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박사학위논문

Topography and histological features of the inferior alveolar neurovascular bundle

조선대학교 대학원

치의생명공학과

이 명 화

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지도교수 김 홍 중

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조선대학교 대학원

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ABSTRACT in KOREAN

아래이틀신경혈관다발의 국소해부 및 조직학적 특징

이 명 화

조선대학교 대학원 치의생명공학과

(지도교수 : 김 홍 중)

턱뼈관내 신경혈관다발의 형태학적 배열과 주행양상, 그리고 조직학적 특징에 관한 지식은 아래턱과 관련된 임플란트 식립, 교정치료, 신경치료 등과 같은 임상시술 시 중요하다. 본 연구에서는 조직학적 방법을 통해 턱뼈관내 아래이틀신경과 동맥의 주행경로와 이들의 위치관계를 확인하고, 아래턱 치아 부위에 따른 각각의 면적 및 조직학적 특징을 평가하고자 하였다.

본 연구에서는 해부학 교육용 시신 10구(남자 8구, 여자 2구; 평균 연령 58.2세)에서 얻어진 아래턱뼈를 사용하였다. 아래턱뼈를 탈회한 후 치아장축에 평행하게 셋째큰어금니, 첫째큰어금니, 첫째작은어금니, 가쪽앞니의 중앙부위를 절단한 다음, 통법에 따라 파라핀 포매하였다. 조직절편을 haematoxylin-eosin(H&E)으로 염색하여 얻은 조직사진에서 각 치아부위별로 아래이틀신경과 동맥의 턱뼈관내 주행경로 및 위치관계를 확인하고, 이들의 면적 및 직경을 측정하였다.

아래이틀신경은 아래입술과 턱 부위에 분포하는 턱끝신경과 아래턱 치아를 지배하는 치아신경으로 구성된 큰 신경줄기처럼 보였다. 턱끝신경은 치아신경보다 아래쪽에 위치하였으며, 셋째큰어금니부위에서는 치아신경에 비해 혀쪽에서 주행하였으

나 앞쪽치아부위로 진행하면서 주행 방향이 볼쪽으로 바뀌어 작은어금니부위에서 턱끝구멍을 통해 턱 부위로 빠져나갔다. 치아신경은 아래이틀동맥과 턱끝신경 사이에 위치하였으며, 각 치아에 가지를 분지하면서 앞니부위까지 계속되었다. 아래이틀동맥은 턱뼈관내에서 전체적으로 아래이틀신경 위쪽에 위치하였다. 턱끝신경의 면적은 큰 변화 없이 일정하게 유지되는 반면 각 치아에 가지를 내는 치아신경과 아래이틀동맥의 면적은 앞쪽치아부위로 진행할수록 감소하였다. 턱끝신경의 형태는 타원형에서 점차 원형의 형태로 변하였으며, 치아신경과 아래이틀동맥은 원형의 형태를 유지하면서 그 직경은 앞쪽치아부위로 진행할수록 감소하였다.

본 연구의 결과들은 임플란트 식립, 매복치 발치, 그리고 골절단술과 같이 아래턱부위에서 시행되는 수술과정과 치과진료 시 신경손상이나 출혈과 같은 합병증을 예방하기 위한 유용한 자료가 될 것으로 생각된다.

중심어: 턱뼈관, 아래이틀신경, 턱끝신경, 치아신경, 아래이틀동맥

I. INTRODUCTION

The inferior alveolar nerve (IAN) is the one of the large branches of the mandibular nerve that innervates the mandibular teeth, periodontium, lower lip, and jaw. It enters the lower jaw through the mandibular foramen, and then runs downward and forward within the mandibular canal (MC), generally below the apex of the teeth.[1] The IAN within the MC divides into the mental nerve (MN) and the dental nerve (DN); the MN exits via the mental foramen located below the second premolar, while the DN continues from the premolar region in the incisive canal.[2]

The IAN can be affected by excessive intrusion of the drill or fixture into the MC during implant placement that causes the formation of an adjacent hematoma that presses against the nerve.[3] Surgical procedures such as third molar extraction are also a common cause of IAN damage, as is segmental osteotomy near the mental foramen.[4, 5] Damage of the IAN and MN causes sensory disturbances such as paresthesia or anesthesia of the labiomandibular region.

