Anatomical Relationships between Dental Roots and Surrounding Tissues, and Topography of the Neurovascular Structures within the Mandibular Canal

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저는 지금 저의 학문의 길에서 한 고지를 넘고 있습니다. 제가 해부학이라는 학문에 들어설 수 있게 도와주신 모든 분들께 감사드립니다. 1994년 본과 1학년 때의 만남을 시작으로 지금까지 13년 동안 언제나 옆에서 지켜보면서 올바른 학문의 길로 인도해주신 김 희진 교수님께 가장 큰 감사를 드립니다. 또한, 저에게 언제나 큰 등불이 되어 주시는 정 인혁 교수님과 고 기석 교수님께 감사를 드립니다. 이 논문이 완성되기 까지 바쁘신 와중에도 많이 지도해주신 이 승일, 한 동후, 정 한성 교수님과 구강생물학교실 모든 교수님들께도 감사의 마음을 전합니다. 여러 가지 바쁜 일 중에도 자기 일처럼 실험을 도와주신 강 민규 선생님과 해부파트 모든 조교선생님들께도 감사의 마음을 전합니다.

끝으로, 제가 이 자리에 올 때까지 저를 키워주시고 물심양면으로 도와주신 아버지, 어머니, 장인어른, 장모님과 끝없는 내조로 제가 학문의 길을 계속해서 정진할 수 있도록 도와주는 나의 사랑하는 아내 송 현정과 씩씩한 아들 민혁, 귀여운 딸 민영, 민지에게 이 논문을 바칩니다.

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Abstract

Anatomical Relationships between Dental Roots and Surrounding Tissues, and Topography of the Neurovasular Structures within the Mandibular Canal

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Although early implant technique was used only to replace missing teeth, it is now used in other various dental fields such as orthodontic anchorage and so on. As the demand of dental implants increased, there also has been an increase in complications after the dental implantation. The major complication during or after the dental implantation is the loss of sensation resulted in the damage of the inferior alveolar nerve. This damage occurs because the precise information such as the location of the mandibular canal and the traveling course of the inferior alveolar nerve, artery and vein is not clearly clarified. The major complication after the miniscrewing procedure as an orthodontic anchorage are the fracture of bone and tooth, and the tooth hypersensitivity. These are resulted from the difficulty in locating the precise position in fixing the miniscrew. Therefore, the purposes of this study were to elucidate the relationship between the dental roots, and to verify the topography of the inferior alveolar nerve, artery, and vein within the mandibular canal. Thirty mandibles and 20 maxillas were used for this study. In the 200 sections of

each mandible and maxilla, 9 items were measured for investigating the relationship between the dental roots. The mandibular canal was reconstructed three dimensionally for investigating topography of the inferior alveolar nerve, artery and vein.

The interroot distance increased from anterior to posterior teeth, and from the cervical line to the root apex in both the maxilla and mandible. 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 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 mandible, the interroot distance was greatest between the first and second molars. *U*nlike the maxillary arch, the 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. The maxillary buccolingual bone width exceeded 8 mm from 5, 3, and 1 mm above the cervical line from the central incisor to the canine, from the canine to the first molar, and between the first and second molars, respectively. The buccolingual bone width exceeded 10 mm from 7, 5, and 4 mm above the cervical line between the canine and the first premolar, between the second premolar and the first molar, and between the first and second molars, respectively. The mandibular buccolingual bone width did not exceed 8 mm in the anterior teeth region, but it did exceed 8 mm from 5 and 2 mm below the cervical line from the canine to the second premolar and from the second premolar to the second molar, respectively. The buccolingual bone width exceeded 10 mm from 7 and 4 mm below the cervical line between the second premolar and the first molar, and between the first

and second molars, respectively.

The inferior alveolar vessel traveled above the inferior alveolar nerve within the main part of the mandibular canal in most cases (80%, 8/10), with the inferior alveolar artery being lingual to the inferior alveolar vein. There were two cases where the inferior alveolar vessel was buccal to the nerve (20%, 2/10).

This data is expected to help prevent complications of implant fixtures, such as loss of sensation, tooth hypersensitivity, and bone fracture, and to expand the application field of dental implant.

Key words : root, interroot distance, miniscrew, mandibular canal, inferior alveolar nerve, inferior alveolar vessel, dental implant

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Ⅰ. INTRODUCTION

Bränemark et al. (1964) observed the first to firmly anchor titanium to bone without an adverse tissue reaction. They could demonstrate that the titanium implants had been stable for 5 years, and had osseointegrated into bone. Since then, the use of dental implants has become widespread (Bränemark et al., 1969). The early implant techniques were used only to replace missing teeth, but they are now used in various dental fields such as orthodontic anchorage.

Roberts et al. (1984) were the first to use an implant as an orthodontic anchorage, and such endosseous implants were applied to subsequently clinical orthodontics by Shapiro and Kokich (1988) and Robert et al. (1990). Dental implants (Herrero, 1998; Wehrbein et al., 1999), miniplates (Jenner and Fitzpatrick, 1985; Umemori et al., 1998), and miniscrews (Costa et al., 1998; Giancotti et al., 2003; Kyung et al., 2003) have been used as orthodontic anchorages, but the miniscrew type is now the most widely used due to its low cost and ease of implantation (Ishii et al., 2004; Schnelle et al., 2004). In clinical use, the early orthodontic implant was used simply as an orthodontic anchorage for tooth movement, but current orthodontic implants are used to provide additional anchorage for orthopedic treatment as well as for complex procedures such as distalization of the molar, intrusion of the molar, and treatment of the ectopic molar (Smalley et al., 1988; Giancotti et al., 2003; Kyung et al., 2003; Bae and Kyung, 2006; Jeon et al., 2006; Lin et al., 2006; Park, 2006; Xun et al., 2007). Also, the miniscrew has been inserted at not only the interradicular area of the molar region but also various other regions such as the anterior nasal spine, hard palate, maxillary tuberosity, mandibular retromolar torus, mental region, and mandibular lingual region (Kanomi, 1997; Costa et al., 1998; Wehrbein et al., 1998, 1999; Kyung et al., 2003; Maino et al., 2003; Paik et al., 2003; Park, 2006). Most research related to orthodontic implants has focused on morphologic investigations such as the type, shape, diameter, and length of the miniscrew, and investigations of the initial stability of the miniscrew (Roberts et al., 1990; Odman et al., 1994; Kanomi, 1997; Klokkevold et al., 1997). In contrast, few studies have evaluated and measured the anatomical sites for safe placement of miniscrews in the interroot spaces of the maxillary and mandibular arches. This is probably responsible for the high 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 using panorama radiography, computed tomography (CT), and micro-CT (Ishii et al., 2004; Schnelle et al.

