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ABSTRACT in KOREAN

턱끝구멍 사이 부위에서 MicroCT를 이용한 턱끝관의 삼차원 재건 및 해부학적 분석

이 철 권

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아래이틀신경혈관다발을 포함하고 있는 턱뼈관은 첫째작은어금니 부위에서 앞쪽고리를 형성하며, 후외상방으로 굽어지는 턱끝관과 앞쪽으로 계속 주행하는 앞니관으로 갈라지게 된다. 턱끝구멍사이 부위에서 턱뼈관은 삼차원 방향으로 복잡한 갈림이 일어남으로 이 부위에서 임플란트 식립 및 턱끝성형술과 같은 시술 시 주의하여 한다. 따라서 본 연구에서는 턱뼈관이 턱끝관과 앞니관으로 갈림이 일어나는 턱끝구멍사이 부위에서 microCT (microscopic computerized tomography) 영상의 삼차원 재건(3D-Reconstruction)을 통해 형태를 확인하고, 관의 내부에 주행하는 아래이틀신경혈관다발의 조직학적 분석을 통해 해당 부위에 대한 전반적인 해부학적 특징을 살펴보고자 한다.

본 연구에서는 조선대학교 의학전문대학원에 기증된 시신 19구(남자 16구, 여자 3구, 평균연령 54.4세)에서 얻어진 34쪽의 아래턱을 사용하였다. 얻어진 아래턱은 microCT 촬영 후 삼차원 재건을 시행하여 턱끝관이 후상방으로 갈라지는 형태를 기준으로 3가지 유형으로 분류하고, 턱끝구멍의 정중점과 앞쪽고리의 최전방점의 치아 관련 위치를 조사하였다. 이후 통상적인 방법에 따라 조직 절편 제작 후 H&E 염색하여 아래이틀신경혈관다발과 관의 조직학적 구성을 광학현미경으로 관찰하였다.

삼차원 재건 결과 턱끝관은 턱뼈관에서 후상방으로 약 50°(type 2=30~60°)로 굽어져 주행하는 형태가 59% (13쪽)로 가장 많았다. 턱끝구멍은 둘째작은어금니 아래

에, 앞쪽고리의 최전방점은 첫째작은어금니 아래에 대부분 위치하였다. 아래이틀신경혈관다발은 겉질뼈로 뚜렷하게 형성된 턱뼈관 안에서 주행하다, 턱끝구멍사이 부위에서 턱끝관으로 달리는 턱끝가지와 앞쪽으로 관의 겉질뼈의 구성이 무너진 앞니관으로 연속되는 치아가지로 나뉘는 것을 다시 확인할 수 있었다.

결론적으로 턱뼈관은 첫째작은어금니 아래에서 앞쪽고리를 형성하며 후상방 약 50° 각도로 턱뼈관에서 굽어져 첫째작은어금니 아래의 턱끝구멍으로 나왔다. 따라서 임상의들은 턱끝구멍사이 부위에서 외과적 시술시 턱끝구멍으로부터 앞쪽으로 작은 어금니 하나 정도의 너비에서 더 주의를 기울일 필요가 있겠다.

중심어: 턱끝관, 앞니관, 삼차원 재건, MicroCT, 조직학적 구성

I. INTRODUCTION

The mandibular canal includes the inferior alveolar neurovascular bundle and courses through the intraosseous space of the mandibular body. It then continues on to the anterior teeth region, seperating at the premolar region into the mental and incisive canals [22]. The mental canal curves upward, backward, and laterally to reach the mental foramen, which is located below the second premolar [10, 16], and the incisive canal continues toward the anterior teeth in a slightly downward direction, eventually reaching the chin [9].

This means that the mandibular canal runs along the lingual cortical plate at the mandibular ramus and body, and then continues to the mental canal with three dimensional (3D) complex course to exit toward the mental foramen [7, 12]. The mandibular canal runs more anteriorly past the mental foramen and divides into the mental and incisive canals. At this ramification point the canal forms an anterior loop and transitions back posteriorly to the mental canal; the mandibular and mental canals exist as two canals simultaneously [1]. Therefore, at the interforaminal region, between the mental foramen and the point at which the anterior loop develops, there is required special care during surgical procedures such as dental implant placement and genioplasty to avoid damaging the neurovascular bundle [1, 7, 16].

In addition, the mandibular canal covered by a cortical wall courses an intraosseous path, continues to the incisive canal, and runs through the intertrabecular spaces of the cancellous bone [19]. On panoramic imaging, which is used widely for preoperative evaluation of the jaw, the mandibular canal and mental foramen are reportedly readily visible in 49% of images, while the anterior loop is readily visible in only 3% [8]. Although cone beam computed tomography imaging was recently found to enhance the visualization of the mandibular anatomical structures, detailed evaluation remains difficult [16, 21].

