Anatomical Topography of the Mandibular Symphysis in the Korean Population: A Computed Tomography Analysis

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Anatomical Topography of the Mandibular Symphysis in the Korean Population: A Computed Tomography Analysis

Directed by Professor Ui-Won Jung

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Yonsei University
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감사의 글

언제나 부족한 저에게 아낌없는 가르침을 주시고 논문이 완성되기까지 이끌어 주신 정의원 교수님께 깊은 감사를 드립니다. 그리고 늘 따뜻한 관심과 조언을 아끼지 않으셨던 김종관 교수님, 채중규 교수님, 조규성 교수님, 최성호 교수님, 김창성 교수님, 이중석 교수님께 감사드립니다. 또한 바쁘신 중에도 기꺼이 심사를 맡아주시고 세심한 조언으로 지도해주신 허경석, 김성태 교수님께도 감사드립니다.

저의 연구가 완료되고 출판될 수 있도록 도움을 준 공동저자 김민수 교수님께 감사드리며, 김유진 선생님을 비롯한 치주과 모든 의국원들 및 연구원들께도 감사의 말씀을 전합니다.

무엇보다도 항상 제가 잘 되길 바라며 때로는 격려를, 때로는 충고를 아끼지 않으신 사랑하는 부모님, 친아들처럼 저를 아껴 주시며 사랑해 주시는 장인 어른과 장모님, 인생 선배로서 철없는 동생을 보듬어 주는 형, 그리고 어떤 일이 있어도 제 곁을 지켜주며 늘 행복을 주는 저의 소중한 아내와 아들에게 고마움의 마음을 전합니다.

2015년 12월

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The objective of this study was to reveal the topography of the mandibular symphysis according to gender and age in the Korean population using computed tomography (CT) to provide a mean anatomical database for the safety zone during block bone harvesting.

The following parameters were measured in CT images taken from Korean subjects: interforaminal distance (ID), vertical distance between the inferior mandibular border and the apices of the anterior teeth (VD), and

horizontal distance between the labial cortical bone and the apices of the anterior teeth (HD). Differences between genders and among age groups, and the correlations among measurements were analyzed.

A total of 973 images (411 males and 562 females; mean age = 41.2 years) were selected. The overall mean ID, VD, and HD were 55.38±5.13, 22.16±3.84 and 5.21±1.70 mm, respectively. The ID and VD were significantly larger in males than in females ($P < 0.001$), and ID was significantly smaller in the youngest age group than in other age groups ($P < 0.001$), while HD differed significantly only between the youngest and oldest groups ($P < 0.05$). There was a weak positive correlation between ID and HD ($\gamma > 0.10$).

This study provides information on the topography of the mandibular symphysis in the Korean population based on a large number of CT images. In general, gender seemed to influence the symphyseal dimensions strongly, whereas the influence of age was limited.

Keywords: mandible, chin, anatomy, computed tomography, risk assessment

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I. Introduction

Block bone grafting has become a standard procedure for augmenting the alveolar ridge in patients with an alveolar bone volume insufficient for dental implant placement. Several complications have been reported with autogenous bone blocks obtained from extraoral donor sites, but those taken from intraoral sites have been widely used because of advantages such as reduced morbidity, convenient surgical access, absence of extraoral scar

formation, reduced operation time, use of local anesthesia without hospitalization, and lower cost[1,2]. Thus, intraoral sites are regarded as the sites of choice for obtaining autogenous bone for alveolar ridge augmentation. As an intraoral donor site, the mandibular symphysis provides convenient accessibility and a sufficient volume of corticocancellous bone[3] relative to other sources such as the mandibular ramus, maxillary tuberosity, and mandibular torus[4,5]. Although the mandibular symphysis has many benefits, several complications have been reported after obtaining block bone for grafting from the chin area[6,7]. Common complications include intraoperative bleeding, mental nerve injury, and loss of pulp vitality in the lower anterior teeth[1]. Such complications are related to invasion of vital anatomical structures such as the mental foramina and apices of the anterior teeth. Hence, a thorough presurgical risk assessment of anatomical indicators is strongly recommended.