2004; Deguchi et al., 2006; Poggio et al., 2006). However, previous studies have not fully characterized the anatomic structures because of errors in the radiographs and the investigations being restricted to the molar region.

The demand for prosthetic implants is increasing, and there has been a concomitant increase in complications after dental implantation, predominantly perforation of the maxillary sinus and the loss of sensation resulting from damage to the inferior alveolar nerve. In addition, unexpected hemorrhage can occur in the maxilla and mandible. This damage occurs because precise information is not available on factors such as the location of the mandibular canal and the traveling courses of the inferior alveolar nerve, artery, and vein within the mandibular canal. Research into dental implants used for restoration of tooth loss has focused on factors related to the placement of implants, such as how well they are integrated inside the alveolar bone and how fast they can be surgically placed, with little attention paid to postoperative complications after implant surgery. Only Polland et al. (2001) and Kieser et al. (2004) have studied the traveling course of the inferior alveolar nerve within the mandibular canal in the edentulous region for installation of implants, but they did not describe the relative locations of the inferior alveolar nerve, artery, and vein. Wadu et al. (1997) reported how the neurovascular bundle within the mandibular canal is arranged, with the inferior alveolar vein, artery, and nerve from superior to inferior. However, Zoud and Doran (1993) described that the inferior alveolar artery travels below the nerve in the main part of the mandibular canal, and then superior to the nerve in the distal part of the canal, with the nerve and artery forming an intertwined plexus throughout the mandibular canal. These discrepancies in the reported relationships of the inferior alveolar nerve, artery, and vein indicates that three-dimensional reconstruction of the mandibular canal is required to accurately understand the morphology of the neurovascular bundle within the mandibular canal.

The purposes of this study were to elucidate the relationship between the dental roots and between the roots and surrounding structures. and to verify the topography of the inferior alveolar nerve, artery, and vein within the mandibular canal by three-dimensional reconstruction of these structures.

Ⅱ. MATERIALS & METHODS

1. Materials

Jaw cross sections 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), and 10 mandibles (7 males, 3 females mean age 62.9 years, age range 36 - 78 years) were used for the three-dimensional reconstruction. All specimens had normal occlusion and normal teeth alignment, and a minimum of five continuous teeth.

2. Methods

A. Cross section of the arch

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

The constructed resin blocks were cut serially at 1 mm intervals from the cervical line to the root apex using Macro Cutting & Band System (300CP, EXAKT Co., Germany). Images of each section (including a ruler) were then obtained at a resolution of 600 DPI using a computer scanner (Perfection 3490 Photo, EPSON Co., China) and stored in JPEG format with high-quality compression (Figs. 1, 2).

In the 200 sections of each mandible and maxilla, the following items were measured using an image analysis system (Image-Pro® Plus, ver. 4.0, Media

Cybernetics Co., USA) after performing a standard calibration (Fig. 3):

1. Interroot distance (buccal and lingual).

2. Shortest distance from the cortical bone to a line perpendicular to the interroot distance (buccal and lingual).

3. Buccolingual bone width.

4. Cortical bone thickness (buccal and lingual).

5. Mucosa thickness (buccal and lingual).

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

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

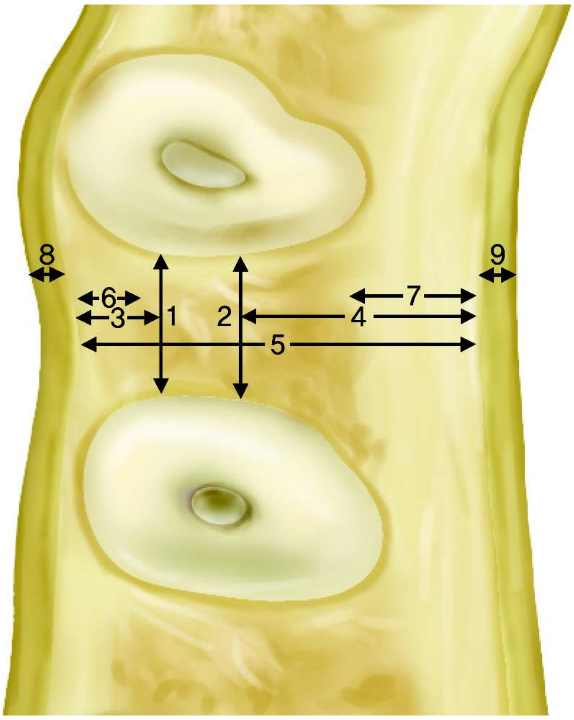


Fig. 3. Measurements of a sectioned specimen. 1: buccal interroot distance, 2: lingual interroot distance, 3: buccal shortest distance, 4: lingual shortest distance, 5: buccolingual bone width, 6: buccal cortical bone thickness, 7: lingual cortical bone thickness, 8: buccal mucosa thickness, 9: lingual mucosa thickness.

