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Anatomic study of the anterior loop of the mandibular canal in Koreans

조선대학교 대학원

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ABSTRACT in KOREAN

한국인에서 턱뼈관 앞쪽고리의 해부학적 연구

김 석

조선대학교 대학원 치의학과
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아래이틀신경혈관다발을 포함하고 있는 턱뼈관은 작은어금니부위에서 턱끝관과 앞니관으로 나뉜다. 이러한 갈림이 일어나는 부위에서 아래이틀신경혈관다발은 턱끝구멍을 지나 앞쪽으로 진행한 후, 턱끝구멍을 통해 바깥쪽으로 빠져나오기 위해 후외상방으로 방향을 바꾸면서 앞쪽고리를 형성하게 된다. 따라서, 본 연구에서는 한국인에서 형태계측학적 방법을 통하여 앞쪽고리를 포함한 턱뼈관의 갈림 부위에 대한 전반적인 해부학적 특징을 살펴보고자 한다.

본 연구에서는 조선대학교 의학전문대학원에 기증된 시신 19구(남자 16구, 여자 3구, 평균연령 54.4세)에서 얻어진 26쪽의 아래턱뼈를 사용하였다. 얻어진 아래턱뼈는 탈회하여 신경혈관다발이 드러나도록 미세해부를 시행한 후, 디지털 캘리퍼를 이용하여 턱끝구멍을 기준으로 한 앞쪽고리의 위치와 턱뼈관, 턱끝관 및 앞니관의 직경과 위치를 각각 측정하였다.

턱뼈관의 앞쪽고리는 턱끝구멍의 앞쪽경계로부터 전방 3.05±1.15mm, 위쪽경계로부터 하방 2.72±1.41mm에 위치하였으며, 턱끝구멍에서 앞쪽고리까지의 턱끝관의 길이는 4.34±1.46mm 였다. 턱뼈관, 턱끝관 및 앞니관의 직경은 각각 2.80±0.49mm, 2.63±0.64mm, 2.22±0.59mm 였으며, 아래턱뼈 아래모서리에서부터 각각의 구조물까지의 거리는 각각 7.82±1.52mm, 10.11±1.27mm, 9.08±1.66mm 였다.

결론적으로 턱뼈관은 턱끝구멍을 기준으로 전방 3.1mm, 하방 2.7mm 지점에서 앞쪽고리를 형성한 후 턱끝관과 앞니관의 두 개의 관으로 나뉘게 된다. 턱끝관은 후상방으로 계속되어 턱끝구멍을 통해 바깥으로 나오게 되고, 앞니관은 전방으로

연속되어 턱끝에 이르게 된다. 이러한 앞쪽고리를 포함한 턱뼈관 갈림 부위의 형태학적 분석은 아래턱 작은어금니 및 앞니 부위 시술시 유용한 해부학적 자료를 제공해 줄 것으로 기대된다.

중심어: 앞쪽고리, 턱뼈관, 작은어금니 및 앞니 부위, 신경손상

I. INTRODUCTION

The mandibular canal includes the inferior alveolar neurovascular bundle, originates from the mandibular foramen, curves downward and forward at the mandibular angle, and runs through the intraosseous space of the mandibular body. It then continues on to the anterior teeth region, dividing into the mental and incisive canals at the premolar region (1). The mental canal curves upward, backward, and laterally to reach the mental foramen, which is located below the second premolar (2, 3), and the incisive canal continues to the mandibular canal in a slightly downward direction, ultimately reaching the chin (4).

The mandibular canal crosses the mental foramen anteriorly and forms the anterior loop of the mandibular canal at the region where it splits into the mental and incisive canals (5). The anterior loop continues beyond the anterior margin of the mental foramen and can be identified by the presence of the two separate canals (6), and develops during the double back process when the mental canal exits to the mental foramen from the mandibular canal (5).

At this point the inferior alveolar neurovascular bundle passes through the mandibular canal, finally divides into two parts (the mental and incisive branches), and participates in the formation of the anterior loop. The mental branch supplies the skin and mucous membrane of the lower lip and chin, and the vestibular gingiva of the mandibular anterior teeth, while the incisive branch innervates the anterior teeth including the first premolar (4, 7). Therefore, a complete understanding of the anatomical structures in the interforaminal region containing the anterior loop is essential to prevent neurosensory disturbances resulting from direct or indirect damage to the neurovascular bundle during surgical procedures involving the mandible, such as dental implant installation, open reduction of a mandibular fracture, and genioplasty (8-11).

