Original Article

Relationships between Dental Roots and Surrounding Tissues for Orthodontic Miniscrew Installation

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ABSTRACT

Objective: To elucidate relationships between the dental roots and surrounding tissues in order to prevent complications after placement of a miniscrew.

Materials and Methods: Twenty human mandibles and maxillas were used for this study. In the 200 sections of each mandible and maxilla, nine items were measured to investigate the relationships between the dental roots.

Results: The interroot distance increased from anterior to posterior teeth and from the cervical line to the root apex in both the maxilla and the mandible. In the maxilla, the greatest interroot distance was between the second premolar and the first molar. In the mandible, the greatest interroot distance was between the first and second molars. The maxillary buccolingual bone width exceeded 10 mm from 7 mm (between canine and first premolar), 5 mm (between second premolar and first molar), and 4 mm (between first and second molars) above the cervical line. The mandibular buccolingual bone width exceeded 10 mm from 7 mm (between second premolar and first molar) and 4 mm (between first and second molars) below the cervical line.

Conclusions: The safest zone for placement of a miniscrew in the maxilla was between the second premolar and the first molar, from 6 to 8 mm from the cervical line. The safest zone for placement of a miniscrew in the mandible was between the first and second molars, less than 5 mm from the cervical line. (*Angle Orthod.* 2009;79:37–45.)

KEY WORDS: Dental root; Interroot distance; Miniscrew; Complication

INTRODUCTION

Roberts et al[1] were the first to use an endosseous dental implant as orthodontic anchorage; such endosseous implants were applied to clinical orthodontics subsequently by Shapiro and Kokich[2] and by Roberts et al.[3] Dental implants,[4] miniplates,[5] and miniscrews[6] have been used as orthodontic anchorage, but the miniscrew type of anchorage is now the most widely used because of its low cost and ease of implantation.[7,8]

In clinical use, the early orthodontic implant provided orthodontic anchorage for simple tooth movements. Currently, orthodontic implants are used for complex procedures such as distal movement of the molar, intrusion of the molar, and treatment of an ectopic molar.[9–12]

Most research related to orthodontic implants has focused on the morphology of the miniscrew, including its type, shape, diameter, and length, as well as its initial stability.[3,13,14] In contrast, a few studies have evaluated and measured anatomical sites for safe placement of miniscrews in the interroot spaces of the maxillary and mandibular arches. This practice is probably responsible for the prevalence of complications such as hypersensitivity of the root, root fracture, and alveolar bone fracture resulting from miniscrew insertion. The interradicular space has been investigated through the use of panoramic radiography, computed tomography (CT), and micro-CT.[7,8,15,16] However, pre-

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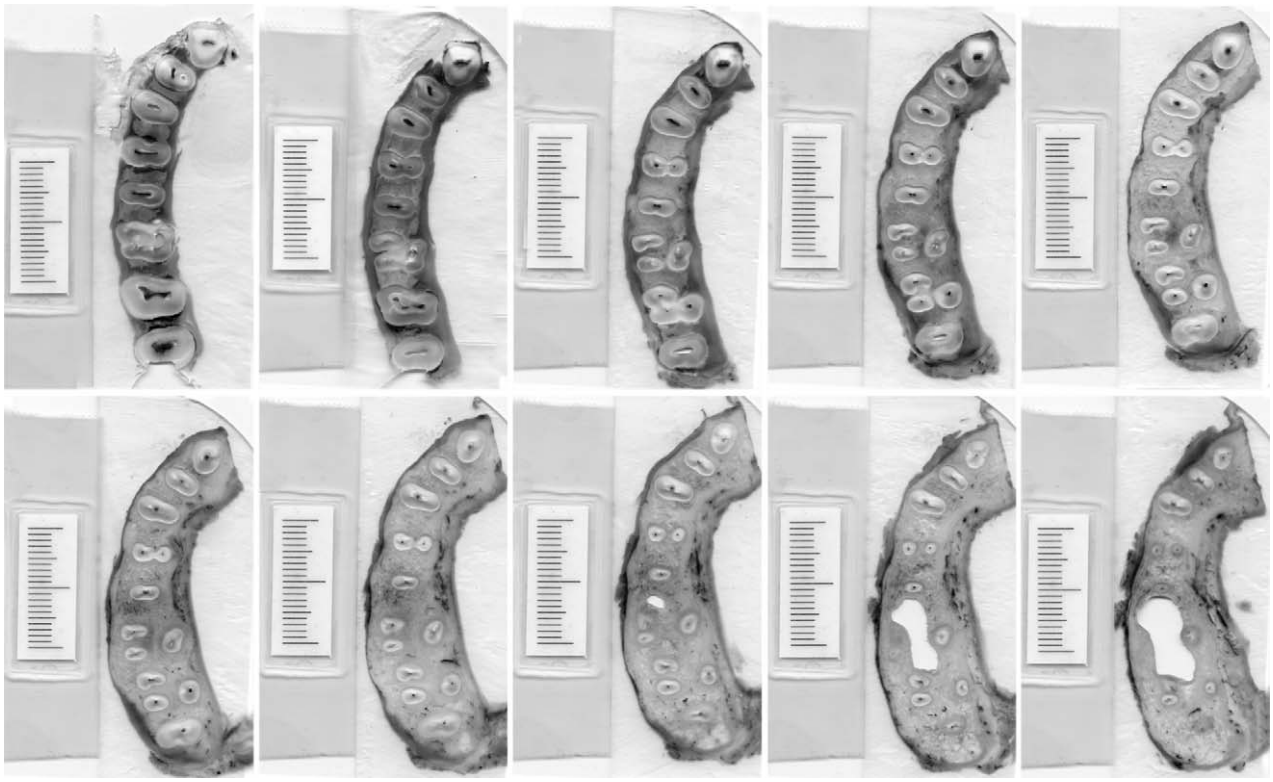