The width, height, and depth of the block bone to be collected from the mandibular symphysis should be determined on the basis of well-defined measurements. The width is affected by the interforaminal distance, or the separation between the two mental foramina. The mental foramen is the end of the mandibular canal through which the inferior alveolar nerve and blood vessels pass[8]. Injury in this area can result in impaired sensitivity in the anterior teeth and the soft tissue of the mandible[9]. The topography of the

mental foramina should, therefore, be characterized before bone is harvested from the mandibular symphysis so that such injury can be avoided during surgery. The height and depth of the block bone graft are affected, respectively, by the height of bone below the roots of the anterior mandibular teeth and the thickness of the labial bone. The apices of the anterior teeth should not be affected during bone-graft procedures. Negative pulp sensitivity frequently occurs after bone grafting from the mandibular symphysis, and permanent loss of tooth vitality has been reported in up to about 20% of patients[1]. Even if the apices of the anterior teeth are not injured directly, there can be pulp insensitivity and paresthesias[3]. Hence, the vertical and horizontal distances from the apices of teeth should be considered to avoid postoperative complications.

Establishment of safety margins requires accurate but cost-effective methods for analyzing various anatomical structures. In previous studies, skulls obtained from cadavers were used to analyze mandible topography[10,11], but the high cost of this process limited the number of skulls that could be analyzed. The recent development of a noninvasive technique using computed tomography (CT) images has thus received increasing attention, since large numbers of samples can be collected easily with no significant increase in cost, and with acceptable margins of error[12,13,14]. In addition, measurements on CT

images can be applied practically in the clinical situation for assessing anatomical risk factors noninvasively.

The objective of this study was to reveal the topography of the mandibular symphysis according to gender and age in the Korean population using CT to provide a mean anatomical database for the safety zone during block bone harvesting.

II. Materials and methods

Mandibular CT images obtained between September 2006 and September 2009 at the Department of Oral and Maxillofacial Radiology, Yonsei University Dental Hospital, Seoul, South Korea, were selected after the research protocol was approved by the hospital's institutional review board (permission no. 2- 2012-0014).

INCLUSION AND EXCLUSION CRITERIA

The following patient inclusion criteria were used:

1. Older than 17 years, so that the anatomical features of the permanent dentition could be evaluated.

2. Mandibular CT images with six anterior mandibular teeth (i.e., no missing anterior mandibular teeth).

3. No history or presence of any pathological condition in the mandible.

The patient exclusion criteria were:

1. Poor visibility of the mental foramina and apices of the anterior teeth on CT images.

RADIOGRAPHIC ANALYSIS

Mandibular CT images were acquired using a helical CT device (HiSpeed Advantage, GE Medical Systems, Milwaukee, WI, USA). A high-resolution bone algorithm was used with the following parameters: 15-cm-diameter field of view, 200 mA, 120 kVp, and a scanning time of 1 s=slice. The cross-sectional images were reconstructed using a 3D reconstruction program (OnDemand 3D, Cybermed, Seoul, Korea). The following anatomical landmarks were evaluated in the reconstructed CT images:

1. The interforaminal distance (ID): On each axial image where the bilateral mandibular foramina were observed, the distance between the foramina was measured along the labial cortical bone (Fig. 1A).

2. The vertical distance between the inferior mandibular border and the apices of the six anterior mandibular teeth (VD): On each cross-sectional image where the apex of each anterior mandibular tooth was observed, the distance between the apex and the inferior border of the mandible was measured for each of those teeth (Fig. 1B).

3. The horizontal distance between the labial cortical bone and the apices of the six anterior mandibular teeth (HD): On each cross-sectional image where

the apices of all such teeth were observed, the horizontal distance between the apex and the labial cortical bone was measured for each of them (Fig. 1B).

INTRAEXAMINER RELIABILITY

Measurements were performed by a single expert examiner (Dr. K. A. Lee) after a calibration process, in which measurements were made on 10 initial subjects by two independent examiners and the variability was always found to be less than 0.5 mm.

STATISTICAL ANALYSIS

The statistical significance of differences in ID, VD, and HD values between males and females was calculated with an unpaired t test using SPSS (version 18 for Windows, SPSS, Chicago, USA). The level of statistical significance was set at $P < 0.05$. The statistical significance of differences in ID, VD, and HD between different age groups was calculated using analysis of variance and post-hoc analysis with Bonferroni tests. The correlations among ID, VD, and HD were analyzed using Pearson's correlation coefficient. The data are presented as mean±SD.