Several studies have been conducted to identify the prevalence and location of the anterior

loop, as well as anterior loop length (ALL), which is a ramification point of the mandibular canal with complex directivity regarding its exit from the mental foramen. Previous researchers have set a plane that passes through the anterior-most margin of the anterior loop that is coincident with the origin of the incisive canal as a standard reference for the anterior loop (5, 8, 12). A radiologic study set a cutoff point of 3 mm as the maximum diameter of the incisive canal as it separates from the anterior loop (3, 6). However, standard references for the anterior loop differ according to the study method.

At the region where the inferior alveolar neurovascular bundle divides into the mental and incisive branches, the incisive nerve bundle is totally separated from the surrounding epineurium of the mental nerve bundle (13). In the present study, a standard reference was defined for the anterior loop by locating the perineurium of the inferior alveolar neurovascular bundle, which divides into the mental and incisive nerve bundles, using the micro-dissection at the interforaminal region. The main aim of this study was to elucidate the general anatomical structure of the anterior loop of the mandibular canal in Korean cadavers using morphometry relative to the defined standard references.

II. MATERIALS AND METHODS

The anterior loop of the mandibular canal was examined in 19 embalmed Korean cadavers (26 hemimandibles; 16 males and 3 females) with a mean age at death of 54.4 years (range, 29 - 75 years). These cadavers had been donated for educational purposes to the Department of Anatomy, School of Medicine, Chosun University. This study followed the Declaration of Helsinki with respect to the medical protocol and ethics.

All hemimandibles that had been taken to identify the intraosseous course where the mandibular canal ramifies were decalcified for 3 days in a decalcification solution (10% nitric acid), after which they were neutralized in distilled water for 12 hours. The buccal cortical and cancellous bone was then carefully removed, taking great care not to damage the inferior alveolar neurovascular bundle. The configuration of the mental foramen was also preserved with care. The mental and incisive neurovascular bundles were covered with a separate epineurium and had specific terminal distribution areas (13). Bearing that in mind, the mandibular canal where the neurovascular perineurium divides into the mental and incisive branches were meticulously dissected with the aid of a surgical microscope (OPMI-FC, Carl Zeiss, Oberkochen, Germany).

After determining the cutoff point of the neurovascular bundle, that point was determined as the anterior-most margin of anterior loop coincident with the origin of incisive canal. Fiducial points were set based on this location defined as a reference point: the mandibular canal was 10 mm back from the reference point, and the incisive canal was 5 mm forward of the reference point. The diameters of the mandibular, mental, and incisive canal were measured at each reference point. Then, the distance was measured from the inferior border of the mandible to the inferior margin to the points 10 mm to the rear (i.e., mandibular canal),

the reference point (the point that was ahead of the anterior loop and defined autonomously as stated above), and 5 mm forward of that point (i.e., incisive canal) (Fig. 1).

The topography of the anterior loop was investigated with reference to the mental foramen. Only the contour of mental foramen was preserved; the buccal alveolar bone was eliminated, which meant that it was possible for the location of the foramen to change. Therefore, the locations of the alveolar crest and the mental foramen by the inferior border of the mandible were measured before removal of the alveolar bone, and then had a conjugation for establishing the accurate landmark. The distance between the midpoint of the mental foramen and the anterior loop (i.e., the length of the mental canal), the horizontal distance between the anterior margin of the mental foramen and the anterior loop, and the vertical distance between the superior margin of the mental foramen and the anterior loop were measured (Fig. 1). Measurements were made using digital vernier calipers (Mitutoyo, Kawasaki, Japan) to an accuracy of 0.01 mm in all cases.

Two investigators measured the same items twice on subsequent days. Statistical analysis using one-way ANOVA was performed with SPSS (version 12.0, SPSS, Chicago, IL, USA) to determine the mean, SD, interobserver difference, and difference between the left and right sides. The interobserver analysis indicated that there was no statistically significant difference between the values measured by the two investigators (P=0.847), and so the mean of each measurement pair was used as the final value of each measurement. There was no significant difference between the right and left sides (P=0.649). Furthermore, the diameter of each canal and the distance from the inferior border of the mandible at the reference point of each canal were evaluated using one-way ANOVA with a post-hoc comparison on Scheffé's method. No distinctions were made with regard to either age or gender. The data are presented as mean±SD values, and the cutoff for statistical significance was set at P<0.05.