Figure 1. Sectioned specimens of the maxillary arch from 1 mm (upper left) to 10 mm (lower right) below the cervical line.

vious studies have not fully characterized the anatomical structures because of errors on the radiographs, and because investigations were restricted to the molar region.

The purposes of this study were to elucidate the relationships between the roots and surrounding structures and to identify the optimal sites for miniscrewing.

MATERIALS AND METHODS

Cross sections of human jaws were analyzed in 20 mandibles (17 males, 3 females; mean age, 63.3 years; age range, 29–75 years) and 20 maxillas (14 males, 6 females; mean age, 66.1 years; age range, 45–80 years).

Resin blocks were produced by dehydrating the specimens with the use of a conventional method for 3 days before infiltrating them with a mixture of Technovit 7200 (No. 51000; EXAKT Co., Norderstedt, Germany) and 100% alcohol. The infiltrated samples were placed in an embedding mold and were polymerized for 1 day with a light that had a 450 nm wavelength in a light-curing unit (520 light polymerization unit; EXAKT Co).

The resin blocks were cut serially at 1 mm intervals from the cervical line to the root apex with the use of a macrocutting and band system (300CP; EXAKT Co). Images of each section then were obtained at a resolution of 600 DPI with a computer scanner (Perfection 3490 Photo; Epson Co., Shanghai, China) and were stored in TIFF format with high-quality compression (Figures 1 and 2).

In all, 200 sections of each mandible and each maxilla were prepared, and the following items were measured with an image analysis system (Image-Pro Plus, version 4.0; Media Cybernetics Co., Bethesda, Md, USA) after a standard calibration was performed (Figure 3):

Interroot distance (buccal and lingual)
Buccolingual bone width
Cortical bone thickness (buccal and lingual)
Mucosal thickness (buccal and lingual)

RESULTS

The measurements did not differ significantly with regard to sex, age, or side ($P > .05$).

Interroot Distance

The interroot distance increased from anterior to posterior teeth and from the cervical line to the root apex in both the maxilla and the mandible (Tables 1 and 2). In the maxilla, the interroot distance was greatest between the second premolar and the first molar. The interroot distance from the central incisor to the