Microcomputed tomography (microCT) can produce high-resolution images and is an effective method for detailed evaluation of the internal structure of bones [2, 4]. Furthermore, since 3D reconstructions are possible with these acquired high-resolution images, it is a very effective tool for examining the small facial canals [20]. Therefore, in order to elucidate the complex course and overall characteristics of the mental canal that runs within the intraosseous space at the interforaminal region, the purposes of this study were to identify and classify the shape of the divergence of the mental canal using 3D reconstruction of microCT images and to analyze the histologic composition at the region where the mandibular canal diverges into two canals.

II. MATERIALS AND METHODS

Thirty-four hemimandibles from 19 cadavers that had been donated to the Department of Anatomy, School of Medicine, Chosun University for educational purposes were examined in this study. These cadavers comprised 16 males and 3 females, with a mean age at death of 54.4 years (range, 29-75 years). In all dentulous specimens, hemimandibles were harvested from the first molar to the lateral incisor. Twenty-six specimens were subjected to microCT scanning, and the remaining 8 specimens were analyzed histologically to determine the composition of the neurovascular bundle. This study followed the Declaration of Helsinki with respect to the medical protocol and ethics.

The specimens were placed onto the holder so that the inferior border of the mandible was touching and perpendicular to the floor, and were scanned using microCT (TVX-IMT225CT Dual type Micro CT, Techvalley, Seongnam, Korea) with a focus size of 1μm. The obtained serial images were three-dimensionally reconstructed using 3D Doctor Software (3D-Doctor V 3.5 demo version, Able Software Corporation, MA, USA). Every fifth image was used for reconstruction because the three-dimensionally reconstructed results did not affect the original morphology of the mandible. On the three-dimensionally reconstructed images, the mandibular and mental canals were identified and the mandibular canal was set as the horizontal line. The specimens were then classified into three types according to the divergent shape of the mental canal from the mandibular canal in the posteriosuperior direction. In addition, the positions of the mental foramen and the anterior loop of the mental canal, which coincides with the starting point of the mental canal, were examined relative to tooth site.

After microCT scanning, the specimens were decalcified for 3 days in 10% nitric acid and then neutralized in distilled water for 12 hours. While conserving the outer shape of the mental foramen, the buccal cortical and cancellous bone were carefully removed with the aid of a surgical microscope (OPMI-FC, Carl Zeiss, Oberkochen, Germany) to prevent damage to the inferior alveolar neurovascular bundle. The shape of the divergence of the mental canal from the mandibular canal and the positions of the mental foramen and the anterior loop of the mental canal relative to tooth site were reexamined on the dissected specimens.

The remaining eight hemimandibles were decalcified for 1 week in 10% nitric acid and then neutralized in distilled water for 12 hours. They were sectioned coronally at the midline of the first molar, first premolar, and lateral incisor perpendicular to the inferior border of the mandible using a microtome blade (Feather, Osaka, Japan). The specimens were then embedded in paraffin and sectioned at a thickness of 8μm using a microtome. Each section was stained with hematoxylin-eosin and the histologic composition within the canals observed using a light microscope (EZ4HD, Leica, Wetzlar, Germany) with a built-in image acquisition system (LAS Basic v4.0, Leica).

III. RESULTS

The mandibular and mental canals were observed running anteriorly past the mental foramen on the serial, coronal-plane microCT images (Fig. 1). While the cortical wall that surrounds the mandibular canal was well formed, the cortical wall of the mental and incisive canals was partially broken down, rendering it difficult to identify the canal borders.

As a result of 3D reconstruction, the divergent shape of the mental canal, which runs a curved course posteriosuperiorly from the mandibular canal, was classified into three types according to the angle of that curvature: 0~30º, 30~60º, and 60~90º. Type 1 (0~30º) was observed in 18% (*n*=4) of the specimens, with the mental canal lying almost parallel to the mandibular canal. Type 2 (30~60º) was the most common type, occurring in 59% (*n*=13) of the specimens; the mode was 50º. Type 3 (60~90º) appeared in 23% (*n*=5) of the specimens, and since the mental canal in these cases was almost perpendicular to the mandibular canal, the anterior loop of the mental canal was absent (Fig. 2).

The mental foramen was observed most commonly below the second premolar (54.6%, *n*=12), and the anterior loop of the mental canal, which is the location of the origin of the mental canal, was observed most commonly below the first premolar (45.5%, *n*=10; Table 1).