B. Three-dimensional reconstruction of the mandibular canal

Histologic sections were obtained by postfixing each specimen for 72 h with 4% paraformaldehyde and then decalcifying for 3 weeks in 1 l of decalcification solution comprising 8 N formic acid (SHOWA, Japan) and 1 N sodium formate (JUNSEI, Japan), which was then diluted with 1 l of distilled water. After decalcification, the specimens were neutralized for 2-3 days in neutralization solution prepared from 5 g of sodium sulfate in 100 ml of distilled water.

The decalcified specimens were divided into five parts from the mental foramen to the mandibular foramen and embedded in paraffin wax. Eight-micron-thick sections were taken from each paraffin block at 1 mm intervals. Each section was mounted on a glass slide, stained with hematoxylin and eosin, and then observed histologically under a light microscope at 8 magnification, with photographs taken using a digital camera (Spot RT, DFC300FX, Leica Co.,, Germany) (Fig. 4). Three-dimensional reconstructions were calculated from about 60 photographs using Reconstruct (ver 1.0.8.0), in which the topography of the inferior alveolar nerve, artery, and vein was analyzed.

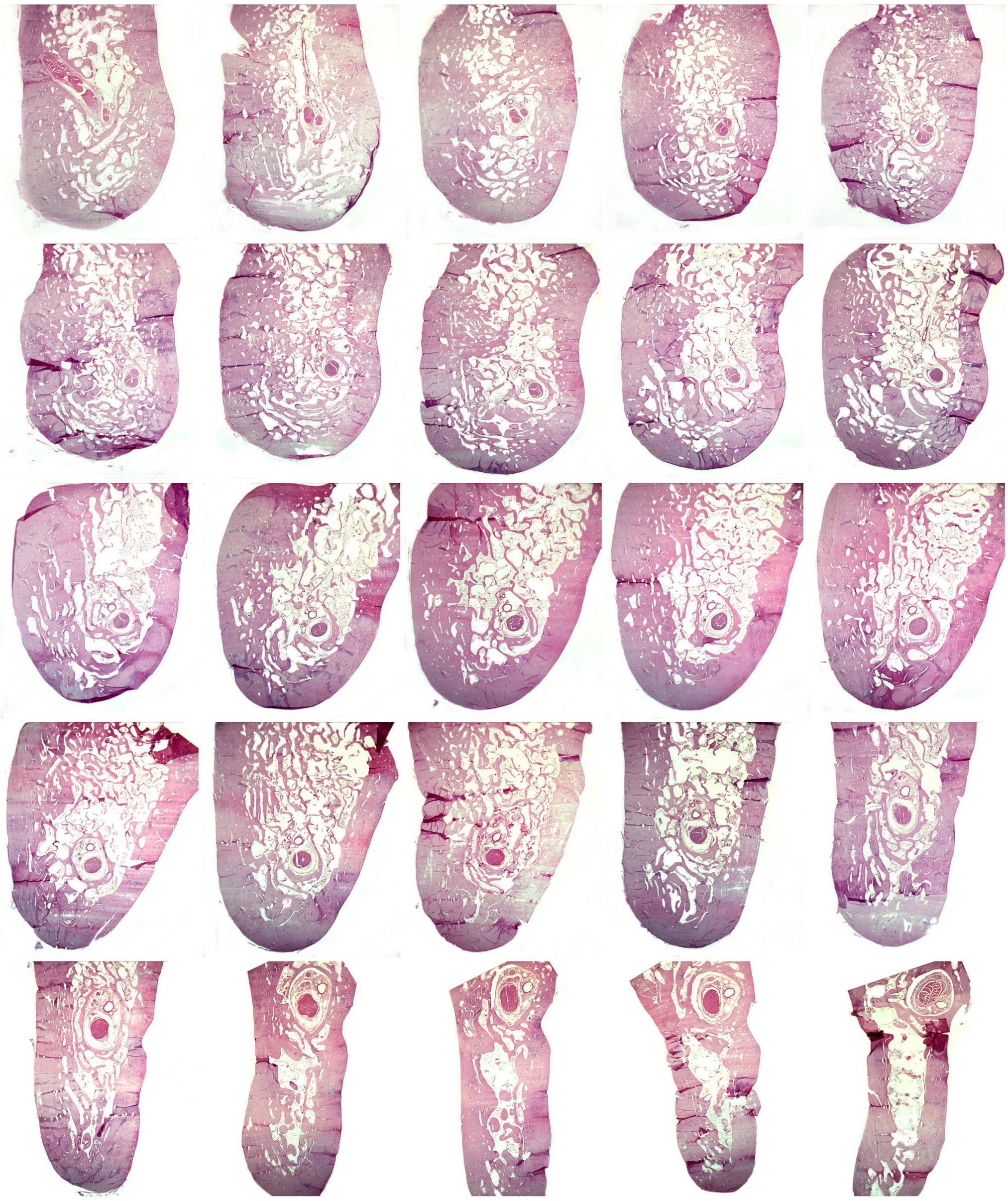


Fig. 4. Histologic serial sections (X8) at obtained 1 mm intervals from mental foramen (uppermost left) to mandibular foramen (lowermost right).

Ⅲ. RESULTS

1. Anatomic relationship between the dental root and alveolar bone in the interroot space

The measurements did not differ significantly with sex, age, or side.

A. 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 mandible (Tables 1, 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 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 maxillary anterior teeth, the interroot distance exceeded 3 mm from 7 and 9 mm above the cervical line on the buccal and palatal sides, respectively. In maxillary posterior teeth, the interroot distance exceeded 3 mm from 3 and 2 mm above the cervical line on the buccal and palatal sides, respectively. However, the buccal interroot distance between the first and second molars was very small, with this only exceeding 3 mm from 8 mm above the cervical line (Table 1). The roots of the first molar and second molars penetrated the maxillary sinus at 8–9 mm above the cervical line in 5 of the 25 cases (25%).