III. Results

After the inclusion and exclusion criteria had been applied, 973 images were selected for analysis. The subjects comprised 411 males (42.2%) and 562 females (57.8%) with a mean age of 41.2 years (range, 18–86 years; Fig. 2).

The overall value of ID was 55.38±5.13 mm, but it was significantly larger in males (56.41±4.83 mm) than in females (54.62±5.21 mm; $P < 0.001$). It also increased with age (Fig. 3), being significantly smaller in the youngest age group than in the other age groups ($P < 0.05$).

The VD values of the central incisors, lateral incisors, and canines are presented in Table 1. These values differed significantly between all pairs of teeth ($P < 0.05$), and the value for each tooth was significantly larger in males than in females ($P < 0.05$). VD was independent of age.

The values of HD did not differ significantly between the central incisors, lateral incisors, and canines, and gender was a significant factor only for the canines, HD being smaller for females than for males ($P < 0.05$; Table 2). Moreover, HD was lower in the youngest age group than in the oldest, irrespective of tooth type ($P < 0.05$), but did not differ significantly among the other age groups (Fig. 4).

There was a weak positive correlation between VD and HD (γ >0.10), and strong correlations among both the VD and the HD values of the three tooth types (γ >0.70 for both HD and VD; Table 3). There was no correlation between ID and either VD or HD (γ < 0.10).

IV. Discussion

The topography of the mental foramina, the apices of the teeth, and the thickness of the cortical bone were analyzed using CT images obtained from adult human patients. The findings can be considered representative of the topography of the mandibular symphysis, since the study population was far larger than in other studies (973 patients, 1846 sites) and the distribution of subjects was not biased toward any age group or gender. Such anatomical measurements could help to establish a "safety zone" representing an area for block bone harvesting that is located far enough from vital anatomical structures to be less likely to cause postoperative complications. The ID can be used to estimate the dimensions of symphyseal bone available for harvesting without risking neurosensory alterations to the chin and lower lip.

The mean ID in this study (55.38 mm) is consistent with those found in previous studies. Neiva et al. (2004) found a mean ID of 55.2 mm in 22 Caucasian skulls. Moreover, analysis of 110 mandibles from Thai cadavers yielded a mean distance between the mental foramina and the midline of about 28 mm[15], and measurements of another 106 Thai skulls revealed a value of 28.52 mm, corresponding to an ID of 57.04 mm[16]. The width of block bone that is harvestable from the mandibular symphysis can be estimated by

considering the length of the bilateral anterior loops from the ID. The anterior loop is the extension of the inferior alveolar nerve beyond the mental foramen, which is readily identifiable in most patients[17]. The mean length of the bilateral anterior loops can vary[18]. A study using conebeam CT found an average of 1.4 mm with a maximum of 4.6 mm[19]. Therefore, it is recommended that the most-distal anterior landmark for harvesting symphyseal bone should be located more than 4 mm anterior to the mental foramen[20]. The mean width of the symphyseal block bone should be determined by subtracting the mean length of the bilateral anterior loops from the mean ID. In this study, the mean horizontal dimension of block bone harvested from the mandibular symphysis would be less than 47.38 mm (calculated by subtracting the bilateral mean anterior loop size of 8 mm from the mean ID of 55.38 mm).

There have been few reports of the vertical dimension of the mandibular symphysis. It has been suggested that harvesting a bone block with an average height 9.9 mm would provide a safety zone of 5 mm[21]. It has been recommended that the osteotomy site should be set 5 mm from the inferior border of the mandibular symphysis, the apex of the teeth, and anterior to the mental foramina[22]. A height of 9.9 mm corresponds to the mean VD of 19.9 mm (taking into consideration the 5-mm safety zone from the tooth apices and

the inferior border of the mandible), consistent with the range of VD values found in this study (19.2–24.2 mm). Some authors recommend that the distance from the most-superior bone cut to the tooth apices should be 8 mm, and suggest that this will avoid nerve injury in more than 75% of patients regardless of the depth of the harvest defect[1].

