

Soft-tissue and cortical-bone thickness at orthodontic implant sites

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Introduction: To obtain sufficient stability of implants, the thickness of the soft tissue and the cortical bone in the placement site must be considered. However, the literature contains few anatomical studies of orthodontic implants. **Methods:** To measure soft-tissue and cortical-bone thicknesses, maxillae from 23 Korean cadavers were decalcified, and buccopalatal cross-sectional specimens were obtained. These specimens were made at 3 maxillary midpalatal suture areas: the interdental area between the first and second premolars (group 1), the interdental area between the second premolar and the first molar (group 2), and the interdental area between the first and second molars (group 3). **Results:** In all groups, buccal soft tissues were thickest closest to and farthest from the cementoenamel junction (CEJ) and thinnest in the middle. Palatal soft-tissue thickness increased gradually from the CEJ toward the apical region in all groups. Buccal cortical-bone thickness was greatest 6 mm apical to the CEJ and thinnest in the middle in groups 1 and 2. Palatal cortical-bone thickness was greatest 6 mm apical to the CEJ in groups 1 and 3, and 2 mm apical to the CEJ in group 2. Along the midpalatal suture, palatal mucosa remained uniformly 1 mm thick posterior to the incisive papilla. **Conclusions:** Surgical placement of miniscrew implants for orthodontic anchorage in the maxillary molar region requires consideration of the placement site and angle based on anatomical characteristics. (Am J Orthod Dentofacial Orthop 2006;130:177-82)

nchorage control is a critical consideration when planning treatment for patients with dental and skeletal malocclusions. In edentulous jaws, anchorage from the periodontal ligament is not available, and securing anchorage, either internal or external, depends greatly on patient cooperation. Poor compliance can cause unexpected complications or compromised results. Therefore, the use of endosseous implants for absolute orthodontic anchorage has been the focus of many studies. Gainsforth and Higley¹ placed vitallium screws in the jaw bones of dogs. Roberts et al² used titanium screws as orthodontic implants in dog mandibles. Shapiro and Kokich³ and Schweizer et al⁴ reported the first use of endosseous implants in orthodontics, and Block and Hoffman⁵ used onplants.

When intraoral anchorage is stable, biocompatible, and free from site specificity, it can be used effectively without patient compliance. Systems that can satisfy these criteria include miniplates, miniscrews, and microscrews. These implants can be placed in the inferior ridge of the piriform aperture, maxillary alveolar bone, the infrazygomatic crest, palatal alveolar bone, a maxillary tuberosity, the hard palate, and the midpalatal suture area.

In this study, buccopalatal cross-sectional samples from interdental areas of the posterior teeth and midpalatal suture areas of adult Korean cadavers were evaluated. We hope this information can be used as a standardized reference for the placement of orthodontic miniscrew implants.

MATERIAL AND METHODS

Our material consisted of 23 maxillary sections from 23 cadavers (16 men, 7 women; mean age, 49.5) (Table I).

To measure soft-tissue and cortical-bone thicknesses in buccopalatal alveolar bone and in the maxillary midpalatal suture area where orthodontic screws are most frequently placed, cadavers with all maxillary premolars and intact molars were selected. To measure the incisal areas, cadavers with intact maxillary occlusal planes (at least incisors and first molars remaining) were selected.

Sectioned sites of the maxillary bone sections were decalcified in solution (aluminium chloride hexahydrate, 7 g; 30% hydrochloric acid, 8.5 mL; formic acid, 5 mL; distilled water) for 4 to 7 days and then neutralized in solution (sodium sulfate, 5 g; distilled water, 100 mL) for

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		Age	e (y)
Sex	Number	Mean	SD
Men	16	46.9	19.16
Women	7	60.7	16.02
Total	23	49.5	17.99

Table I. Mean ages and standard deviations of subjects

2 to 3 days. Cross-sectional specimens were made at 3 maxillary midpalatal suture areas: the interdental area between the first and second premolars (group 1), the interdental area between the second premolar and the first molar (group 2), and the interdental area between the first and second molars (group 3). The specimens were made with an autopsy blade (#170 Feather Safety Razor, Osaka, Japan). Sectioned samples along with reference rulers were digitally scanned (HP Scanjet 4c, Hewlett Packard, Houston, Tex). Scanned images were calibrated and measurements were made with image-analysis software (Image-pro Plus, version 4.0, Media Cybernetics, Silver Springs, Md).

We measured the thickness of soft and hard tissues at 5 sectional areas parallel to the buccopalatal cementoenamel junction (CEJ) line at 2-mm intervals. The landmarks were as follows (Fig 1).