In the mandible, the interroot distance was greatest between the first and second molars. Unlike the maxillary arch, the 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 mandibular anterior teeth, the interroot distance exceeded 3 mm from 9 mm below cervical line on the buccal side, but from 10 mm only between the central and lateral incisors. *U*nlike the maxillary arch, the aspect of the mandibular posterior teeth region varied. The interroot distance exceeded 3 mm from 3, 7, and 2 mm below the cervical line between the first and second premolars, the second premolar and the first molar, and the first and second molars, respectively. In the posterior teeth region, the interroot distance was smallest between the second premolar and the first molar (Table 2).

Table 1. Interroot distance of the maxilla (unit: mm)

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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, P: palatal

Red indicates regions with an interroot distance of at least 3 mm.

Table 2. Interroot distance of the mandible (unit: mm)

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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

Red indicates regions with an interroot distance of at least 3 mm.

In the maxilla, the shortest distance from the buccal cortical bone to a line perpendicular to the interroot distance was greatest at 5, 6, and 7 mm above the cervical line (2.6-3.9 mm), and decreased gradually from this region toward the cervical line and the root apex. However, this distance decreased more in the cervical region (0.9-2.4 mm) than in the root apex region (1.6-3.4 mm). This distance increased from anterior to posterior teeth. *U*nlike the buccal side, the shortest distance from the palatal cortical bone to a line perpendicular to the interroot distance increased from posterior to anterior teeth and from the cervical line to the root apex (Table 3). In the mandible, the shortest distance from the cortical bone to a line perpendicular to the interroot distance increased from anterior to posterior teeth and from the cervical line to the root apex, with the change being larger on the buccal side (anterior teeth: from 1.7 to 2.9 mm, posterior teeth: from 2.7 to 5.0 mm) than on the lingual side (anterior teeth: from 1.3 to 3.2 mm, posterior teeth: from 2.8 to 6.6 mm) (Table 4).

Table 3. Shortest distance from the cortical bone to a line perpendicular to the interroot distance of the maxilla. (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	CI-LI	B	0.9	1.6	1.8	2.2	2.6	2.5	2.5	2.1	1.8	1.6
		L	3.6	2.6	3.1	3.5	3.6	4.4	4.8	5.1	6.1	6.5
	LI-C	B	1.4	1.7	1.9	2.2	2.6	2.9	3.0	2.6	2.2	1.9
		L	3.1	2.9	3.0	3.2	3.3	3.8	4.4	4.7	5.2	5.8
	C-FP	B	1.4	1.8	2.2	2.6	3.0	3.2	3.1	2.7	2.4	2.2
		L	2.4	2.1	2.7	3.0	3.3	3.2	4.1	4.7	5.3	5.9
	FP-SP	B	1.8	2.2	2.5	3.1	3.1	3.2	3.2	3.1	2.7	2.6
		L	2.5	2.0	2.8	2.9	3.1	3.5	3.9	4.5	5.1	5.9
	SP-FM	B	2.2	2.7	3.1	3.6	3.8	3.8	3.5	3.3	3.1	3.0
		L	2.5	2.6	3.2	3.3	3.8	4.2	4.4	4.3	5.0	5.8
	FM-SM	B	2.4	2.5	2.6	2.9	3.9	3.7	3.9	3.8	3.6	3.4
		L	2.9	2.5	2.1	2.8	2.7	3.0	3.0	3.1	3.3	3.7

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

Table 4. Shortest distance from the cortical bone to a line perpendicular to the interroot distance of the mandible (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	CI-LI	B	1.7	2.2	2.3	2.3	2.1	2.0	1.8	2.1	2.9	2.9
		L	1.3	2.2	2.0	2.0	2.1	2.3	2.4	3.1	3.2	3.2
	LI-C	B	1.7	1.9	2.2	2.2	2.4	2.2	1.8	1.7	1.8	1.8
		L	1.5	1.7	2.1	2.5	2.6	2.7	2.8	3.0	3.3	3.2
	C-FP	B	1.9	2.0	2.4	2.4	2.3	2.2	2.1	2.2	2.3	2.4
		L	2.5	2.8	3.1	3.5	3.8	4.3	4.7	4.9	5.3	5.2
	FP-SP	B	1.9	2.2	2.2	2.3	2.3	2.2	2.3	2.4	2.6	3.1
		L	2.5	3.2	3.6	4.0	4.6	5.2	5.7	6.1	6.3	6.7
	SP-FM	B	2.1	2.3	2.3	2.7	2.4	2.4	2.7	2.9	3.2	3.3
		L	2.2	3.0	3.2	3.5	3.8	4.6	5.0	5.6	6.0	6.3
	FM-SM	B	2.7	3.3	3.9	3.8	4.2	4.6	5.0	5.4	5.5	5.0
		L	2.8	2.9	3.3	3.6	4.0	4.7	5.2	5.6	6.4	6.6

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

B. 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, 3, and 1 mm above the cervical line from the central incisor to the canine, from the canine to the first molar, and between the first and second molars, respectively. The buccolingual bone width exceeded 10 mm from 7, 5, and 4 mm above the cervical line between the canine and the first premolar, between the second premolar and the first molar, and between the first and second molars, respectively (Table 5).

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 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 and 2 mm below the cervical line from the canine to the second premolar and from the second premolar to the second molar, respectively. The buccolingual bone width exceeded 10 mm from 7 and 4 mm below the cervical line between the second premolar and the first molar, and between the first and second molars, respectively. In general, the mandibular buccolingual bone was narrower than the maxillary bone (Table 5).