This study found a weak positive correlation between VD and HD; patients with a larger VD tended to exhibit a larger HD. However, there was no general correlation between ID and either VD or HD. There were gender-related differences in some of the measurements, with ID and VD being larger in males than in females. Few studies have investigated gender differences in ID and VD. Agthong et al. (2005) reported that the distance between the mental foramen and the midline was similar in both genders after measuring the skulls of 70 males and 40 females, but the number of subjects was insufficient to determine whether a small difference was statistically significant. However, owing to the large number of subjects, this study revealed a highly reliable anatomical difference in the mandibular symphysis between males and females, indicating that the bone volume is less in females. The HD for canines differed significantly between males and females, and the depth of the bone cut should be lower in females. In addition, cortical bone thickness is affected much more by age in females than in males[23]. These

findings suggests that the depth of block bone should be determined more carefully in females because of the smaller horizontal dimension and the thinner cortical bone thickness, especially in the canine area.

There have been few studies on the effect of age on ID. The difference among age groups in the position of the mental foramen was studied by analyzing 58 skulls, and no significant difference in the interforaminal distance was revealed[24]. Although ID increased with age in this study, the only significant difference was found between the youngest and the other age groups. More evidence is required to confirm whether ID is consistently smaller in the young. One possible reason is that growth is not complete in all people in their early 20s. In other words, some people continue to grow during their third decade, which would reduce their values in comparison to the other age groups.

The difference in HD among age groups was not generally significant, except between the oldest and youngest groups. This study excluded patients with any missing teeth in the lower anterior area. Edentulism leads to thinner cortical bone relative to dentate skulls[25,26]. Because only dentate subjects were included in this study, there was no resorption of alveolar bone followed by edentulism. Therefore, future studies should include edentulous subjects to clarify the correlation between age and alveolar bone resorption, which affects

the dimensions of the mandible in edentulous patients.

There are anatomical structures that should be considered in establishing the safety zone in the mandibular symphysis. The mandibular incisive canal, which carries a neurovascular bundle comprising a mandibular incisive nerve and accompanying vessels, should not be injured during block bone grafting. The mean distance from the mandibular incisive canal to the mandibular lower border was reported to be 9.86 mm[22]. Another study suggested that to lower the risk of injury to less than 24%, the safety zone from the tooth apices should be 8 mm[1]. In this study, the mean VD was 22.16 mm. If we consider that the mandibular incisive canal is usually located 9.86 mm above the mandibular inferior border, the distance between root apices and the mandibular incisive canal is 12.3 mm on average.

V. Conclusion

This study provides information on the topography of the mandibular symphysis in the Korean population based on a large number of CT images. In general, gender seemed to influence the symphyseal dimensions strongly, while the influence of age was limited.

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Legends

Figure 1. Measurements made on computed tomography images.

(A) Interforaminal distance (ID). (B) Vertical distance (VD) between the inferior mandibular border and the apices of anterior mandibular teeth, and horizontal distance between the labial cortical bone and the apices of the same teeth (HD).

Figure 2. Distribution of the subjects according to age and gender.

Figure 3. Mean ID according to age group. *: Statistically significant difference at $P < 0.05$.

Figure 4. Mean HD values of the central incisors, lateral incisors, and canines according to age group. *: Statistically significant difference at $P < 0.05$.

Tables

TABLE 1. VERTICAL DISTANCE (VD) VALUES ACCORDING TO TOOTH TYPE AND GENDER

	Males	Females	Total
Central incisors	25.61±3.23	23.07±3.09*	24.14±3.39
Lateral incisors	24.30±3.29	21.75±2.94*	22.83±3.34
Canines	20.47±3.00	18.77±3.08*	19.49±3.16

Data are mean±SD values in millimeters.

*: Significantly different from males ($P < 0.05$).

TABLE 2. HORIZONTAL DISTANCE (HD) VALUES ACCORDING TO TOOTH TYPE AND GENDER

	Males	Females	Total
Central incisors	5.33±2.02	5.32±2.20	5.32±2.12
Lateral incisors	5.31±1.58	5.21±1.62	5.26±1.60
Canines	5.21±1.25	4.95±1.24*	5.06±1.24

Data are mean±SD values in millimeters.

*: Significantly different from males ($P < 0.05$).