III. RESULTS

The diameters of the mandibular canal at the point 10 mm back from the anterior loop, at the mental canal, and at the incisive canal at the point of 5 mm forward of the anterior loop were 2.80, 2.63, and 2.22 mm, respectively. There was significant difference between the diameters of the mandibular and incisive canals. The distances from the inferior border of the mandible to the point 10 mm back from the anterior loop, to the anterior loop, and to the point 5 mm forward of the anterior loop were 7.82, 10.11, and 9.08 mm, respectively. The mandibular canal ascended to the area where the mental and incisive canals diverged, and then passed downward to the incisive canal. The distances between the inferior border of the mandible and mandibular canal and anterior loop differed significantly (Table 1).

The distance from the midpoint of the mental foramen to the anterior loop was 4.34±1.46 mm. The mean horizontal distance from the anterior margin of the mental foramen to the anterior loop was 3.05 mm, and ranged from 1.17 to 5.18 mm; the distance was >4.0 mm in 19.2% of cases (n=5). The mean vertical distance from the superior margin of the mental foramen to the anterior loop was 2.72 mm, and ranged from 1.19 to 6.34 mm; the distance was >4.0 mm in 11.5% of cases (n=3) (Table 2).

IV. DISCUSSION

The anterior loop is an anatomical structure located anterior to the mental foramen, and is formed just before the ramification of the mandibular canal into the incisive canal (6). As the mandibular canal divides into two terminal branches, the mental canal including the anterior loop displays a Y-shaped or delta-shaped divergence (8, 14). The anterior overextension of the anterior loop beyond the mental foramen and the large size of the incisive canal warrant careful attention during surgical procedures in the interforaminal region and parasymphyseal area (4, 10). Repetitive and empirical surgeries performed without an accurate understanding of these anatomical structures preoperatively may result in discomfort and postoperative pain for the patients.

The anterior loop, which can be described as the extension of mandibular canal anterior to the mental foramen, includes the mental and incisive nerves; therefore, caution should be taken during surgical procedures in the interforaminal region to avoid nerve damage (1, 3, 6). Many researchers have made attempts to detect the prevalence and location of the anterior loop, as well as the ALL in this context (Table 3), and a safe guideline has been proposed for implant treatment planning in the distal aspect of the interforaminal area. However, the recommended guideline varies greatly, from 1 to 6 mm (10). This wide range may be attributable to interindividual anatomical variability associated with gender, age, and race, and the use of different measurement techniques (4, 10). However, it was thought that the difference in the standard used for defining the anterior loop was the most important factor. The present study micro-dissected the inferior alveolar nerve, which runs within the mandibular canal; the ramification point of each epineurium that covers the mental and incisive nerves was defined as the anterior loop, and the topography of the anterior loop was then analyzed relative to the mental foramen.

As with the ALL defined in previous research, in the present study the mean horizontal distance between the anterior margin of the mental foramen and the anterior loop was 3.05mm. This anterior extension of the mandibular canal from the mental foramen did not differ significantly with respect to side, age, and dental state, but it was significantly longer for male, great height, and Asians race; thus, race-related physique is an important influencing factor (3, 6, 12, 15, 16). In addition, it is important to be aware of the longest measurement of the anterior loop in order to avoid nerve injury during surgery. Previous studies have found values of 9 mm in panoramic radiographs (17) and 11 mm in cadavers (15), whereas that in the present study was smaller at 5.18 mm. Additional studies must be conducted with larger samples to determine the true maximum value relative to gender, age, and race.

Full knowledge of the vertical distance below the mental foramen must be acquired to enable a safe sliding osteotomy during genioplasty (9). In the present study, the average vertical distance below the superior margin of the mental foramen was 2.72 mm, with a maximum value of 6.34 mm. Hwang et al. (9) recommended a safety margin of at least 4.5 mm below the inferior margin of the mental foramen.

The mandibular canal usually crosses the mental foramen below the second premolar, then forms the anterior loop, and continues outward, backward, and upward to the mental canal and forward and downward to the incisive canal (18). During development of the anterior loop, a triangular hazardous space might form that is 3.05 mm horizontally anterior and 2.72 mm vertically inferior to the mental foramen. Therefore, when blocking the mental nerve, it is recommended to incline the needle to around 55° from back to front and around 40° from outward to inward (19). In addition, during implant placement, if the prosthetic is tilted 25~35° from the anterior loop, then an average distance of 6.5 mm can be earned for

prosthetic support (20).