Table 5. 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	CI-LI	Mx	6.3	6.7	6.9	7.8	8.3	9.0	9.4	9.2	9.4	9.4
		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	8.9	9.3	9.1	9.0	9.2
		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	8.5	9.2	9.5	10.0	9.9	10.0	10.1
		Mn	6.2	6.7	7.4	7.9	8.1	8.4	8.5	8.7	8.9	9.1
	FP-SP	Mx	7.2	7.4	8.4	8.9	9.1	9.3	9.4	9.4	9.7	10.0
		Mn	5.8	6.7	7.1	7.6	8.2	8.7	9.0	9.4	9.8	10.3
	SP-FM	Mx	7.3	7.9	9.2	9.8	10.4	10.7	10.8	10.8	11.1	11.9
		Mn	6.7	8.0	8.5	8.9	9.2	9.8	10.3	10.7	11.1	11.5
	FM-SM	Mx	8.8	9.1	9.6	10.8	12.3	12.7	13.2	13.6	13.8	14.0
		Mn	7.6	8.7	9.5	10.1	11.0	12.0	12.9	13.3	13.4	13.1

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, Mx: maxilla, Mn: mandible. Red and blue indicate bone widths of 8.0 - 9.9 and at least 10.0 mm, respectively.

C. 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 the 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 6).

The mandibular cortical bone thickness increased from the anterior to posterior teeth regions and from the cervical line to the root apex. The change in the 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 buccal side in the anterior teeth region, and on buccal side than on lingual side in the posterior teeth region (Table 7). The cortical bone thickness was similar in the mandibular and maxillary arches in the anterior teeth region, but was greater in the mandibular arch in the posterior teeth region.

Table 6. Cortical bone thickness of the maxilla (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, P: palatal

Table 7. Cortical bone thickness of the mandible (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

D. Mucosa thickness

The maxillary buccal mucosa thickness was constant at all regions, at 0.5~1.0 mm. However, the maxillary palatal mucosa thickness increased from the cervical line to the root apex. The palatal mucosa was thickest between the canine and second premolar (Table 8). The mandibular mucosa thickness was constant at all regionsof the buccal and lingual sides, at 0.5~1.0 mm (Table 9).

Table 8. Mucosa thickness of the maxilla (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, P: palatal

Table 9. Mucosa thickness of the mandible (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

2. Course of the inferior alveolar nerve, artery, and vein within the mandibular canal

The inferior alveolar vessel traveled above the inferior alveolar nerve within the main part of the mandibular canal in most cases (80%, 8/10), with the inferior alveolar artery being lingual to the inferior alveolar vein. This case was classified into two patterns. One case was where the inferior alveolar artery traveled below the nerve in the mandibular foramen region, and then above the nerve from the mandibular angle region (60%, 6/10). The other case was where the inferior alveolar artery above the nerve over the entire mandibular canal (20%, 2/10) (Figs. 5, 6). There were two cases where the inferior alveolar vessel was buccal to the nerve (20%, 2/10). In this case, the inferior alveolar vessel traveled above the nerve where it exited from the mental foramen.

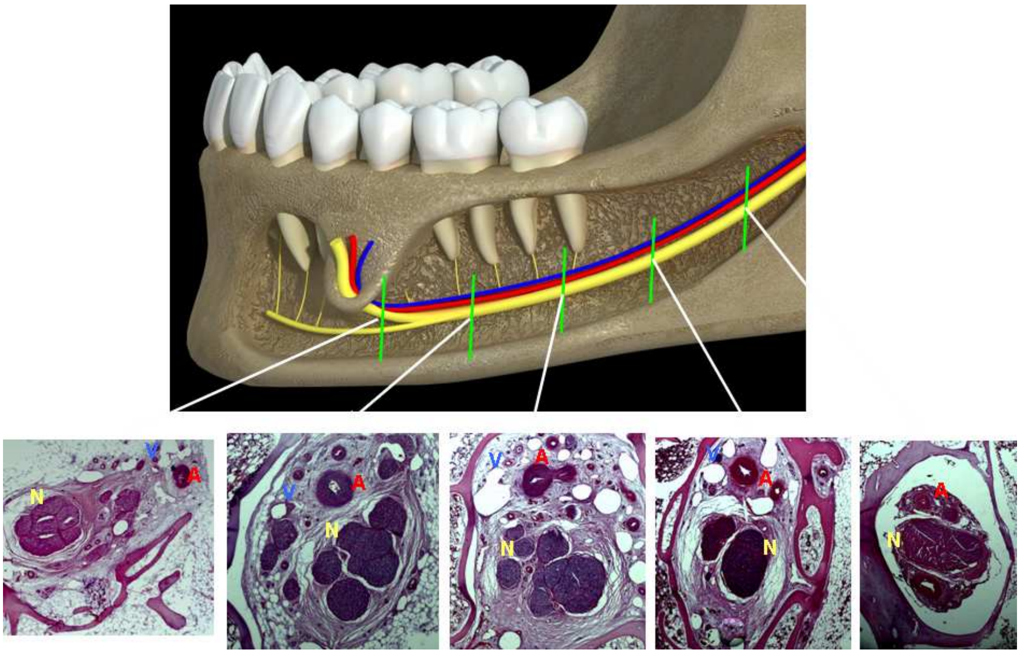
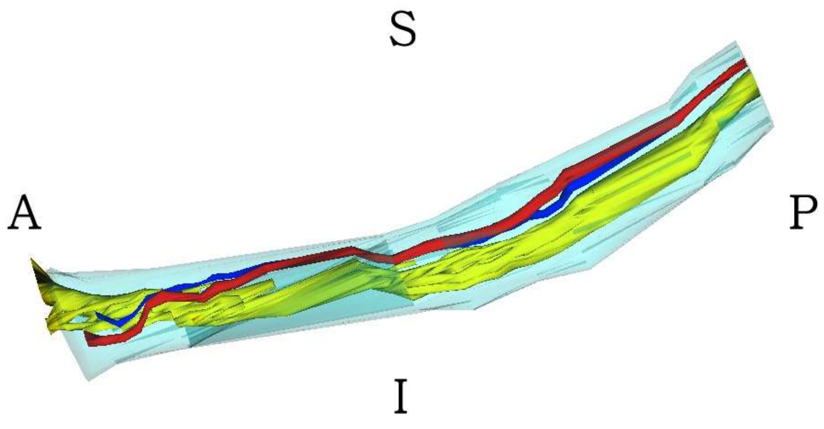
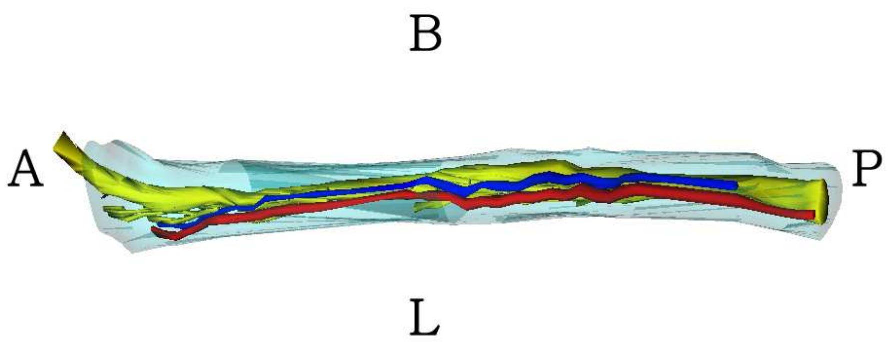