TABLE 3 PEARSON'S CORRELATION COEFFICIENTS BETWEEN VD AND HD

	VD1	VD2	VD3	HD1	HD2	HD3
VD1	1					
VD2	0.936 [b]	1				
VD3	0.819 [b]	0.836 [b]	1			
HD1	0.166 [a]	0.136 [a]	0.104 [a]	1		
HD2	0.184 [a]	0.190 [a]	0.142 [a]	0.754 [b]	1	
HD3	0.238 [a]	0.238 [a]	0.228 [a]	0.531 [b]	0.705 [b]	1

[a]: Positive correlation ($\gamma > 0.10$).

[b]: Strong positive correlation ($\gamma > 0.70$).

VD1: VD of central incisors.

VD2: VD of lateral incisors.

VD3: VD of canines.

HD1: HD of central incisors.

HD2: HD of lateral incisors.

HD3: HD of canines.

Figures

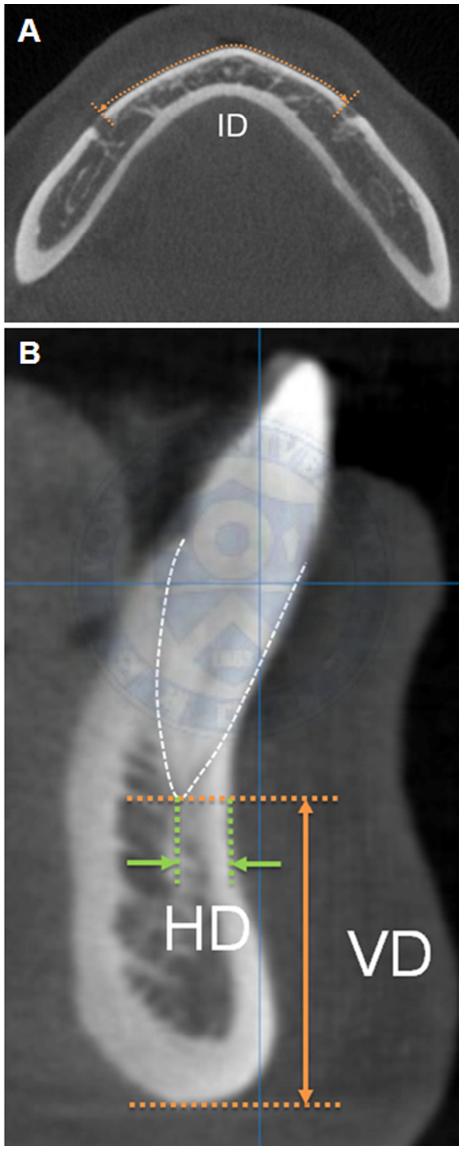
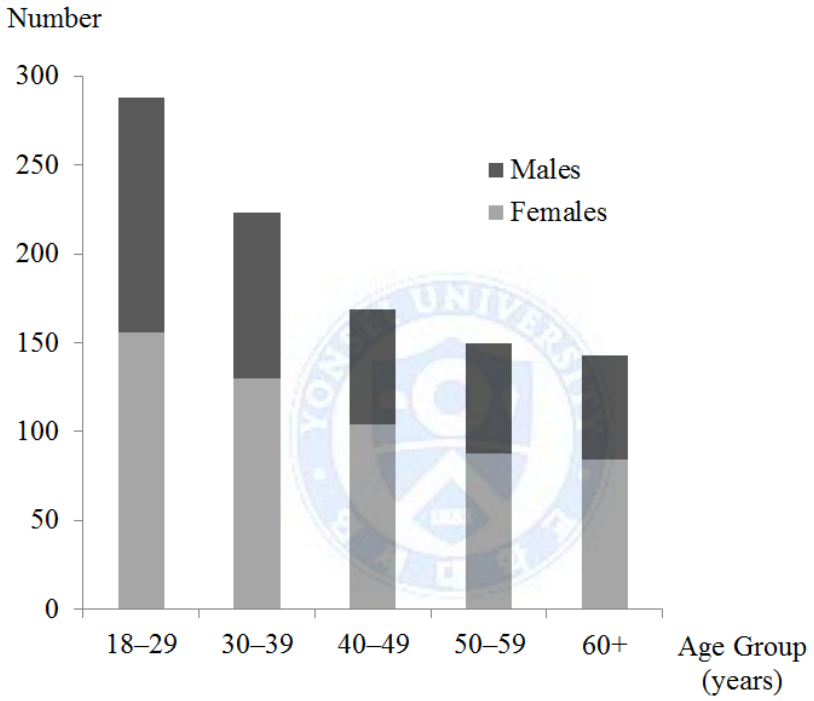