Histologic evaluation was reconfirmed that at the first molar, the inferior alveolar nerve comprised the mental and dental branches running inside the canal, which had a well-formed cortical wall, forming a bundle with the inferior alveolar artery. At the first premolar, the neurovascular bundle running anteriorly past the mental foramen also divided, with the mental branch coursing toward the buccal side through the mental foramen separating from the bundle, while the dental branch continued anteriorly with the artery. At the lateral incisor, the morphology of the canal was incomplete as the cortical wall had broken down, and although the size of the neurovascular bundle was considerably decreased at this point, the dental branch and artery could still be observed (Fig. 3).

IV. DISCUSSION

The mandibular canal crosses the mental foramen, then forms the anterior loop at the interforaminal region, and separates into the mental canal and the incisive canal [18]. When the clinicians give a surgical treatment in the interforaminal region including the parasymphyseal area, the mental canal with its complex course, the anterior overextension of the anterior loop beyond the mental foramen, and the large size of the incisive canal need to pay careful attention [5, 7, 9]. Repetitive and empirical surgeries performed without an accurate preoperative understanding of these anatomical structures may result in discomfort and postoperative pain for patients.

The mandibular canal has direction with 67.2º superior based on the mental foramen, forms the anterior loop in 61.5%, and transitions into the mental canal [7, 17]. In the present study, measurement of the divergent shape of the mental canal from the mandibular canal on 3D reconstruction images revealed that in most cases (59%) the angle was within the range of 30~60º. Therefore, when blocking the mental nerve, it is recommended that the needle be inclined to around 55º from back to front and around 40º from outward to inward [3]. And, if the fixture is tilted 25~35º from the anterior loop during implant placement, an average distance of 6.5 mm can be earned for prosthetic support [13].

The mental canal was almost parallel (0~30º) with the mandibular canal in type 1 cases, meaning that there may be sufficient alveolar bone height superior to the alveolar crest to enable a relatively stable implant placement. However, in type 3 the mental canal was almost perpendicular to the mandibular canal (60~90º), and so no anterior loop was formed; this could have a negative effect on implant placement, but since the anterior mandible at the interforaminal region is relatively extended horizontally, it could have a positive effect on genioplasty. Hu et al. [6] noted a vertically formed anterior loop of the mental nerve in 15.4%

of cases, and a straight form toward the anterior teeth in 23.1% of the cases. Hence, additional research is needed to study the correlation between the divergent angle of the mental canal relative to the mandibular canal and the length from the mental foramen to the anterior loop, and to identify cases in which the mental canal continues toward the anterior teeth with an angle of more than 90º.

The mental foramen is typically found at the apex of the second premolar with related to the tooth site, although racial differences do exist [5]. The length from the anterior margin of the mental foramen to the anterior loop varies in the range 0-9 mm. Hence, a safe guideline of 3~6 mm anterior to the mental foramen has been recommended in previous research for implant treatment planning in the interforaminal region [1, 6, 14]. In the present study, the mental foramen was most commonly found below the second premolar, and the anterior loop of the mental canal was most commonly found below the first premolar. Therefore, it need to be pay attention about width of a premolar tooth, which is approximately 7 mm [11], from the mental foramen anteriorly in older edentulous patients.

At the mental foramen region, the incisive nerve is totally separated from the surrounding epineurium of the mental nerve, being located lingually and inferiorly thereto, and continued into the incisive canal, which is less corticated and has a smaller diameter than the mandibular canal [8, 17, 22]. The histologic results of this study were reconfirmed like the study of Lee et al. [15] that the mental and dental branches in the first molar region, which formed a compact neurovascular bundle together with the artery, ran inside the canal and were well covered by the cortical wall. The mental and dental branches divided at the anterior loop region of the mental canal, and only a small diameter dental branch and artery were found inside the incisive canal.

At this point, the cortical wall of the incisive canal was incompletely formed rather than being less corticated; it was difficult to distinguish from the surrounding trabecular bone, and so was more difficult to visualize on the radiograph images. Moreover, the inferior alveolar artery is found superior to the inferior alveolar nerve in the mandibular canal, thus, damage to the superior aspect of the canal may cause hematoma and indirect damage to the nerve, resulting in temporary numbness [12].