Fig. 5. Histologic photographs of five regions. The inferior alveolar vessels are located above the inferior alveolar nerve (yellow, N), and the inferior alveolar artery (red, A) is located more buccally than the inferior alveolar vein (blue, V), respectively.



(a)



(b)

Fig. 6. Medial (a) and superior (b) aspects of a three-dimensional reconstruction of the neurovascular structure within the mandibular canal (light blue). The inferior alveolar vessels are located above the inferior alveolar nerve, and the inferior alveolar artery is located more lingually than the inferior alveolar vein. A: anterior, B: buccal, I: inferior, L: lingual, P: posterior, S: superior

Ⅳ. DISCUSSION

The form (dental implant, miniplate, and miniscrew) and size of orthodontic implants have changed considerably since Roberts et al. first used an implant as an orthodontic anchorage in 1984, and the miniscrew type is now the most widely used due to 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 (Deguchi et al., 2006). For installation of the miniscrew without damage of the periodontal tissue and dental root, minimum clearance of 1mm of alveolar bone around the screw is needed (Poggio et al.,, 2006). When be considered diameter of the miniscrew and minimum clearance of alveolar bone, the miniscrew could be installed safely if at least 3 mm of space are available in the interradicular space.

Many researches have measured the interroot distance using decalcified specimens, panoramic radiography, CT, and micro-CT (Heins and Wieder, 1986; Ishii et al., 2004; Schnelle et al., 2004; Deguchi et al., 2006; Poggio et al., 2006). 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 in 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 (1986) 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 mostly in the cervical third and 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 also found that the interroot distance is greater between the second premolar and the first molar than between the first and second molars. However, these distances were larger in this 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 the tissue during the decalcification process. Moreover, the same difference was evident in the mandible.

The interroot distance was greater for CT data than for the data obtained in this study in the anterior teeth region, and smaller than that in the posterior teeth region in both the maxilla and mandible (Tables 10, 11). In CT, the border between the alveolar bone and the cementum of the root is unclear because of their similar densities, and hence the interroot distance varies with the threshold used in CT. This makes accurate measurements difficult in CT images. The buccolingual bone width is not influenced by this effect, and did not differ greatly between the CT data and this study (Table 12). The micro-CT data differed greatly from the data obtained in this study (Table 10), but this might be due to the small number of samples (only five).

In the maxilla, it is safe 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 safe zone was less than 2 mm from the cervical line. However, the safe zone 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 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.

Table 10. Comparison of this study, CT study and micro CT study in maxillary interroot distance (unit: mm)

				Distance from cervical line (mm)						
				2	4	5	6	8	10	11
Teeth	C-FP	CT	B	3.0		3.4		3.9		4.3
		this study	B	2.4	2.7	2.8	2.9	3.4	3.9	
	FP-SP	CT	B	2.9		3.2		3.5		3.3
		this study	B	3.0	3.2	3.3	3.3	3.5	4.0	
	SP-FM	CT	B	2.7		2.9		3.0		1.6
			P	4.5		5.5		4.6		1.9
		this study	B	2.9	3.2	3.3	3.5	4.2	4.8	
			P	3.1	3.5	3.7	4.2	5.1	5.9	
	FM-SM	CT	B	2.5		2.3		2.5		0.8
			P	3.4		3.9		3.1		1.0
		micro CT	B	3.6	4.2		4.6	5.9	4.3	
			P		6.5		7.2	8.3	6.7	
		this study	B	2.8	2.7	2.5	2.6	3.1	4.8	
			P	3.0	3.6	4.0	4.2	5.3	5.6	

The CT data are result of Poggio et al. (2006). The micro CT data are result of Ishii et al. (2004). C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, P: palatal.