- A, outer point of the buccal side of the sectioned specimen on a parallel line drawn 2 mm inferior to the CEJ line.
- B, outer point of the buccal side of the sectioned specimen on a parallel line drawn 4 mm inferior to the CEJ line.
- C, outer point of the buccal side of the sectioned specimen on a parallel line drawn 6 mm inferior to the CEJ line.
- D, outer point of the buccal side of the sectioned specimen on a parallel line drawn 8 mm inferior to the CEJ line.
- E, outer point of the buccal side of the sectioned specimen on a parallel line drawn 10 mm inferior to the CEJ line.
- A', outer point of the palatal side of the sectioned specimen on a parallel line drawn 2 mm inferior to the CEJ line.
- B', outer point of the palatal side of the sectioned specimen on a parallel line drawn 4 mm inferior to the CEJ line.
- C', outer point of the palatal side of the sectioned specimen on a parallel line drawn 6 mm inferior to the CEJ line.
- D', outer point of the palatal side of the sectioned specimen on a parallel line drawn 8 mm inferior to the CEJ line.

• E', outer point of the palatal side of the sectioned specimen on a parallel line drawn 10 mm inferior to the CEJ line.

We also measured the thickness of soft tissue at the 6 landmarks including the incisive papilla (IP) on the palate, which meet with the line perpendicular to the occlusal plane and passing the closest 5 points from the incisive papilla at 4-mm intervals. The landmarks were as follows (Fig 2).

- IP-4, outer point of the sectioned specimen contacted with a parallel line drawn 4 mm posterior to the line passing through IP perpendicular to the occlusal plane.
- IP-8, outer point of the sectioned specimen contacted with a parallel line drawn 8 mm posterior to the line passing through IP perpendicular to the occlusal plane.
- IP-12, outer point of the sectioned specimen contacted with a parallel line drawn 12 mm posterior to the line passing through IP perpendicular to theocclusal plane.
- IP-16, outer point of the sectioned specimen contacted with a parallel line drawn 16 mm posterior to the line passing through IP perpendicular to the occlusal plane.
- IP-20, outer point of the sectioned specimen contacted with aparallel line drawn 20 mm posterior to the line passing through IP perpendicular to the occlusal plane.

Statistical analysis

Mean and standard deviations were calculated by using SAS software (version 6.04, SAS, Cary, NC).

Buccopalatal soft-tissue and cortical-bone thicknesses for each group were compared by using t tests. Statistical differences in cortical-bone and soft-tissue thickness between the 3 groups were assessed by using analysis of variance (ANOVA) with a 5% confidence level.

RESULTS

In group 1, soft-tissue and cortical-bone thicknesses in the cross sections between the maxillary first and second premolars were greatest closest to and farthest from the CEJ (B/a-m mean, 1.39 mm; B/e-m mean, 1.38 mm; B/a-c mean, 1.55 mm; B/e-c mean, 1.16 mm); areas near the middle were the thinnest (B/c-m mean, 0.86 mm; B/d-c mean, 1.07 mm) (see Table II for definitions). Buccal alveolar-bone thickness was greatest in the apical and coronal portions. Palatal soft-tissue thickness gradually increased from P/a'-m to P/d'-m (mean, 3.06 mm) but decreased from P/d'-m to P/e'-m (see Table III for definitions). Similarly, palatal cortical-bone thickness increased from P/a'-c to P/c'-c (mean, 1.85 mm) and then slightly decreased from P/c'-c to P/e'-c. In all cases, soft tissue and cortical bone were thicker in palatal areas than in buccal areas.



Fig 1. Measurement of the thickness of the soft and hard tissue at 10 points on the buccal gingiva and palate of the sectioned specimen. A-E, Outer points on the buccal side of the sectioned specimen on parallel lines drawn 2, 4, 6, 8, and 10 mm, respectively, and inferior to the buccopalatal cementoenamel junction (CEJ). 1-5, Lines perpendicular to the tangent line on point A to E, respectively. A'-E', Outer points of the palatal side of the sectioned specimen on parallel lines drawn 2, 4, 6, 8, and 10 mm, respectively. A'-E', Outer points of the palatal side of the sectioned specimen on parallel lines drawn 2, 4, 6, 8, and 10 mm, respectively, and inferior to the buccopalatal CEJ. 6-10, Lines perpendicular to the tangent line on point A' to E', respectively.