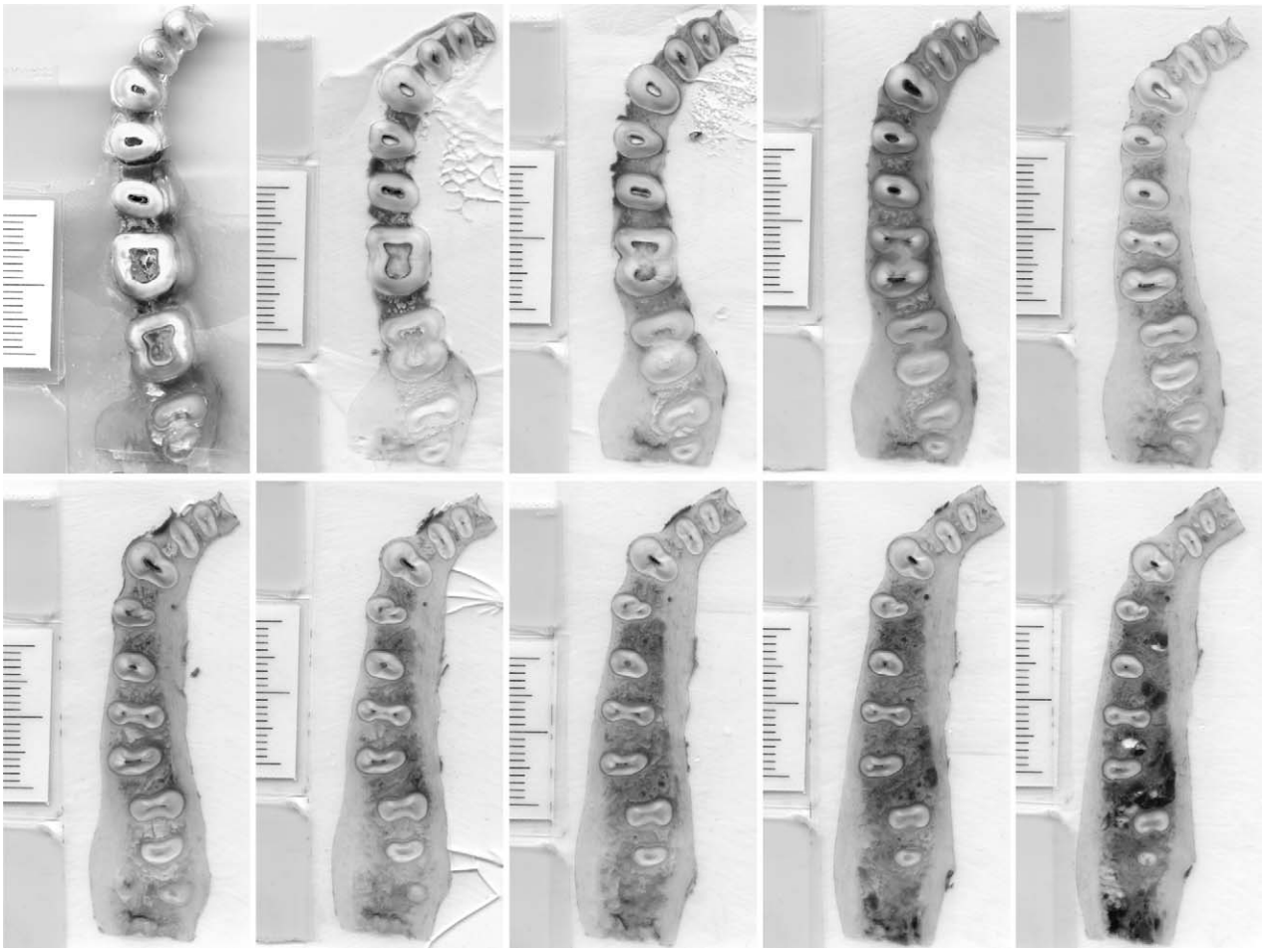

Figure 2. Sectioned specimens of the mandibular arch from 1 mm (upper left) to 10 mm (lower right) below the cervical line.

first premolar was greater on the buccal side than on the palatal side but was similar on both sides between the first and second premolars. The interroot distance from the second premolar to the second molar was greater on the palatal side than on the buccal side. In the maxillary anterior teeth, the interroot distance exceeded 3 mm from 7 mm above the cervical line on the buccal side and 9 mm on the palatal side. In the maxillary posterior teeth, the interroot distance exceeded 3 mm from 3 mm above the cervical line on the buccal side and 2 mm on the palatal side (Table 1). The roots of the first and second molars penetrated the maxillary sinus at 8 to 9 mm above the cervical line in 5 of 25 cases (20%).

In the mandible, the interroot distance was greatest between the first and second molars. In contrast to the maxillary arch, interroot distances from the central incisor to the canine and from the second premolar to the second molar were greater on the buccal side than on the lingual side. However, the interroot distance from the canine to the second premolar was similar on both sides. In the mandibular anterior teeth, the interroot distance exceeded 3 mm from 9 mm below the cervical line on the buccal side. In contrast to the maxillary arch, the aspect of the region of the mandibular posterior teeth varied. The interroot distance exceeded 3 mm from 3 mm below the cervical line (between first and second premolars), 7 mm (between second premolar and first molar), and 2 mm (between first and second molars). In the region of the posterior teeth, the interroot distance was smallest between the second premolar and the first molar (Table 2).

Buccolingual Bone Width

The maxillary buccolingual bone width increased from anterior to posterior teeth and from the cervical line to the root apex. The buccolingual bone width exceeded 8 mm from 5 mm above the cervical line (from central incisor to canine), 3 mm (from canine to first molar), and 1 mm (between first and second molars). The buccolingual bone width exceeded 10 mm from 7 mm above the cervical line (between canine and first molar), 5 mm (between second premolar and first mo-