The inferior alveolar artery (IAA), a branch of the maxillary artery, travels with the IAN within the MC, and supplies the mandible. It is also important in dental implant surgery and osteotomy since hemorrhagic accidents occur frequently in the interforaminal region.

The recent increase in the demand for implant placements has been associated with a concomitant increase in the incidence of postoperative complications. Damage to the IAN is one of the most frequent complications, and is usually due to insufficient information about the location of the MC and the course of the IAN within the MC.[6]

Accordingly, numerous investigators have employed various methods to examine the locations and intramandibular courses of the MC and IAN by various methods.[6-9] However, the histological structure and topographic relationships of the neurovascular bundle have yet to be completely identified.

It is clear that knowledge of the morphological configuration, course, and histological features of the neurovascular bundle within the MC has strategic importance for clinical dental procedures such as implant surgery, orthodontic treatment, and endodontic treatment, in terms of aiding in diagnosis, treatment planning, and surgery.[10, 11]

The purposes of the present study were to verify the relationships and to determine the areas and diameters of the IAN and IAA relative to tooth region through microscopic histological examination. The findings of this study will provide useful anatomical information for clinical dentistry that could be used to minimize the risk of injury to the inferior alveolar neurovascular bundle during surgical procedures such as dental implant placement in the mandibular region.

II. MATERIALS AND METHODS

1. Materials

Twenty embalmed dentulous hemimandibles (eight males and two females) were obtained from human cadavers that had been donated for educational purposes to the Department of Anatomy, Chosun University School of Medicine. The age of the cadavers at death ranged from 29 to 75 years (mean: 58.2 years).

2. Tissue preparation

All specimens were decalcified in 10% nitric acid for 10 days and then rinsed with distilled water for 12 hours. The decalcified mandibles were cut at the midline of the third molar, first molar, first premolar, and lateral incisor, parallel to the long axis of the tooth. The tissues were then dehydrated and embedded in paraffin. Histological sections were cut at a thickness of 8 μm and stained with hematoxylin-eosin, and then observed with the aid of a light microscope (EZ4HD, Leica, Wetzlar, Germany) equipped with a built-in digital camera. Digital photographs of the sections were taken for subsequent histometric analysis.

3. Measurement

The intramandibular courses and relationships of the IAN and IAA from the third molar to the lateral incisor were observed on digital photographs. The areas and diameters of the neurovascular bundle, IAN (MN and DN), and IAA were measured using image-analysis software (iSolution Capture, iMT, Vancouver, Canada). The areas and diameters of the neurovascular bundle and MN were not measured in the region of the first premolar and lateral incisor because the MN exits through the mental foramen (Fig. 1).

4. Statistical analysis

All statistical analyses were performed using SPSS 12.0 (SPSS, Chicago, IL, USA). One-way ANOVA was used to analyze the interobserver difference and differences between the right and left sides. Since no significant interobserver differences were found ($P = 0.890$), the average of the measurement values obtained by two investigators was used as the final measurement value. Similarly, there were no significant differences between the right and left sides ($P = 0.655$). In addition, measurements were analyzed according to tooth site by one-way ANOVA with a post-hoc comparison using Scheffé's method. The statistical significances of differences in gender and age were not considered. All measurements are presented as mean±SD values, and the level of statistical significance was set at $P<0.05$.

III. RESULTS

1. Courses and relationships of the IAN and IAA

In all specimens, the IAN within the MC was divided completely into the MN, which innervates the lower lip and chin region, and the DN, which supplies the mandibular teeth. The MN was located inferior to the DN and IAA within the MC, lying lingually to the DN in the third molar region and passing it buccally in the first molar region, to finally emerge through the mental foramen located below the second premolar. The DN was located between the IAA and MN, running lingually to the MN in the first molar region and then coursing labially in the lateral incisor region. The IAA traveled superolingually to the MN and DN over the entire MC (Fig. 2).