Since the mandibular canal divides into two terminal canals, the mental canal including the anterior loop presents a Y-shaped or delta-shaped divergence [18, 19]. In the present study, the mental canal diverged from the mandibular canal by approximately 50º in the posteriosuperior direction below the first premolar, and exited to the mental foramen below the second premolar. Therefore, it could form a hazardous triangular space at the interforaminal region in which there is the potential for simultaneous damage to the mental and dental branches. The clinician need to be pay attention about width of a premolar tooth from the mental foramen anteriorly during dental implant placement and genioplasty at the interforaminal region.

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VI. FIGURES

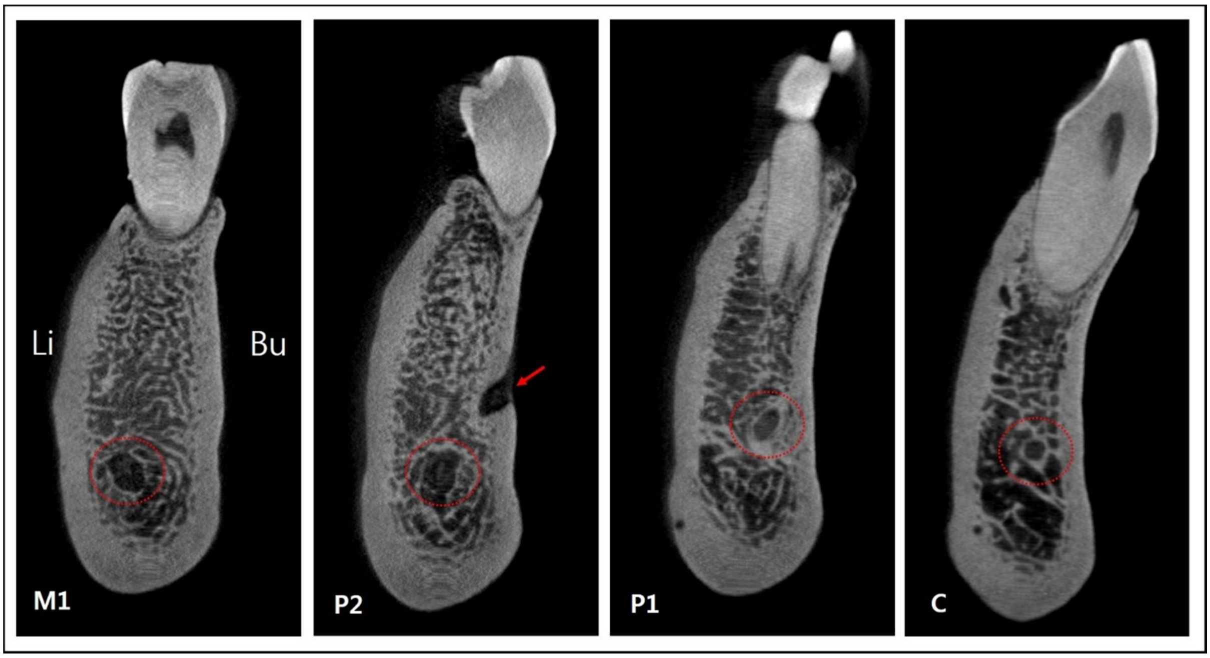

Fig. 1. Serial images (coronal views) of the mandibular canal obtained using microCT scanning. The dashed circle indicates the course of the mandibular canal at each tooth site. The arrow indicates the mental canal. M1, first molar; P2, second premolar; P1, first premolar; C, canine. Bu, buccal side; Li, lingual side.