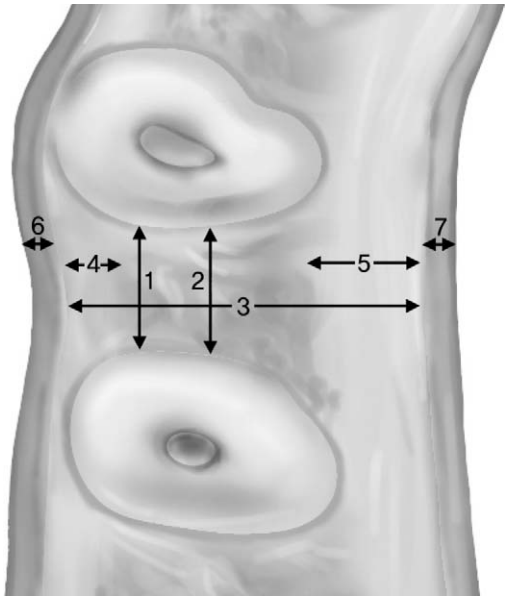

Figure 3. Measurements of a sectioned specimen. 1 indicates buccal interroot distance; 2, lingual interroot distance; 3, buccolingual bone width; 4, buccal cortical bone thickness; 5, lingual cortical bone thickness; 6, buccal mucosal thickness; and 7, lingual mucosal thickness.

lar), and 4 mm (between first and second molars) (Table 3).

The mandibular buccolingual bone width also increased from anterior to posterior teeth. This bone width was greatest at 5 mm below the cervical line from the central incisor to the canine, and it increased from the cervical line to the root apex in other regions. The buccolingual bone width did not exceed 8 mm in the anterior teeth region, but it did exceed 8 mm from 5 mm below the cervical line (from canine to second premolar) and 2 mm (from second premolar to second molar). The buccolingual bone width exceeded 10 mm from 7 mm below the cervical line (between second premolar and first molar) and 4 mm (between first and second molars). In general, the mandibular buccolingual bone width was narrower than the maxillary bone width (Table 3).

Cortical Bone Thickness

The maxillary buccal cortical bone was thicker in the posterior teeth region than in the anterior teeth region, but the difference (0.2 mm) was small and the thickness did not change from the cervical line to the root apex. The maxillary palatal cortical bone thickness was similar to buccal cortical bone thickness from the anterior to posterior teeth regions. However, it increased by about 0.5 mm from the cervical line to the root apex (Table 4).

The mandibular cortical bone thickness increased from anterior to posterior teeth regions and from the cervical line to the root apex. The change in bone thickness was greater in the posterior teeth region than in the anterior teeth region. The mandibular cortical bone was thicker on the lingual side than on the buccal side in the anterior teeth region, and on the buccal side than on the lingual side in the posterior teeth region (Table 5). The cortical bone thickness was similar in the mandibular and maxillary arches in the anterior teeth region, but it was greater in the mandibular arch in the posterior teeth region.

DISCUSSION

The form (endosseous dental implant, miniplate, or miniscrew) and size of orthodontic implants have changed considerably since Roberts et al[1] first used an implant for orthodontic anchorage in 1984; the mini-

Table 1. Interroot Distance of the Maxillary Teeth (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[b]											
CI-LI	B	1.8	1.8	1.9	2.2	2.5	2.9	3.1[a]	3.3[a]	3.8[a]	4.0[a]
	P	1.4	1.5	1.5	1.8	2.0	2.3	2.6	2.9	3.4[a]	4.0[a]
LI-C	B	1.8	1.9	2.1	2.4	2.5	2.8	2.9	3.1[a]	3.3[a]	3.6[a]
	P	1.8	1.9	2.2	2.4	2.4	2.6	2.7	2.8	3.0[a]	3.4[a]
C-FP	B	2.2	2.4	2.5	2.7	2.8	2.9	3.1[a]	3.4[a]	3.6[a]	3.9[a]
	P	2.4	2.5	2.5	2.7	2.7	2.9	3.0[a]	3.2[a]	3.5[a]	3.7[a]
FP-SP	B	2.5	3.0[a]	3.0[a]	3.2[a]	3.3[a]	3.3[a]	3.4[a]	3.5[a]	3.8[a]	4.0[a]
	P	2.6	3.1[a]	3.1[a]	3.3[a]	3.3[a]	3.4[a]	3.5[a]	3.6[a]	3.8[a]	3.9[a]
SP-FM	B	2.5	2.9	3.0[a]	3.2[a]	3.3[a]	3.5[a]	3.8[a]	4.2[a]	4.7[a]	4.8[a]
	P	2.7	3.1[a]	3.3[a]	3.5[a]	3.7[a]	4.2[a]	4.6[a]	5.1[a]	5.9[a]	6.0[a]
FM-SM	B	2.4	2.8	2.7	2.7	2.5	2.6	2.8	3.1[a]	3.8[a]	4.8[a]
	P	2.4	3.0[a]	3.2[a]	3.6[a]	4.0[a]	4.2[a]	4.6[a]	5.3[a]	5.6[a]	6.3[a]

[a] Interroot distance is at least 3.0 mm.

[b] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; P, palatal; SM, second molar; and SP, second premolar.