2. Areas of the IAN and IAA

The area of the neurovascular bundle was 13.45 mm^2 at the third molar and 10.11 mm^2 at the first molar; the difference between the two tooth sites was statistically significant. The areas of the IAN at the third and first molars were 3.98 and 4.02 mm^2, respectively, and those of the MN were 2.13 and 2.16 mm^2. The areas of the IAN and MN did not differ significantly at the two tooth sites, indicating a uniformity of their areas within the molar region. The areas of the DN at the third molar, first molar, first premolar, and lateral incisor were 1.40, 0.91, 0.76, and 0.46 mm^2, respectively, and those of the IAA were 0.61, 0.30, 0.29, and 0.13 mm^2. The areas of both the DN and IAA decreased significantly toward the anterior tooth region (Table 1 and Fig. 3).

3. Diameters of the IAN and IAA

The mean horizontal (H) and vertical (V) diameters of the neurovascular bundle in the molar region were 3.20 and 4.58 mm, respectively, and those of the IAN were 1.96 and 2.54 mm. Both the neurovascular bundle and the IAN had a vertically oval shape in this region. The diameters of the MN were 1.70 (H) and 1.35 (V) mm at the third molar and 1.53 (H) and 1.52 (V) mm at the first molar. The diameters of the DN were 1.06 (H) and 0.91 (V) mm at the third molar, and 0.63 (H) and 0.65 (V) mm at the lateral incisor; these values the IAA were 0.78 (H) and 0.83 (V) mm and 0.36 (H) and 0.38 (V) mm, respectively. Thus, the diameters of the DN and IAA tended to decrease toward the anterior tooth region, although the difference was only statistically significant between the third molar and the lateral incisor (Table 2).

4. Histological features

On all specimens, the IAN appeared as a large trunk comprising two larger nerves (MN and DN). The MN and DN were separately wrapped in perineurium, and ultimately wrapped with epineurium in the main trunk of the IAN. The MN usually consisted of three or four close nerve bundles each wrapped with perineurium, but the nerve bundles of the DN varied between specimens. In the molar region the MC had a bony wall composing cancellous bone, but in some sections of the third molar region the canal lay alongside the inner aspect of the cortical bone that formed part of its wall. In most specimens the incisive canal was not found anterior to the mental foramen but in the lateral incisor region, with small nerve bundles and arteries present in intertrabecular spaces of various sizes. As the nerve bundles and arteries divided into smaller branches anteriorly, the connective tissue surrounding them became looser but they were still surrounded by an epineurium (Fig. 4).

IV. DISCUSSION

The MC is a canal within the mandible with a course that begins in the mandibular foramen on the medial surface of the mandibular ramus, and runs downward and forward in the ramus and body of the mandible.[12] Within the MC the IAN runs alongside the IAA, and together they are known as the inferior alveolar neurovascular bundle.[13] Knowledge of the courses and morphologies of the MC and neurovascular bundle is important for avoiding nerve damage during invasive dental procedures such as implant placement, osteotomy, and mandibular third molar extraction, since the MC runs close to the root apices of the mandibular molars.[14-16]

Anatomical dissections are commonly used to investigate the course and relationships of the neurovascular bundle within the MC. However, this method can damage the inferior alveolar vessels and change their locations and that of the nerve. Therefore, the histological methods of investigation are essential for accurately examining these parameters. A histological method was used herein to describe the intramandibular courses, areas, and histological features of the IAN and IAA relative to tooth region.

The intramandibular courses and relationships of the IAN and IAA have described variably in previous reports; the IAA as traveling superiorly to the IAN within the MC,[6,17] the IAA lies buccally to the IAN at the mandibular foramen,[8] and the IAN and IAA form a plexus throughout the MC.[18] The present study found that the IAA was located superolingually to the IAN over the entire MC, similar to the description of Li et al.[17] and Kim et al.[6] Therefore, if the superior part of the MC was damaged during implant placement or mandibular osteotomy, there is high probability of bleeding before the nerve is damaged. An intraneural hematoma caused by arterial bleeding during surgery in the mandibular region may result in a neuropathy of the IAN.[19] However, transient hematoma-induced numbness will resolve naturally once the hematoma disappears.