In group 2, soft-tissue and cortical-bone thicknesses between the maxillary premolar and the first molar were similar to those of group 1. Buccal soft-tissue thickness was greatest closest to and farthest from the CEJ (B/a-m, 1.45 mm; B/e-m, 1.77 mm); portions in the middle showed the least thickness (B/c-m, 1.02 mm). As in group 1, cortical bone was thickest closest to the CEJ (B/a-c, 1.33 mm) and thinnest in the middle portion (B/d-c mean, 1.13 mm). There was no difference in thickness in B/b-c, B/c-c, and B/e-c.

Palatal soft-tissue thickness showed a similar pattern to that of group 1, gradually increasing from P/a'-m, peaking at P/d'-m (mean, 3.07 mm), and decreasing at P/e'-m.

Cortical-bone thickness in group 2, unlike in group 1, gradually decreased from P/a'-c (mean, 1.81 mm) to P/e'-c

(mean, 1.54 mm). As in group 1, soft-tissue and cortical-bone thicknesses in all cases except a-c were greater in palatal areas than in buccal areas (Tables II and III).

In group 3, soft-tissue and cortical-bone thicknesses between the maxillary first and second molars were similar to those of groups 1 and 2. Buccal soft-tissue thickness was greatest closest to (B/e-m mean, 1.07 mm) and farthest from (B/a-m mean, 1.58 mm) the CEJ. Buccal cortical-bone thickness in group 3, unlike groups 1 and 2, was greatest at the middle (P/b'-c mean, 0.94 mm), with no significant difference in the rest.

Palatal soft-tissue thickness increased from P/a'-m (mean, 2.67 mm) to P/e'-m (mean, 5.40 mm). Cortical-bone thickness increased from P/a'-c to P/c'-c and decreased from P/d'-c to P/e'-c. In all samples, soft-tissue and cortical-bone thicknesses



Fig 2. Measurement of the thickness of the soft tissue at 6 points on the palate of the sectioned specimen. IP-4–IP-20, Outer points of the sectioned specimen that meet with lines 1-6, which were drawn at 4-mm intervals from the incisive papilla (IP) and perpendicular to the occlusal plane (OCC), respectively. 7-12, Lines perpendicular to the tangent line on point IP, IP-4, IP-8, IP-12, IP-16, IP-20, respectively (IE, dentinoenamel junction on the incisal edge of the central incisor; 6MB, dentiono-enamel junction on the mesiobuccal cusp on the first molar).

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Measurement	Group 1		Group 2		Group 3				
	Mean	SD	Mean	SD	Mean	SD	1 and 2	2 and 3	3 and
B/a-m	1.39	0.54	1.43	0.56	1.58	0.64	NS	NS	NS
B/b-m	1.09	0.48	1.07	0.37	0.78	0.30	NS	*	*
B/c-m	0.86	0.35	1.02	0.34	0.77	0.41	NS	NS	NS
B/d-m	1.09	0.53	1.38	0.60	0.82	0.40	*	*	NS
B/e-m	1.38	0.87	1.77	0.74	1.07	0.48	*	*	NS
B/a-c	1.55	0.43	1.33	0.40	0.85	0.33	NS	*	*
B/b-c	1.18	0.40	1.18	0.39	0.94	0.28	NS	NS	NS
B/c-c	1.09	0.39	1.20	0.46	0.85	0.21	NS	*	NS
B/d-c	1.07	0.38	1.13	0.41	0.82	0.26	NS	*	NS
B/e-c	1.16	0.38	1.17	0.40	0.87	0.36	NS	*	NS

Table II. Comparison of measurements (in mm) of sectioned specimens at buccal side

B/a-m, Thickness of soft tissue measured along line 1 in Fig 1; *B/b-m,* thickness of soft tissue measured along line 2 in Fig 1; *B/c-m,* thickness of soft tissue measured along line 3 in Fig 1; *B/d-m,* thickness of soft tissue measured along line 4 in Fig 1; *B/e-m,* thickness of soft tissue measured along line 5 in Fig 1; *B/a-c,* thickness of cortical bone measured along line 1 in Fig 1; *B/b-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/c-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/c-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/c-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 3 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1; *B/d-c,* thickness of cortical bone measured along line 5 in Fig 1.

*P < .05; NS, not significant.

were greater on the palatal side than on the buccal side (P < .001) (Tables II and III).

Soft-tissue thicknesses at the midpalatal suture areas were greatest at M/IP-4 (mean, 2.93 mm) and similar at M/IP-8, M/IP-12, M/IP-16, and M/IP-20 (Table IV).