Figure 1


Number
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250
200
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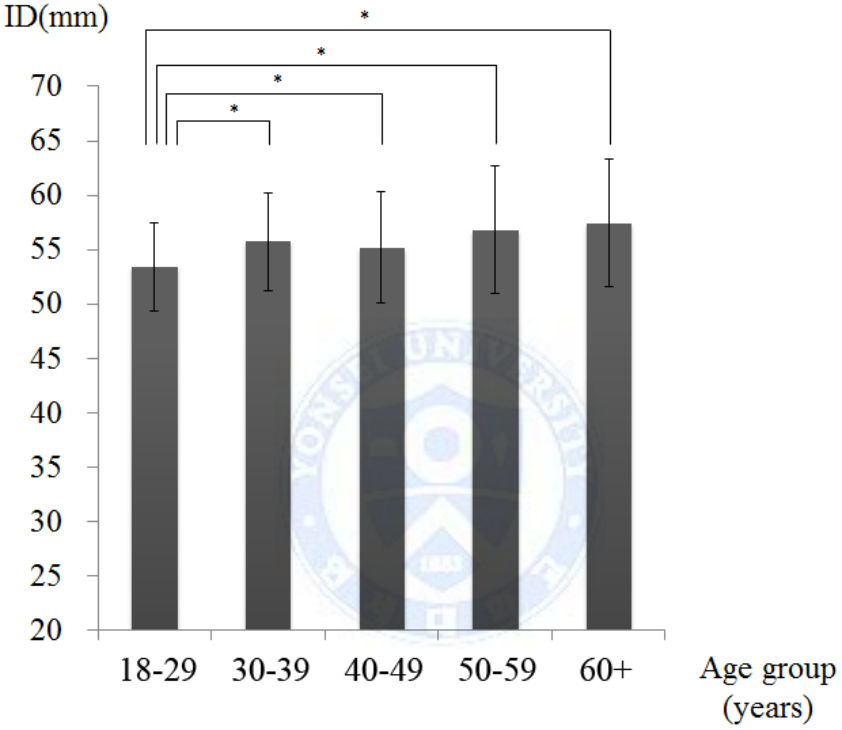
Males
Females
18–29
30–39
40–49
50–59
60+
Age Group
(years)

Figure 2


ID(mm)
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65
60
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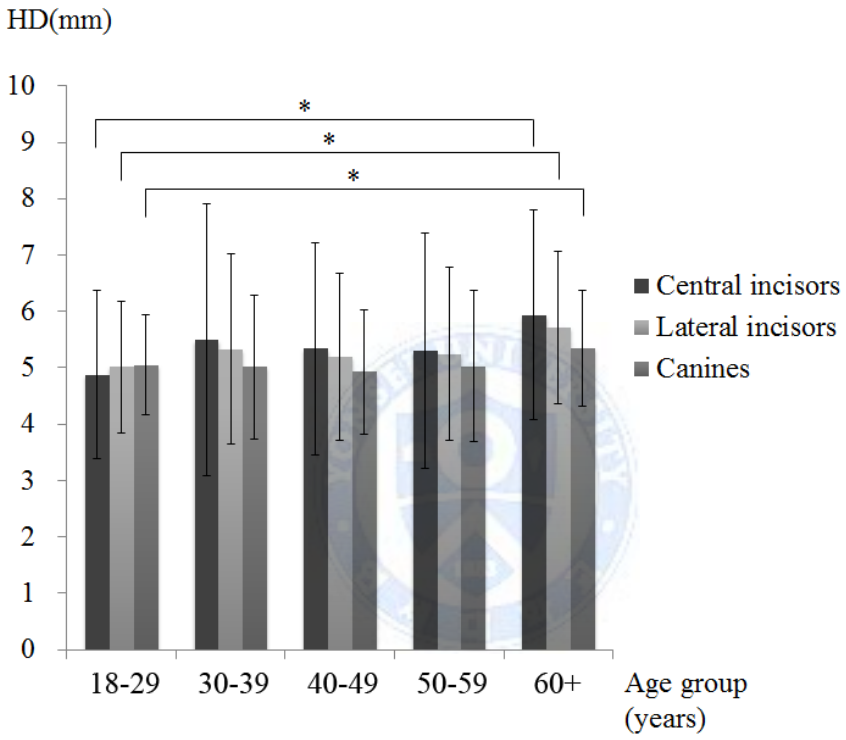
18-29
30-39
40-49
50-59
60+
Age group
(years)