Kqiku et al.[20] studied the course of the MN and DN within the MC. They reported that the MN runs lingually to the DN in the posterior molar region and passes it inferiorly in the anterior molar region, to finally emerge from the canal buccally in the premolar region through the mental foramen, whereas the DN continues from the premolar region in the incisive canal. In the present study, the MN was located inferior to the DN and IAA within the MC, running lingually to the DN in the third molar region, and passing it buccally in the first molar region to exit through the mental foramen located below the second premolar. The DN was located between IAA and MN, lying lingually to the MN in the first molar region and running labially in the lateral incisor region. These results are similar to those reported by Kqiku et al.,[20] with there being a slight difference in the location of the MN and DN in the first molar region. If the placement of an implant fixture is close to the MC, it can induce mechanical stresses on the IAA and DN located superiorly to the MN. These mechanical stresses may produce hemorrhage of the IAA and sensory disturbances of the mandibular teeth, and the bleeding and edema can cause functional impairments in the MN.

The area of the neurovascular bundle decreased from the third molar (13 mm^2) to the first molar (10 mm^2). It is thought that this is because the DN and IAA give off the branches to the molars. In addition, the area of the MN, which is distributed in the angular, inferior labial, and mental regions passing through mental foramen,[2] did not change toward the anterior teeth, and there was no marked difference in the area of the IAN- which comprises the MN and DN- between third and first molars, notwithstanding the DN giving off branches. Any changes in area may be due to loosening of both the epineurium covering the IAN and the perineurium enveloping the MN and DN, independently, and traveling within the MC.

The diameters of the IAN and IAA have been determined in several studies, but investigations have generally been limited to the mandibular foramen and the molar region; moreover, there are no reports on the areas of each structure individually. Therefore, the diameters and areas of the neurovascular bundle, IAN (MN and DN), and IAA were measured relative to tooth region in the present study.

In present study the mean diameters of the neurovascular bundle were 3.20 (H) and 4.58 (V) mm in the molar region, similar to the values reported by Hur et al.[21] The mean diameters of the IAN were 1.96 (H) and 2.54 (V) mm in the molar region. Thus, the neurovascular bundle and IAN were vertically oval shape in the molar region, consistent with the results of Ikeda et al.[22] and Polland et al.[23] In addition, the diameters of the DN and IAA decreased by around half toward the anterior tooth region while maintaining a round shape. This decrease is thought to be attributable to both the DN and IAA giving off branches to each tooth as they travel within the MC.

The histological structure of the IAN has yet to be completely identified. It has been reported that the IAN runs as a large single bundle in the MC,[24] although other studies found that the IAN divides into the mental and incisive branches in the molar region, which then run parallel to one another and communicate via a network of small fibers,[8] or that the IAN presents as a large trunk containing MN and DN, separately wrapped in perineurium.[20] In the present study the main trunk of the IAN divided in the MC into the MN and DN, consistent with the observations of Wadu et al.[8] and Kqiku et al.[20] The MN and DN were separately enclosed in perineurium, and ultimately enveloped with epineurium in the main trunk of IAN. The MN usually consisted of three or four close bundles of nerve fibers, each surrounded by perineurium. In most specimens the incisive canal was absent, but in the lateral incisor region small incisive bundles were observed to traverse intertrabecular spaces of various sizes without any bony canal. These findings are similar to those of Polland et al.,[23] but contrast with those of Mardinger et al.[25] There is high incidence of errors in measurements of the incisive canal and so extreme care is needed when performing surgical procedures in the incisor region.

The details of the course and local relationships of the neurovascular bundle in the MC provided herein represent anatomical data that will be useful in the prevention of damage to the IAN and IAA during dental procedures such as implant placement, impacted tooth extraction, and osteotomy in the mandibular region.

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VI. FIGURES

Fig. 1. Measurements of the inferior alveolar nerve and artery in a histological section. The broken lines indicate the areas of the inferior alveolar nerve, including the mental (MN) and dental (DN) nerves and the inferior alveolar artery (IAA). The asterisks indicate the diameters of these three vessels. Li, lingual side; Bu, buccal side. (H & E stain; bar 500 μm)