Table 2. Interroot Distance of the Mandibular Teeth (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[b]											
CI-LI	B	2.0	1.8	2.0	2.1	2.1	2.2	2.4	2.4	2.0	3.3[a]
	L	1.4	1.5	1.6	1.6	1.6	1.8	2.2	2.3	2.2	3.0[a]
LI-C	B	1.7	1.8	2.1	2.3	2.5	2.7	2.9	3.3[a]	3.3[a]	3.7[a]
	L	1.2	1.4	1.4	1.6	1.8	2.0	2.2	2.4	2.7	3.1[a]
C-FP	B	2.0	2.1	2.2	2.4	2.6	2.7	2.9	2.9	3.2[a]	3.6[a]
	L	1.9	2.1	2.2	2.4	2.6	2.7	2.9	3.0[a]	3.1[a]	3.5[a]
FP-SP	B	2.3	2.6	3.0[a]	3.3[a]	3.4[a]	3.6[a]	3.8[a]	4.1[a]	4.4[a]	4.7[a]
	L	2.4	2.8	3.1[a]	3.4[a]	3.5[a]	3.7[a]	3.9[a]	4.1[a]	4.5[a]	4.7[a]
SP-FM	B	2.4	2.6	2.7	2.8	2.9	3.0[a]	3.2[a]	3.7[a]	3.8[a]	4.0[a]
	L	2.3	2.6	2.7	2.7	2.8	2.9	3.1[a]	3.3[a]	3.6[a]	3.8[a]
FM-SM	B	2.9	3.2[a]	3.4[a]	3.7[a]	3.9[a]	4.1[a]	4.7[a]	4.9[a]	5.2[a]	6.1[a]
	L	2.6	3.0[a]	3.2[a]	3.4[a]	3.6[a]	3.9[a]	4.4[a]	5.1[a]	5.0[a]	5.8[a]

[a] Interroot distance is at least 3.0 mm.
[b] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; P, palatal; SM, second molar; and SP, second premolar.

Table 3. Buccolingual Bone Width of the Maxilla and Mandible (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[c]											
CI-LI	Mx	6.3	6.7	6.9	7.8	8.3[a]	9.0[a]	9.4[a]	9.2[a]	9.4[a]	9.4[a]
	Mn	5.4	6.0	6.2	6.3	6.1	6.1	5.7	5.9	5.7	4.7
LI-C	Mx	6.3	6.6	7.2	7.5	8.3[a]	8.9[a]	9.3[a]	9.1[a]	9.0[a]	9.2[a]
	Mn	5.7	6.3	7.0	7.5	7.6	7.5	7.2	7.0	7.2	7.3
C-FP	Mx	7.0	7.3	8.2[a]	8.5[a]	9.2[a]	9.5[a]	10.0[b]	9.9[a]	10.0[b]	10.1[b]
	Mn	6.2	6.7	7.4	7.9	8.1[a]	8.4[a]	8.5[a]	8.7[a]	8.9[a]	9.1[a]
FP-SP	Mx	7.2	7.4	8.4[a]	8.9[a]	9.1[a]	9.3[a]	9.4[a]	9.4[a]	9.7[a]	10.0[b]
	Mn	5.8	6.7	7.1	7.6	8.2[a]	8.7[a]	9.0[a]	9.4[a]	9.8[a]	10.3[b]
SP-FM	Mx	7.3	7.9	9.2[a]	9.8[a]	10.4[b]	10.7[b]	10.8[b]	10.8[b]	11.1[b]	11.9[b]
	Mn	6.7	8.0[a]	8.5[a]	8.9[a]	9.2[a]	9.8[a]	10.3[b]	10.7[b]	11.1[b]	11.5[b]
FM-SM	Mx	8.8[a]	9.1[a]	9.6[a]	10.8[b]	12.3[b]	12.7[b]	13.2[b]	13.6[b]	13.8[b]	14.0[b]
	Mn	7.6	8.7[a]	9.5[a]	10.1[b]	11.0[b]	12.0[b]	12.9[b]	13.3[b]	13.4[b]	13.1[b]

[a] Buccolingual bone width is between 8.0 mm and 9.9 mm.
[b] Buccolingual bone width is at least 10.0 mm.
[c] C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; Mn, mandibular; Mx, maxillary; SM, second molar; and SP, second premolar.

screw type is now the most widely used because of its low cost and ease of implantation. Miniscrews typically have diameters ranging from 1.2 to 2 mm and lengths of 6, 8, and 10 mm.[15] For installation of the miniscrew without damage to the periodontal tissue and dental root, a minimum clearance of 1 mm of alveolar bone around the screw is needed.[16] When the diameter of the miniscrew and the minimum clearance of alveolar bone are considered, the miniscrew can be installed safely if at least 3 mm of space is available in the interradicular space.

Many studies have measured the interroot distance with the use of decalcified specimens, panoramic radiography, CT, and micro-CT.[7,8,15–17] The tissue can deform during the decalcification process, a panoramic radiographic image can be distorted, and the border between the alveolar bone and the cementum of the root is not clear on CT images. Micro-CT solves these problems, but it cannot be used to examine mucosa or the entire maxilla and mandible. Therefore, the most accurate method is to examine normal specimens that are cut directly from untreated tissue.