The mandibular canal, which is covered by cortical walls, takes an intraosseous path that courses anteriorly within the mandible, continues to the incisive canal, and runs through the intertrabecular spaces of cancellous bone (21). In the present study, the diameter of the mandibular canal decreased significantly from 2.80 mm at the 10 mm posterior point of the anterior loop, to an incisive canal diameter of 2.22 mm at the 5 mm anterior point of the anterior loop. On radiologic studies, the incisive canal can be identified in only 15% of images, with a reported diameter of 1.73 mm at the 4 mm anterior point of the anterior loop (17, 22). Therefore, even though a radiologic examination should be performed as part of the treatment planning before surgical procedures pertaining to the incisive canal at the mandibular anterior teeth region, radiographs should not be solely relied upon for important morphological information, since such images suggest that the diameter is smaller than actual measurements made in cadavers, and moreover the visibility is poor.

In this study, the distances from the inferior border of the mandible to the mandibular canal, anterior loop, and incisive canal were 7.82, 10.11, and 9.08 mm, respectively, as they ran superiorly in order to exit the mental foramen, and then inferiorly and anteriorly to the chin after ramification. The findings that the mandible shape changes from a round shape in the posterior region to a buccal concavity in the anterior region, and that the vertical height of the mandibular body increases toward the anterior region must surely affect the actual location of each canal (1, 9). However, the distance from the inferior border of the mandible to the mandibular canal at the level of the mental foramen remains constant throughout life (23). Thus, the mandibular canal was located close to the alveolar crest of the anterior loop where the ramification occurs, and the incisive canal was located higher than the mandibular canal at the inferior border of the mandible.

In conclusion, the anterior loop of the mandibular canal was located at a mean of 3.1 mm anterior and 2.7 mm inferior to the mental foramen, and continued upward and backward into the mental canal, and forward into the incisive canal. Since the mental and incisive nerves are each covered with an epineurium within the anterior loop, damage at the relevant region might cause dysesthesia not only at the anterior teeth but also at the lower lip and chin. The detailed morphological features of the anterior loop and related structures reported herein represent useful practical anatomical knowledge regarding the interforaminal region.

