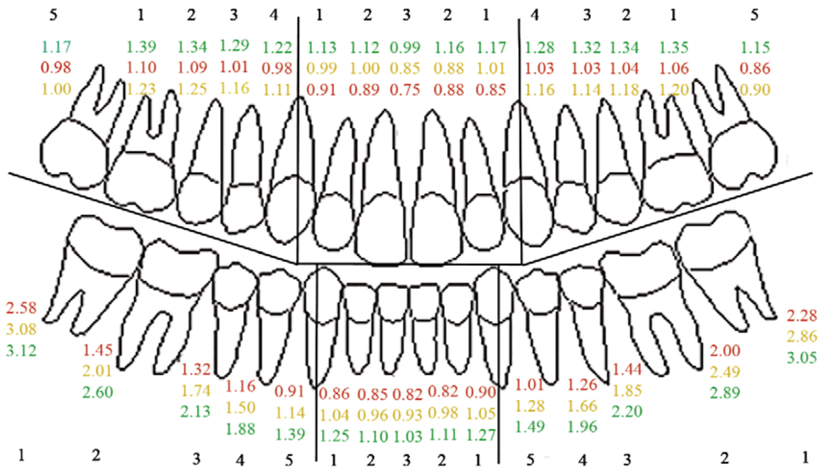

Fig 5. Map of buccal cortical bone thickness in each measurement area: measurement sites are ranked by overall buccal cortical bone thickness in each sextant (1 is the thickest). *Red* is the thinnest measurement in a site; *yellow* is the medium measurement; *green* is the thickest measurement.

for the maxillary retromolar area that provides insufficient buccal cortical bone. This finding reinforces a similar one by Deguchi et al,[24] who found significantly less buccal cortical bone distal to the maxillary second molars. Placement in the anterior sextants of both jaws should be avoided for several reasons: this area provides little cortical bone for anchorage of the implant and little attached gingiva, and it frequently lacks sufficient interradicular distances.[8,25]

It can be debated whether these findings are also clinically significant considering all other factors that can affect mini-implant success rates.[10] It is also well understood that shortcomings in cortical bone thickness can be compensated for by variations of mini-implant angulation or perhaps implant design (cylindrical vs conical shank).[24] However, as Miyamoto et al[20] demonstrated, overall cortical bone thickness is important in implant stability and therefore should be considered when selecting the preferred implant site. Therefore, in addition to the statistical significance, our findings appear to have clinical significance also.

These results were charted in a visual format that might help clinicians in selecting the most ideal placement sites for cortical bone availability, and it can serve as a guideline for preparing the implant site for maximum primary stability and minimal osseous damage in the implant site (Fig 5). When this aid is used, it must be kept in mind that measurements from CBCT slice data, although sufficiently accurate, tend to slightly underestimate the anatomic truth.[26] There might be slightly more bone available than the mean values indicate.

A possible shortcoming of this study was that the distributions of sex and age in this sample are unknown; these might have an impact on the thickness of cortical bone. However, this could not be determined in a previous study.[24] Even if this influences the absolute measured values slightly, it would probably not change the observed pattern.

Although over one third of the sample had at least 1 missing tooth, this cannot be regarded as a limitation, since these teeth were lost postmortem. This is indicated by the alveolar sockets of the missing teeth. If teeth are lost after death as a result of the fixation process or handling, cortical bone thickness is not affected.

CONCLUSIONS

Interdental buccal cortical bone thickness appears to vary according to a distinctive pattern. Knowledge of this pattern can aid clinicians in implant site selection and proper site preparation. A visual aid was created to facilitate the clinical application of these results.

Future studies are needed to determine the exact relationship between cortical bone thickness, the method of implant site preparation, and success rates.

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