Heins and Wieder[17] measured the smallest interroot distance between the premolar and the molar in decalcified specimens. They reported that the distance between the second premolar and the first molar was smallest, particularly in the cervical third and the middle third (distance of 2.03 mm) and between the first and second molars in the middle third (distance of 1.05 mm). In the present study, it was found that the inter-

Table 4. Cortical Bone Thickness of the Maxilla (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	—	1.0	1.0	1.1	1.1	1.2	1.2	1.1	1.3	1.2
	P	—	1.0	1.1	1.2	1.2	1.6	1.5	1.3	1.5	1.4
LI-C	B	—	1.1	1.0	1.1	1.0	1.1	1.2	1.2	1.2	1.3
	P	—	1.1	1.2	1.2	1.3	1.5	1.6	1.5	1.4	1.5
C-FP	B	—	1.1	1.1	1.1	1.0	1.1	1.2	1.1	1.0	1.1
	P	—	1.1	1.3	1.2	1.3	1.5	1.7	1.6	1.6	1.6
FP-SP	B	—	1.2	1.1	1.1	1.0	1.1	1.1	1.0	1.1	1.1
	P	—	1.2	1.2	1.2	1.2	1.4	1.4	1.4	1.5	1.5
SP-FM	B	—	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.2
	P	—	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.7
FM-SM	B	—	1.2	1.3	1.1	1.5	1.3	1.2	1.2	1.2	1.4
	P	—	1.1	1.1	1.3	1.2	1.3	1.3	1.5	1.6	1.6

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; P, palatal; SM, second molar; and SP, second premolar.

Table 5. Cortical Bone Thickness of the Mandible (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	—	0.9	1.0	1.1	1.1	1.3	0.9	1.0	1.1	1.6
	L	—	1.1	1.3	1.4	1.4	1.6	1.6	1.6	1.6	1.3
LI-C	B	—	1.0	1.2	1.3	1.3	1.3	1.2	1.2	1.4	1.3
	L	—	1.3	1.4	2.0	2.2	2.3	2.2	2.2	2.3	2.3
C-FP	B	—	1.3	1.5	1.4	1.5	1.5	1.6	1.5	1.6	1.5
	L	—	1.5	1.7	2.0	2.2	2.7	2.5	2.5	2.8	2.8
FP-SP	B	—	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.9
	L	—	1.5	1.7	1.9	2.2	2.5	2.6	2.7	2.7	3.0
SP-FM	B	—	1.7	1.8	1.9	1.9	1.9	2.0	2.2	2.3	2.5
	L	—	1.4	1.6	1.8	2.1	2.3	2.5	2.4	2.5	2.5
FM-SM	B	—	2.0	2.4	2.3	2.7	3.0	3.2	3.5	3.5	3.8
	L	—	1.7	1.8	1.7	2.1	2.3	2.4	2.2	2.4	3.0

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; L, lingual; LI, lateral incisor; SM, second molar; and SP, second premolar.

Table 6. Mucosa Thickness of the Maxilla (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	0.5	0.5	0.7	0.7	0.7	0.8	0.8	0.8	1.0	1.0
	P	1.1	2.0	2.4	2.7	3.1	3.0	2.8	3.1	3.4	2.9
LI-C	B	0.6	0.5	0.6	0.7	0.6	0.6	0.6	0.7	0.7	0.7
	P	1.0	1.8	2.2	2.9	3.1	3.4	3.5	4.1	3.9	4.2
C-FP	B	0.6	0.7	0.7	0.6	0.5	0.5	0.6	0.6	0.7	0.7
	P	1.1	1.7	2.1	2.8	3.2	3.7	4.0	4.1	4.0	4.5
FP-SP	B	0.6	0.7	0.7	0.6	0.6	0.7	0.7	0.8	0.8	0.8
	P	0.9	1.4	1.6	2.3	2.7	3.2	3.7	3.9	4.1	4.6
SP-FM	B	0.6	0.7	0.7	0.6	0.6	0.7	0.8	0.8	0.8	0.6
	P	0.9	1.4	1.5	2.0	2.0	2.2	2.9	3.4	3.3	3.8
FM-SM	B	0.6	0.6	0.9	0.8	0.5	0.7	0.5	0.5	0.6	0.8
	P	0.9	1.2	1.7	1.8	2.1	2.0	1.9	2.2	2.2	3.6

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; P, palatal; SM, second molar; and SP, second premolar.