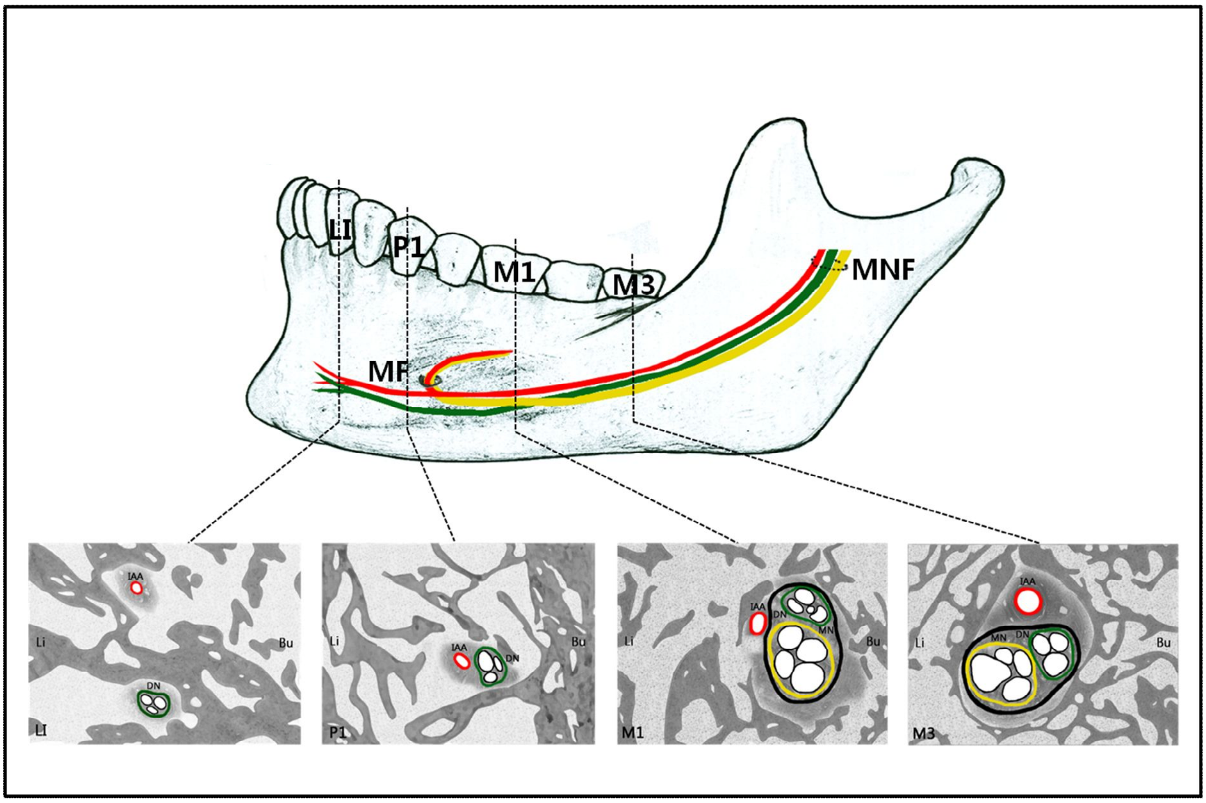

Fig. 2. Intramandibular courses and morphological configurations of the inferior alveolar nerve (MN and DN; yellow and green, respectively) and artery (red). M3, third molar; M1, first molar; P1, first premolar; LI, lateral incisor; MNF, mandibular foramen; MF, mental foramen.