Table 11. Comparison of this study and CT study in mandibular interroot distance (unit: mm)

			Distance from cervical line (mm)				
			2	5	8	10	11
Teeth	C-FP	CT	2.7	2.8	3.0		3.5
		this study	2.1	2.6	2.9	3.6	
	FP-SP	CT	3.2	3.7	4.3		4.9
		this study	2.6	3.4	4.1	4.7	
	SP-FM	CT	3.0	2.9	3.1		3.9
		this study	2.6	2.9	3.7	4.0	
	FM-SM	CT	3.2	3.0	3.5		4.7
		this study	3.2	3.9	4.9	6.1	

The CT data are result of Poggio et al. (2006). C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar

Table 12. Comparison of this study and CT study in buccolingual bone width (unit: mm)

				Distance from cervical line (mm)				
				2	5	8	10	11
Teeth	C-FP	CT	Mx	8.2	9.2	9.6		10.6
			Mn	6.8	8.1	8.3		8.4
		this study	Mx	7.3	9.2	9.9	10.1	
			Mn	6.7	8.4	8.7	9.1	
	FP-SP	CT	Mx	9.3	9.9	10.0		8.2
			Mn	7.2	8.2	8.8		9.3
		this study	Mx	7.4	9.1	9.4	10.0	
			Mn	6.7	8.2	9.4	10.3	
	SP-FM	CT	Mx	10.8	11.4	10.2		5.4
			Mn	8.9	9.7	10.4		10.6
		this study	Mx	7.9	10.4	10.8	11.9	
			Mn	8.0	9.2	10.7	11.5	
	FM-SM	CT	Mx	13.2	14.3	12.0		3.7
			Mn	10.4	12.5	13.4		13.4
		this study	Mx	9.1	12.3	13.6	14.0	
			Mn	8.7	11.0	13.3	13.1	

The CT data are result of Poggio et al. (2006). C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, Mx: maxilla, Mn: mandible

The insertion of miniscrews in the mandibular anterior teeth region was possible less than 10 mm from the cervical line. The safe zone between the first and second premolar, 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 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 both teeth being located more on the buccal side than on the lingual side, and the width of the jaw increasing 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.

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 increases. 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 mucosa thickness. The thickness of the maxillary buccal mucosa and the mandibular buccal and lingual mucosae was constant in all regions, at about 0.7 mm. However, the thickness of the maxillary palatal mucosa was 1-2 mm and 3-4 mm in the cervical and apical regions, respectively, which allows for a longer miniscrew. The recommended length of the miniscrew is 8 mm on the buccal side from the maxillary central incisor to the second premolar, 8 mm on the buccal side between the maxillary second premolar and the first molar to 4 mm above the cervical line, and 10 mm at 5-10 mm above the cervical line. Because the mucosa is thick, the miniscrew should be as long as possible in the maxillary palatal region (at least 10 mm), except for 2-3 mm above the cervical line from the first premolar to the first molar (Table 13).

In the mandible, the miniscrew can be 5 mm long at 10 mm below the cervical line between the central and lateral incisors. However, the interroot bone must be at least 4 mm thick to allow placement of a miniscrew (Schnelle et al., 2004), and the small amount of bone in this region makes insertion impossible. A 6 mm-long miniscrew is recommended between the mandibular lateral incisor and the canine. In the mandibular premolar region, the adequate miniscrew lengths are 6 and 8 mm at 3-5 and 5-10 mm below the cervical line, respectively. In the mandibular molar region, the adequate miniscrew lengths are 8 and 10 mm at 2-4 and 4-10 mm below cervical line, respectively (Table 14).

Table 13. Sum of the maxillary buccolingual bone thickness and mucosa thickness where miniscrew insertion is possible (i.e., possible length of the miniscrew) (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, P: palatal

Table 14. Sum of the mandibular buccolingual bone thickness and mucosa thickness where miniscrew insertion is possible (i.e., possible length of the miniscrew) (unit: mm)

			Distance from cervical line (mm)									
			1	2	3	4	5	6	7	8	9	10
Teeth	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

CI: central incisor, LI: lateral incisor, C: canine, FP: first premolar, SP: second premolar, FM: first molar, SM: second molar, B: buccal, L: lingual

A miniscrew can 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 6, 7). This means that the stability of a miniscrew will be greater for the mandible than for the maxilla since it is more affected by the 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 the cortical bone contact and the allowable miniscrew length, although this requires careful consideration of the maxillary sinus and mandibular canal (Deguchi et al., 2006). We consider that the safety and strength in each region of such oblique placement of miniscrews requires further investigation.

Investigations into the clinical procedure of prosthetic implantation have focused on avoiding the loss of sensation, with there being few anatomic studies on the postoperative complications after implant surgery(Hirsch and Bränemark, 1995; Hoti et al., 2001). Only Polland et al. (2001) and Kisser et al. (2004) have studied the traveling course of the inferior alveolar nerve within the mandibular canal, and Wadu et al. (1997) and Zoud and Doran (1993) reported on the relationships between the inferior alveolar nerve, artery, and vein within the mandibular canal. These previous studies investigated the relationships of the neurovascular bundle within the mandibular canal through direct dissection. However, this direct dissection could have damaged the inferior alveolar vessels, and changed their locations as well as that of the nerve. Therefore, the ideal method for investigating the relationships of the neurovascular bundle within the mandibular canal is to reconstruct the entire mandibular canal three dimensionally from histologic specimens. In this study, the inferior alveolar vessel was located superiorly to the inferior alveolar nerve in 80% of cases, and so damage to the superior part of the mandibular canal would also damage this vessel. Hence, transient numbness is attributable to indirect damage of the nerve by hematoma rather than to direct damage of the nerve, and so will resolve naturally once the hematomas disappear. The data presented here allow clinicians to predict the period of numbness according to the degree of damage to the superior part of the mandibular canal.

V. CONCLUSION

The conclusions of this study are as follows.

1. In the maxilla, it is safe 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 safe zone was less than 2 mm from the cervical line. However, the safe zone 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 and the first molar

2. The recommended length of the miniscrew is 8 mm on the buccal side from the maxillary central incisor to the second premolar, 8 mm on the buccal side between the maxillary second premolar and the first molar to 4 mm above the cervical line, and 10 mm at 5-10 mm above the cervical line.

3. The insertion of miniscrews in the mandibular anterior teeth region was possible less than 10 mm from the cervical line. The safe zone between the first and second premolar, 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.