Table 7. Mucosa Thickness of the Mandible (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	0.7	0.8	0.6	0.7	0.7	0.7	0.8	0.9	1.0	1.0
	L	0.7	0.8	0.8	0.8	0.7	0.7	0.8	0.7	0.8	0.8
LI-C	B	0.6	0.7	0.7	0.6	0.6	0.7	0.8	0.8	0.8	0.6
	L	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.6	0.5	0.6
C-FP	B	0.7	0.7	0.6	0.6	0.6	0.7	0.7	0.8	0.7	0.6
	L	0.6	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.6	0.6
FP-SP	B	0.7	0.6	0.7	0.6	0.7	0.7	0.8	0.8	0.6	0.6
	L	0.5	0.6	0.6	0.7	0.6	0.6	0.6	0.7	0.6	0.6
SP-FM	B	0.8	0.7	0.6	0.6	0.8	0.9	0.8	0.8	0.6	0.6
	L	0.6	0.5	0.6	0.6	0.6	0.5	0.6	0.7	0.6	0.6
FM-SM	B	0.8	0.8	0.7	0.8	0.8	0.7	0.6	0.6	0.7	0.6
	L	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.7

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; L, lingual; LI, lateral incisor; SM, second molar; and SP, second premolar.

Table 8. Sum of the Maxillary Buccolingual Bone Thickness and Mucosa Thickness Where Miniscrew Insertion Is Possible (ie, possible length of the miniscrew) (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	—	—	—	—	—	—	10.2	10.0	10.4	10.4
	P	—	—	—	—		—	12.2	12.3	12.8	13.3
LI-C	B	—	—	—	—	—	—	—	9.8	9.7	9.9
	P	—	—	—	—	—	—	—	13.2	12.9	13.4
C-FP	B	—	—	—	—	—	—	10.6	10.5	10.7	10.8
	P	—	—	—	—	—	—	14.0	14.0	14.0	14.6
FP-SP	B	—	8.1	9.1	9.5	9.7	10.0	10.1	10.2	10.5	10.8
	P	—	8.8	10.0	11.2	11.8	12.5	13.1	13.3	13.8	14.6
SP-FM	B	—	—	9.9	10.4	11.0	11.4	11.6	11.6	11.9	12.5
	P	—	—	10.7	11.8	12.4	12.9	13.7	14.2	14.4	15.7
FM-SM	B	—	—	—	—	—	—	—	14.1	14.4	14.8
	P	—	—	—	—	—	—	—	15.8	16.0	17.6

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; LI, lateral incisor; P, palatal; SM, second molar; and SP, second premolar.

root distance is greater between the second premolar and the first molar than between the first and second molars; however, these distances were greater than in the previous study. Also, this study differed from the previous study in that the smallest distance between the first and second molars occurred in the cervical third. This difference is probably due to deformation of tissue during the decalcification process. Moreover, the same difference was evident in the mandible.

The interroot distance for CT data was greater than for the data obtained in this study in the anterior teeth region, and it was smaller in the posterior teeth region in both the maxilla and the mandible. On CT, the border between the alveolar bone and the cementum of the root is unclear because of their similar densities; hence the interroot distance varies with the threshold used in CT. The buccolingual bone width is not influenced by this effect, and it did not differ greatly between the CT data and data reported in this study. The micro-CT data differed greatly from the data obtained in this study, but this difference might be due to the small number of samples (only five).

Safe Zone for Miniscrew Installation

In the maxilla, it was possible to place a miniscrew at least 7 and 9 mm from the cervical line on the buccal and palatal sides of the anterior teeth, respectively. In the posterior teeth region, the possible insertion site was less than 2 mm from the cervical line. However, the possible insertion site on the buccal side between the first and second molars was from 8 mm above the cervical line. In the maxilla, the safest zone for placement of miniscrews was between the second premolar

Table 9. Sum of the Mandibular Buccolingual Bone Thickness and Mucosa Thickness Where Miniscrew Insertion Is Possible (ie, possible length of the miniscrew) (unit: mm)

		Distance From Cervical Line, mm									
		1	2	3	4	5	6	7	8	9	10
Teeth[a]											
CI-LI	B	—	—	—	—	—	—	—	—	—	5.6
	L	—	—	—	—	—	—	—	—	—	5.5
LI-C	B	—	—	—	—	—	—	—	7.8	8.0	7.9
	L	—	—	—	—	—	—	—	—	—	7.9
C-FP	B	—	—	—	—	—	—	—	—	9.6	9.7
	L	—	—	—	—	—	—	—	9.4	9.5	9.7
FP-SP	B	—	—	7.8	8.2	8.9	9.4	9.8	10.2	10.4	10.9
	L	—	—	7.7	8.3	8.8	9.3	9.6	10.1	10.4	10.9
SP-FM	B	—	—	—	—	—	—	11.2	11.5	11.7	12.1
	L	—	—	—	—	—	—	10.9	11.4	11.7	12.1
FM-SM	B	—	9.4	10.2	10.9	11.8	12.7	13.5	13.9	14.1	13.7
	L	—	9.4	10.1	10.8	11.6	12.6	13.5	13.9	14.1	13.8

[a] B indicates buccal; C, canine; CI, central incisor; FM, first molar; FP, first premolar; L, lingual; LI, lateral incisor; SM, second molar; and SP, second premolar.

and the first molar—at least 6 mm above the cervical line (Table 1). However, if a miniscrew is installed at least 8 mm above the cervical line, it should be confirmed radiographically whether the maxillary root has penetrated the maxillary sinus.