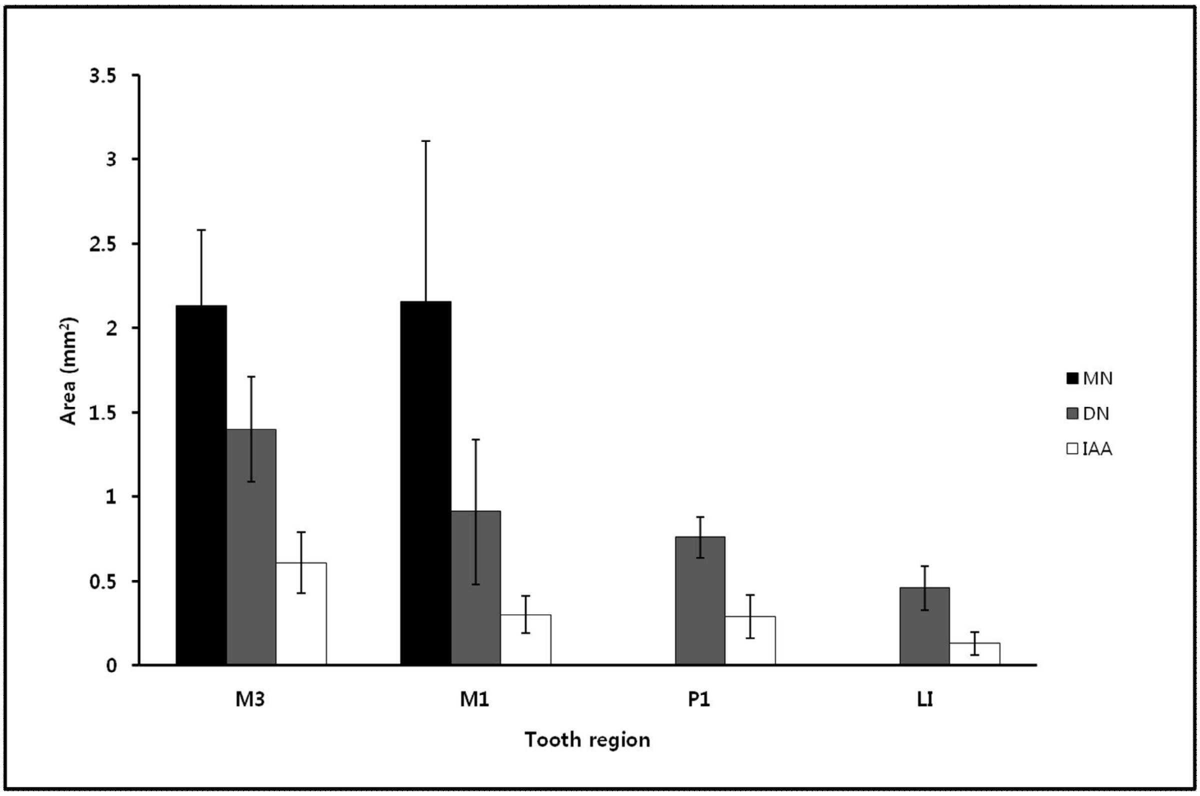

Fig. 3. Areas of the inferior alveolar nerve and artery according to tooth region. Data represent mean and SD values.