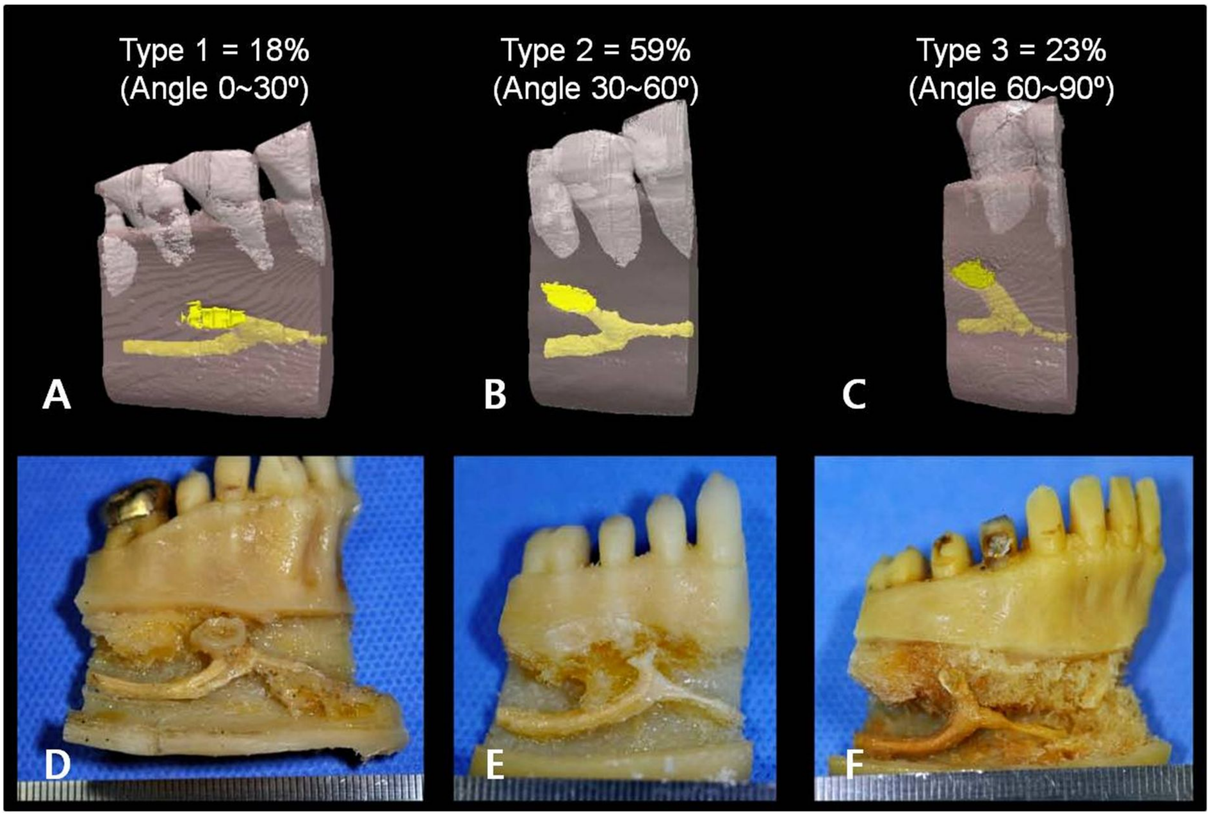

Fig. 2. Shape of the posteriosuperior divergence of the mental canal from the mandibular canal. (A-C) Three-dimensionally reconstructed images showing the 3 types of the mental canal divergence identified, and their prevalence among the 26 examined specimens: type 1 (A), type 2 (B), and type 3 (C). (D-E) Dissected mandibular canal specimens corresponding to the images in A-C, respectively.

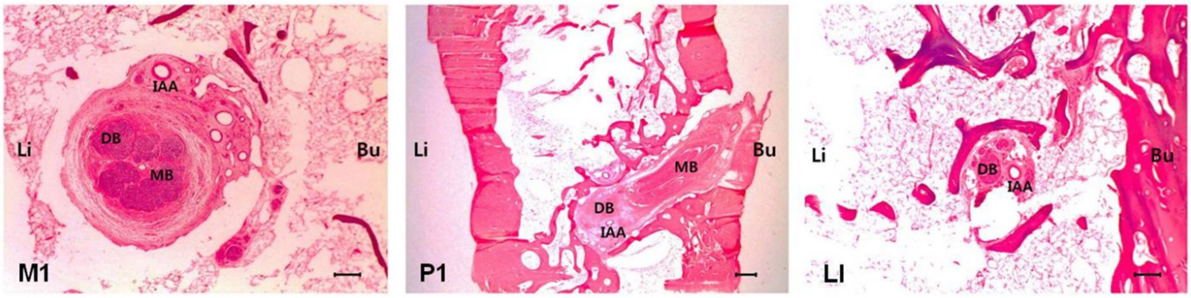

Fig. 3. Histology sections of the inferior alveolar neurovascular bundle at different tooth sites. M1, first molar; P1, first premolar; LI, lateral incisor. IAA, inferior alveolar artery; MB, mental branch; DB, dental branch; Li. Hematoxylin-eosin stain; scale bar=500 µm in M1 and LI, scale bar=1000 µm in P1.

VII. TABLE

Table 1. Positions of the midpoint of the mental foramen and the tip of the anterior loop relative to tooth site

	M1 - P2	P2	P2 - P1	P1	P1 - C
Midpoint of mental foramen	2 (9.1%)	12 (54.6%)	7 (31.8%)	1 (4.5%)	
Tip of anterior loop		2 (9.1%)	8 (36.4%)	10 (45.4%)	2 (9.1%)

Abbreviations: C, canine; P1, first premolar; P2, second premolar; M1, first molar.

Data are *n* (%) values for each tooth site.