Insertion of miniscrews in the mandibular anterior teeth region was possible less than 10 mm from the cervical line. The possible insertion site between the first and second premolars, between the second premolar and the first molar, and between the first and second molars was less than 3, 7, and 2 mm from the cervical line, respectively. In the mandible, the safest zone for placement of a miniscrew was between the first and second molars less than 5 mm from the cervical line (Table 2).

In both the maxilla and the mandible, the shortest distance from the cortical bone to a line perpendicular to the interroot distance was greater on the lingual side than on the buccal side, with this difference increasing from the cervical line to the root apex. This phenomenon is due to (1) the location of both teeth more on the buccal side than on the lingual side, and (2) the increase in width of the jaw from the cervical line to the root apex. Therefore, it is considered safer to insert a miniscrew on the lingual side than on the buccal side.

Stability and Length of the Miniscrew

The stability of a miniscrew is determined by its length and by the cortical bone thickness. When the cortical bone is thicker and the miniscrew is longer, the stability of the miniscrew is increased. Therefore, the installation of a long miniscrew in the thick cortical bone area was profitable for the stability of the miniscrew. The allowable length of a miniscrew is influenced by the buccolingual width of the jaw and the mucosal thickness. The thickness of the maxillary buccal mucosa and of the mandibular buccal and lingual mucosa was constant in all regions, at about 0.7 mm. However, the thickness of the maxillary palatal mucosa was 1 to 2 mm and 3 to 4 mm in the cervical and apical regions, respectively; this allows for use of a longer miniscrew (Tables 6, 7).

The length of the miniscrew is decided by the interroot distance, the buccolingual bone width, and the mucosal thickness. Also, the interroot bone must be at least 4 mm thick to allow placement of a miniscrew.[8] In the maxillary buccal installation, the regions for which an 8 mm miniscrew is recommended are found between central incisor and canine (from 9 mm above cervical line), between first and second premolars (from 3 mm above cervical line), and between second premolar and first molar (from 3 mm to 4 mm above cervical line). The regions for which a miniscrew of 10 mm is recommended are located between canine and first premolar (from 7 mm above cervical line), between second premolar and first molar (from 5 mm above cervical line), and between first and second molars (from 8 mm above cervical line). However, in the case of a palatal installation, the miniscrew should be 2 mm longer than that used in buccal installation because of palatal mucosa thickness (Table 8).

In the mandible, the regions for which a 6 mm miniscrew is recommended are between lateral incisor and canine (10 mm below cervical line) and between first and second premolars (from 3 mm to 4 mm below cervical line). The regions for which an 8 mm miniscrew is recommended are between canine and first premolar (from 9 mm below cervical line), between first and second premolars (from 5 mm to 8 mm below cer-

vical line), and between first and second molars (from 2 mm to 3 mm below cervical line). The regions for which a 10 mm miniscrew is recommended are between first and second premolars (from 9 mm below cervical line), between second premolar and first molar (from 7 mm below cervical line), and between first and second molars (from 4 mm below cervical line) (Table 9).

A miniscrew may be longer in the maxillary arch than in the mandibular arch, whereas the cortical bone is thicker in the mandible than in the maxilla on both buccal and lingual sides (Tables 4 and 5). This means that the stability of a miniscrew will be greater for the mandible than for the maxilla because it is more affected by bone thickness than by the length of the miniscrew. Miniscrews can be placed oblique to the long axis of the teeth so as to increase cortical bone contact and allowable miniscrew length, although this requires careful consideration of the maxillary sinus and the mandibular canal.[15] We believe that further investigation is required regarding the safety and strength of such oblique placement of miniscrews in each region.

CONCLUSIONS

- The safest zone for placement of a miniscrew is between second premolar and first molar, from 6 to 8 mm above the cervical line in the maxilla, and between first and second molars, less than 5 mm from the cervical line in the mandible.
- In the maxillary, the regions for which a miniscrew of 8 mm is recommended are a buccal installation between central incisor and canine (from 9 mm above cervical line), between first and second premolars (from 3 mm above cervical line), and between second premolar and first molar (from 3 mm to 4 mm above cervical line).
- In the mandible, the regions for which a miniscrew of 8 mm is recommended are between canine and first premolar (from 9 mm below cervical line), between first and second premolars (from 5 mm to 8 mm below cervical line), and between first and second molars (from 2 mm to 3 mm below cervical line).

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