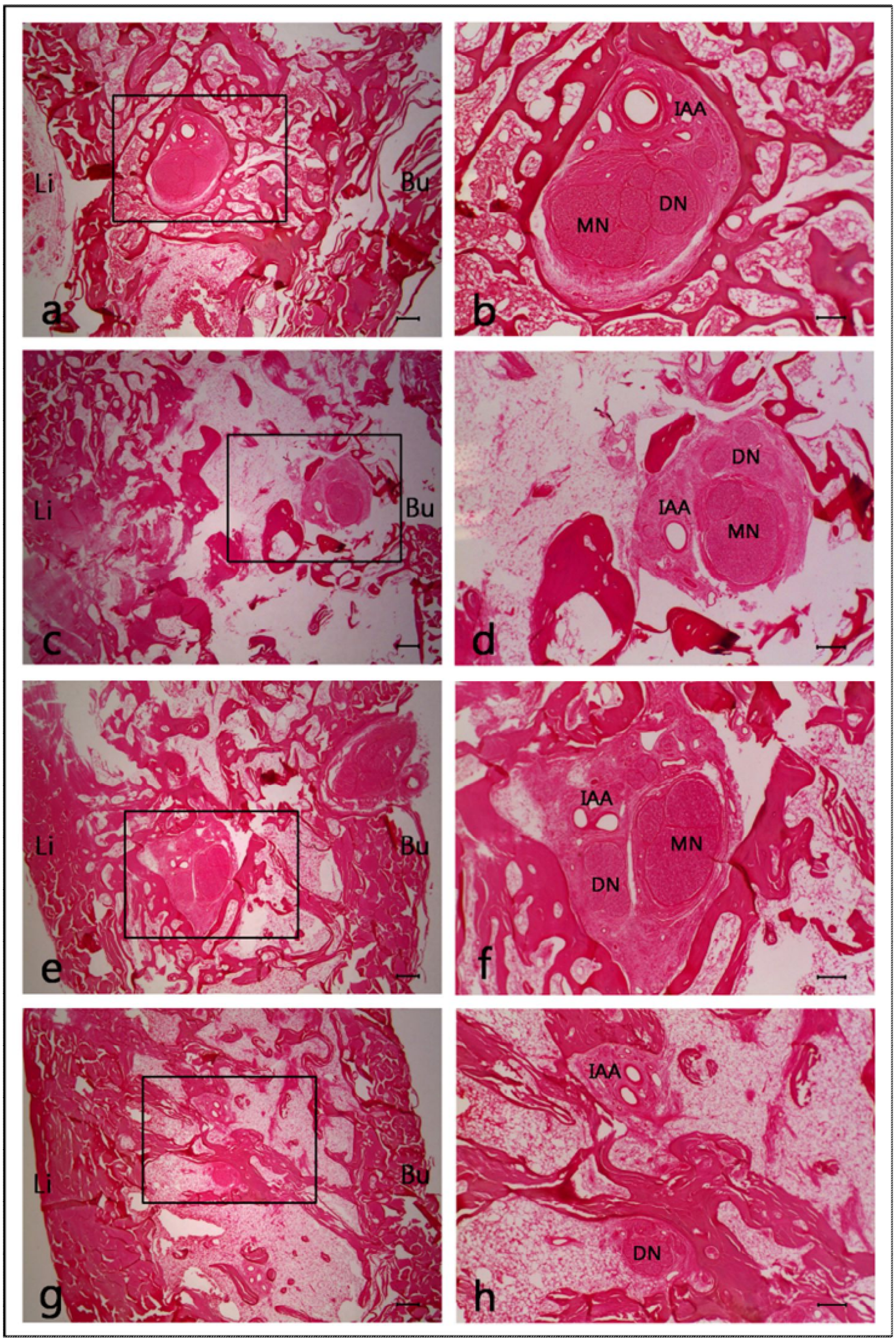

Fig. 4. Histological sections of the inferior alveolar neurovascular bundle according to tooth region: third molar (a and b), first molar (c and d), first premolar (e and f), and lateral incisor (g and h). The areas within the black rectangles in a, c, e, and g are shown at higher magnification in b, d, f, and h, respectively. (H & E stain; bar 1000 μm in a, c, e, and g, and 500 μm in b, d, f, and h)

VII. TABLES

Table 1. Areas of the inferior alveolar neurovascular bundle (in mm^2) according to tooth region. The data represent mean±SD values.

	M3	M1	P1	LI
NVB	13.45±2.23^{a}	10.11±1.85^{a}		
IAN	3.98±0.83	4.02±1.23		
MN	2.13±0.45	2.16±0.95		
DN	1.40±0.31^{bcd}	0.91±0.43^{b}	0.76±0.12^{c}	0.46±0.13^{d}
IAA	0.61±0.18^{efg}	0.30±0.11^{e}	0.29±0.15^{f}	0.13±0.07^{g}

Abbreviations: NVB, neurovascular bundle; IAN, inferior alveolar nerve (mental and dental nerves); MN, mental nerve; DN, dental nerve; IAA, inferior alveolar artery; M3, third molar; M1, first molar; P1, first premolar; LI, lateral incisor. $^{a\text{-}g}$ Identical letters indicate statistically significant differences among the tooth sites at $P<0.05$.

Table 2. Diameters of the inferior alveolar nerve and artery (in mm) according to tooth region. The data represent mean±SD values.

		M3	M1	P1	LI
NVB	H	3.26±0.51	3.14±0.45		
	V	5.03±0.67[a]	4.12±0.50[a]		
IAN	H	2.05±0.34	1.86±0.30		
	V	2.58±0.30	2.49±0.63		
MN	H	1.70±0.24	1.53±0.31		
	V	1.35±0.19	1.52±0.51		
DN	H	1.06±0.36[b]	1.00±0.26	0.86±0.12	0.63±0.13[b]
	V	0.91±0.24[c]	0.81±0.13	0.73±0.19	0.65±0.14[c]
IAA	H	0.78±0.24[d]	0.58±0.15	0.50±0.13	0.36±0.11[d]
	V	0.83±0.19[e]	0.65±0.18	0.57±0.15	0.38±0.13[e]

Abbreviations: H, horizontal; V, vertical. [a-e] Identical letters indicate statistically significant differences among the tooth sites at $P<0.05$.