Figure 3


HD(mm)
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9
8
7
6
5
4
3
2
1
0
*
*
*
18-29
30-39
40-49
50-59
60+
Age group (years)
Central incisors
Lateral incisors
Canines

Figure 4

국문요약

한국인 턱끝 결합부의 해부학적 구조에 대한 전산화 단층 분석

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자가골 채취를 위한 공여부로서 턱끝 결합부는 접근성이 좋고 충분한 양의 골을 제공할 수 있어 광범위하게 이용되어 왔다. 그러나 해부학적 주요 구조물들과 근접해 있어 이신경 손상, 전치의 치수 생활력 소실 등 많은 합병증을 동반한다. 따라서 턱끝 결합부의 해부학적 구조를 술전에 파악하는 것은 안전한 자가골 채취에 큰 도움을 줄 수 있을 것이다. 본 연구는 턱끝 결합부에서 블록골 채취시에 주요 해부학적 구조의 손상을 방지하기 위해 필요한 해부학적 정보를 전산화 단층 촬영을 이용하여 분석하여 한국인에서 연령 및 성별에 따른 데이터베이스를 확립하는 것을 목적으로 한다.

하악 6 전치가 모두 존재하는 성인에서 촬영된 전산화 단층 촬영 영상에서 다음 파라미터를 분석하였다. 1) 이공간 거리(ID; interforaminal

distance): 하악골의 순측면을 따라 측정된 양측 이공 사이의 거리 2) 하악 하연과 치근 사이의 수직적 거리(VD; vertical distance) 3) 치근과 하악 피질골 순면 사이의 수평적 거리 (HD; horizontal distance). 또한 성별 및 연령에 따라 그룹간 차이를 분석하였으며, 측정한 파라미터 사이의 연관성을 Pearson 계수를 이용하여 측정하였다.

총 973 명의 영상을 측정하였으며 (남성 411, 여성 562; 평균 연령 41.2 세) ID, VD, HD 값은 각각 55.38±5.13, 22.16±3.84, 5.21±1.70mm 이었다. 이 중 ID 와 VD 는 남성이 여성에 비해 통계적으로 유의할 만큼 컸다. ($P<0.001$) 반면 HD 는 성별에 따른 통계적 유의차는 없었다.

연령에 따른 차이로는 ID 가 20 대 이하 그룹에서 다른 연령에 비해 유의할 만큼 작았으며, HD 는 20 대 이하 그룹이 60 세 이상 그룹에 비해 통계적으로 유의할 만큼 작은 수치를 보였다. 다른 그룹에서는 연령간 차이를 보이지 않았다. 즉 20 대 이하 그룹에서 이공간 거리와 수평적 거리가 작게 나타나는 경향을 보였다.

측정한 3 개의 파라미터 중 ID 와 HD 사이에서는 약한 양의 상관관계를 발견할 수 있었다. ($\gamma>0.10$) 즉 이공간 거리가 긴 환자가 수평적 거리가 긴 경향이 있으나, 그 연관 정도는 강하지 않았다.

이 연구를 통하여 다수의 전산화 단층 촬영 영상을 이용하여 한국인 턱끝 결합부에서 블록골 채취시에 필요한 해부학적 구조에 대한 정보를

얻을 수 있었다. 또한 성별에 따라서는 차이가 컸던 반면, 연령은 제한적인 영향만을 미치는 것으로 보였다.

핵심되는 말 : 하악골, 턱끝 결합부, 해부학, 전산화 단층 촬영, 위험 분석