DISCUSSION

Obtaining proper anchorage has always been of interest to clinical orthodontists and researchers. Problems in traditional forms of anchorage have been reported.⁶ In areas where active force is applied, reactive force in the opposite direction results in opposite tooth movement. Some clinical trials, such as the pendulum appliance, have been performed and suggest that this unwanted tooth movement can be minimized by grouping several teeth as anchorage.

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The usefulness of this method, however, was limited.⁷ When anchorage in the dental arch is insufficient, intermaxillary appliances can be used, but, when anchorage is critical, these appliances have limited effects. The need for

Measurement	Group 1		Group 2		Group 3				
	Mean	SD	Mean	SD	Mean	SD	1 and 3	2 and 3	3 and 1
P/a'-m	2.56	0.09	2.81	0.98	2.67	0.84	NS	NS	NS
P/b'-m	2.72	1.03	2.59	0.77	2.44	0.68	NS	NS	NS
P/c'-m	3.01	1.08	2.88	1.10	3.57	2.23	NS	NS	NS
P/d'-m	3.28	1.24	3.07	1.23	4.30	2.20	NS	*	*
P/e'-m	3.06	1.17	2.74	0.87	5.40	1.99	NS	*	*
P/a'-c	1.73	0.52	1.81	0.62	1.27	0.42	NS	*	*
P/b'-c	1.76	0.46	1.72	0.31	1.66	0.71	NS	NS	NS
P/c'-c	1.85	0.63	1.73	0.23	1.91	0.59	NS	NS	NS
P/d'-c	1.73	0.56	1.70	0.36	1.79	0.72	NS	NS	NS
P/e'-c	1.68	0.61	1.54	0.31	1.56	0.57	NS	NS	NS

Table III. Comparison of measurements (in mm) in sectioned specimens at palatal side

P/a'-m, Thickness of soft tissue measured along line 6 in Fig 1; P/b'-m, thickness of soft tissue measured along line 7 in Fig 1; P/c'-m, thickness of soft tissue measured along line 8 in Fig 1; P/d'-m, thickness of soft tissue measured along line 9 in Fig 1; P/e'-m, thickness of soft tissue measured along line 10 in Fig 1; P/a'-c, thickness of cortical bone measured along line 6 in Fig 1; P/b'-c, thickness of cortical bone measured along line 7 in Fig 1; P/c'-c, thickness of cortical bone measured along line 8 in Fig 1; P/b'-c, thickness of cortical bone measured along line 8 in Fig 1; P/b'-c, thickness of cortical bone measured along line 8 in Fig 1; P/d'-c, thickness of cortical bone measured along line 9 in Fig 1; P/c'-c, thickness of cortical bone measured along line 8 in Fig 1; P/d'-c, thickness of cortical bone measured along line 9 in Fig 1; P/c'-c, thickness of cortical bone measured along line 10 in Fig 1; P/d'-c, thickness of cortical bone measured along line 10 in Fig 1; P/d'-c, thickness of cortical bone measured along line 10 in Fig 1; P/d'-c, thickness of cortical bone measured along line 10 in Fig 1. *P < .05; NS, not significant.

 Table IV. Measurements (in mm) in sectioned specimens at midpalatal suture area

	Midpa	ılatal
Measurement	Mean	SD
M/IP	1.95	0.44
M/IP-4	2.93	0.47
M/IP-8	1.01	0.33
M/IP-12	0.97	0.38
M/IP-16	0.97	0.37
M/IP-20	0.90	0.21

M/IP, Thickness of soft tissue measured along line 7 in Fig 2; *M/IP-4*, thickness of soft tissue measured along line 8 in Fig 2; *M/IP-8*, thickness of soft tissue measured along line 9 in Fig 2; *M/IP-12*, thickness of soft tissue measured along line 10 in Fig 2; *M/IP-16*, thickness of soft tissue measured along line 11 in Fig 2; *M/IP-20*, thickness of soft tissue measured along line 12 in Fig 2.

proper anchorage when intraoral anchorage is insufficient led to the use of extraoral anchorage, which requires patient cooperation.