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VI. FIGURES

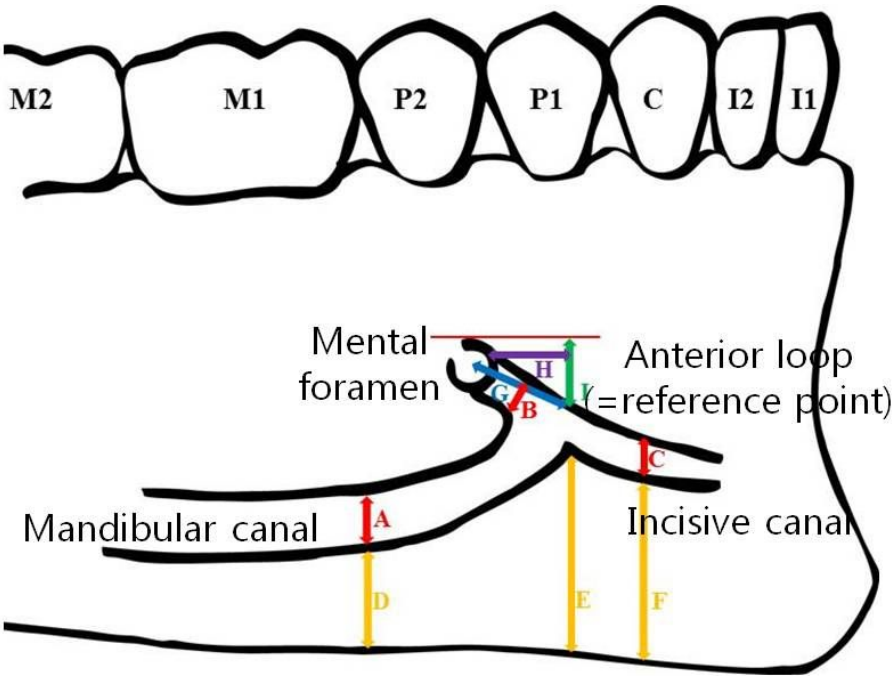

Fig. 1. Diagram showing the dimensions of the anterior loop measured. A, Diameter of the mandibular canal (10mm back from the reference point); B, diameter of the mental canal; C, diameter of the incisive canal (5mm forward of the reference point); D, distance from the mandibular inferior border to the inferior margin of the mandibular canal; E, distance from the mandibular inferior border to the inferior margin of the anterior loop; F, distance from the mandibular inferior border to the inferior margin of the incisive canal; G, length from the anterior loop to the mental foramen; H, horizontal distance from the anterior loop to the anterior margin of the mental foramen; I, vertical distance from the anterior loop to the superior margin of the mental foramen. I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar.

VII. TABLES

Reference	Number	Method	Dental status	Definition	Mean (mm)	Maximum (mm)	Nation
		Mandibular canal	Mental canal	Incisive canal	*P*		
Diameter		2.80±0.49[a] (2.08-3.74)	2.63±0.64 (1.68-3.75)	2.22±0.59[a] (1.35-3.40)	0.016*		
Distance from mandibular inferior border		7.82±1.52[b] (6.05-9.95)	10.11±1.27[b] (7.88-11.86)	9.08±1.66 (6.60-13.58)	0.000*		

Table 1. Measurements of the mandibular, mental, and incisive canals in the mandibular body. Data (in millimeters) are mean ± SD (minimum-maximum) values. Identical letters indicate statistically significant differences among the canals for the indicated measurement ($P<0.05$). * Statistically significant differences among the canals at each measurement position ($P<0.05$).

Table 2. Topography of the anterior loop related to the mental foramen.

	Minimum	Maximum	Mean±SD
Length from AL to MF	2.13	7.21	4.34±1.46
AL to the anterior border of the MF (horizontal)	1.17	5.18	3.05±1.15
AL to the superior border of the MF (vertical)	1.19	6.34	2.72±1.41

Measurements are in millimeters. Abbreviations: AL, anterior loop; MF, mental foramen.

Table 3. Previous research on the anterior loop of mandibular canal.

Bavitz et al. (5)	47	Cadaver Periapical radiographs	D E D E	Horizontal distance*	0.2 0.0 2.5 0.6	1.0 0.0 7.5 2.0	USA
Arzouman et al. (24)	25	Skull Panoramic radiographs (Panelipse/Orthoalix)	D	Length of mental canal Horizontal distance*	6.95 3.18 3.45		USA
Mardinger et al. (8)	20	Cadaver Periapical radiographs		Horizontal distance*	1.05 1.18	2.19 2.95	Israel
Kuzmanovic et al. (25)	22	Cadaver Panoramic radiographs		Horizontal distance†	1.20 1.50	3.31 3.00	New Zealand
Hwang et al. (9)	n=30	Cadaver		Horizontal distance* Vertical distance‡	5.0 4.5		Korea
Kaya et al. (26)	73	Panoramic Radiographs SCT		Horizontal distance**	3.70 3.00		Turkey
Uchida et al. (12)	38	Cadaver	D E	Horizontal distance*	1.7 1.1	6.0 4.0	Japan
Uchida et al. (15)	71 7	Cadaver CBCT	D E	Horizontal distance*	2.1 1.6 2.2	9.0 5.1	Japan
Apostolakis and Brown (6)	93	CBCT	D E	Horizontal distance††	0.91 0.25	5.7 1.5	Greece
Li et al. (3)	68	SCT		Horizontal distance††	2.09	5.31	Chinese
Chen et al. (16)	100 100	CBCT		Horizontal distance*	6.22 7.61	6.55 7.97	Taiwan USA

Definition explains the anterior loop length as a standard reference of the anterior loop in accordance with our measurement standard. * The standard reference of anterior loop defined the anterior-most margin of the mandibular anterior loop. † The standard reference of anterior loop defined the point of the ramification between the incisive and mental branches. ‡ The vertical distance is from the inferior margin of the mental foramen to the anterior loop. ** The standard reference of anterior loop defined that mandibular and mental canals were seen together or attached like a “figure 8”. †† The standard reference of anterior loop defined narrowest position of the mandibular canal-incisive canal complex, and devised a cutoff point of 3 mm for maximum diameter of the incisive canal.

Abbreviations: D, dentulous; E, edentulous; CBCT, cone beam computed tomography; SCT, spiral computed tomography; n, numbers of hemimandibles.