4. A 6 mm-long miniscrew is recommended between the mandibular lateral incisor and the canine. In the mandibular premolar region, the adequate miniscrew lengths are 6 and 8 mm at 3-5 and 5-10 mm below the cervical line, respectively. In the mandibular molar region, the adequate miniscrew lengths are 8 and 10 mm at 2-4 and 4-10 mm below cervical line, respectively.

5. In most cases, the inferior alveolar vessel was located superiorly to the

inferior alveolar nerve within the mandibular canal, and so damage to the superior part of the mandibular canal would also damage this vessel. Hence, transient numbness is attributable to indirect damage of the nerve by hematoma.

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Abstract (in korean)

치아뿌리와 주위조직간의 해부학적 관계 및 턱뼈관내에서 신경혈관구조의 국소해부

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허 경 석

초기 임플란트는 상실된 치아를 대체하기 위하여 사용되었으나, 현재는 이러한 분야뿐만 아니라 교정시 고정원과 많은 다양한 분야에서 사용되고 있고 점점 치의학 여러 분야에서 임플란트의 사용이 늘어나는 추세이다. 그러나 임플란트의 사용이 증가함에 따라 그에 따른 합병증도 많이 나타나는데, 보철을 위하여 사용하는 임플란트의 합병증 중 대표적인 것이 아래이틀신경의 손상에 의한 감각상실이다. 이러한 합병증은 턱뼈관의 정확한 위치와 턱뼈관내에서 신경과 동맥의 국소해부를 정확하게 알지 못하여 일어나게 된다. 또한, 교정시 고정원으로 사용하고 있는 교정용 미니 임플란트의 합병증 중 대표적인 것은 뼈와 치아의 파절과 치아 과민이다. 이러한 이유는 임플란트가 유지될 수 있을 만큼 충분한 뼈두께를 얻을 수 있는 위치를 잘 알지 못하기 때문이다. 따라서, 이 연구의 목적은 치아뿌리사이의 관계를 구명하고, 턱뼈관내에서 아래이틀신경, 동맥, 정맥의 국소해부를 밝히는 데 있다. 이 연국르 위하여 30쪽의 아래턱뼈와 20쪽의 위턱뼈를 사용하였다. 치아뿌리사이의 관계를 조사하기 위하여 각각 위턱뼈와 아래턱뼈 200개의 가로절단면에서 9개의 항목을 계측하였고, 아래이틀신경, 동맥, 정맥의 국소해부학적 관계를 조사하기 위하여 턱뼈관을 3차원으로 재구성하였다.

위턱과 아래턱 모두에서, 치아뿌리사이거리는 앞니부위에서 어금니부위로 갈수록, 치아목선에서 치아뿌리끝으로 갈수록 증가하였다. 위턱에서 치아뿌리사이거리는 둘째작은어금니와 첫째큰어금니 사이에서 가장 컸다. 위턱앞니에서 첫째작은어

금니까지의 치아뿌리사이거리는 입천장쪽보다 볼쪽의 거리가 더 컸으나, 첫째작은어금니와 둘째작은어금니사이의 치아뿌리사이거리는 비슷하게 나타났다. 둘째작은어금니와 둘째큰어금니사이의 치아뿌리사이거리는 볼쪽보다 입천장쪽의 거리가 더 컸다. 아래턱에서 치아사이거리는 첫째큰어금니와 둘째큰어금니가 가장 컸다. 위턱과 달리, 안쪽앞니에서 송곳니까지, 둘째작은어금니에서 둘째큰어금니까지의 치아뿌리사이거리는 혀쪽보다 볼쪽의 거리가 더 컸으나, 송곳니에서 둘째작은어금니까지의 치아뿌리사이거리는 비슷하게 나타났다. 위턱에서 볼혀쪽뼈두께가 8 mm 이상인 부분은 앞니에서 송곳니까지는 치아목선 5 mm, 송곳니에서 첫째어금니까지는 3 mm, 첫째어금니와 둘째어금니 사이에서는 1 mm 위쪽에서 나타났다. 볼혀쪽뼈두께가 10mm 이상인 부분은 송곳니와 첫째작은어금니 사이에서는 치아목선 7 mm, 둘째작은어금니와 첫째큰어금니 사이에서는 5 mm, 첫째큰어금니와 둘째큰어금니 사이에서는 4 mm 위쪽에서 나타났다. 아래턱에서 볼혀쪽뼈두께가 8 mm 이상인 부분은 앞니에서는 나타나지 않았으나, 송곳니에서 둘째작은어금니까지에서는 치아목선 5 mm, 둘째작은어금니와 둘째큰어금니에서는 2 mm 위쪽에서 나타났다. 볼혀쪽뼈두께가 10mm 이상인 부분은 둘째작은어금니와 첫째큰어금니 사이에서는 치아목선 7 mm, 첫째큰어금니와 둘째큰어금니 사이에서는 4 mm 위쪽에서 나타났다.

턱뼈관내에서 아래이틀혈관은 아래이틀신경보다 위쪽에서 주행하는 경우가 대부분이었다 (80%, 8/10). 또한, 이러한 경우 아래이틀동맥이 정맥보다 더 혀쪽에 위치하고 있었다. 아래이틀혈관이 신경보다 볼쪽에 위치하는 경우도 20% (2/10)에서 나타났다.

이와 같은 결과는 치과 임플란트 삽입시, 감각상실, 치아과민, 이틀뼈파절과 같은 부작용을 예방하는 데 도움을 주고, 치과임플란트의 적용 범위를 넓히는 데도 도움을 줄 수 있으리라 생각된다.

핵심되는 말 : 치아뿌리, 치아뿌리사이거리, 미니임플란트, 턱뼈관, 아래이틀신경, 아래이틀혈관, 치과임플란트