Burstone⁸ and Kuhlberg and Burstone⁹ tried to solve the anchorage problem by making use of the fact that tooth tipping is easier to achieve than axial or root movement. They maintained equilibrium with vertical force created by adding cant to the occlusal plane. This system, however, does not apply in partially edentulous patients or those whose remaining teeth must be moved in 1 direction. For this reason, extradental intraoral anchorage systems, such as osseointegrated implants,^{10,11} onplants,⁵ and direct wiring from the zygomatic arch,¹² have been introduced. However, these methods are costly and time-consuming, and have limited applications. Miniscrews, microscrews, and miniplates are relatively easy clinical alternatives.¹³

Orthodontic fixation screws can be placed either with or without flap raising. When screws are placed without a flap, either drilling with a slow-speed handpiece or selftapping with a screwdriver (or a combination of the 2) can be used. Screws pass through the soft tissue, and therefore the thickness of the soft tissue and cortical bone at the surgical site are critical factors for success.

Buccal soft tissue was thinnest in the middle (B/a-m) and relatively thicker in the superior and inferior portion in all 3 groups. Cortical bone showed the same pattern as the soft tissue, thinner in the middle portion in groups 1 and 2. On the other hand, the cortical bone in group 3 was thicker in the middle portion compared to the superior and inferior portion. These findings showed that the buccal alveolar bone became more convex from the premolar to the molar region, gradually continuing to the infrazygomatic crest.

In terms of soft and hard tissus, thin soft tissue is more advantageous because the likelihood of inflammation is lower. The stability of miniscrew implants depends on the quality and quantity of the cortical bone. Because the main objective of an orthodontic screw is to gain maximum retention by placing the screw in an area with the thinnest soft tissue and the thickest cortical bone, positioning the screw 6 mm from the line connecting the buccal and palatal CEJ and angulating the screw placement path might be a good procedure. In patients without attached gingivae in those regions, moving coronally to regions with more gingival support might be needed. In group 3, however, cortical bone was thicker in the middle, so less pronounced angulation of the insertion path might be appropriate. Costa et al¹⁴ reported minimal complications after maxillary sinus perforation with orthodontic screw placement, so it might be wise to obtain sufficient retention regardless of the risk of sinus perforation.

On the palatal side, variations in soft-tissue thickness were greater than variations in cortical-bone thickness. Therefore, it is wise to place screws near the CEJ on the palatal side where the soft tissue is thinnest.

The midpalatal suture is a high-density bone structure with sufficient bone height up to cresta nasalis, making it a good location for orthodontic screws. As for the type of screws in this area, Block and Hoffman⁵ suggested a subperiosteal disc 10 mm in diameter, whereas Wehrbein et al¹⁵⁻¹⁷ recommended small diameter (3.3 mm) shortto-medium (4-6 mm) screws and studied the maximum bone height at the midpalatal suture area that can be used to place orthodontic screws without perforating the nasal cavity. These studies showed that the midpalatal suture is a solid anatomical structure that can be reliably used to place orthodontic screws, with at least 2 mm of additional bone height from the estimate made from lateral cephalograms. Although it could be possible to assess differences between actual and estimated bone height from lateral cephalograms, cortical-bone thickness at the midpalatal suture was excluded from this study because of the difficulty in locating and sectioning the thickest portion of the area. Cortical-bone thickness at the midpalatal suture can be assessed from computerized tomograms, which can be a good reference for the placement of the screw.

Soft-tissue measurements at the midpalatal suture area showed that the thickest portion was 4 mm posterior to the IP, and the thickness remained consistent at 1 mm posterior to this point. This area, with its consistent soft-tissue thickness, might be the most appropriate location to place the orthodontic implant.

Soft-tissue and cortical-bone thicknesses in the buccal side were greatest in group 2 and least in group 3. At the palatal side, cortical-bone thickness showed no difference between the 3 groups, whereas soft-tissue thickness showed significant differences farthest from the CEJ in group 3.

Care should be taken in interpreting these results because of the relatively small number of samples; nevertheless, these results suggest an anatomical pattern to the thicknesses of the soft and hard tissues that could be useful to clinicians. When orthodontic implants are placed at the midpalatal suture area, screw retention can be enhanced if the implant is placed where soft-tissue thickness is uniform.

CONCLUSIONS

- Buccal soft tissues were thickest closest to and farthest from the CEJ, and thinnest in the middle in all groups. Palatal soft-tissue thickness increased gradually from the CEJ toward the apical region.
- 2. Buccal cortical bone was thickest closest to and farthest from the CEJ and thinnest in the middle in groups 1 and 2; in group 3, the thickest area was 4 mm apical to the CEJ. Palatal cortical bone was thickest 6 mm apical to the CEJ in groups 1 and 3, and 2 mm apical to the CEJ in group 2.
- 3. Along the midpalatal suture, the palatal mucosa was thickest at a point 4 mm from the IP and remained uniformly thick 1 mm posterior to this point.

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