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Evaluation of Morphometric Characteristics of Mandibular Foramen and Mandibular Ramus in Different Vertical Growth Patterns: A CBCT Study

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Research Article

History

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ABSTRACT

Objectives: To reveal the morphometric characteristics of the ramus area and mandibular foramen (MF) in non-growing patients with different vertical facial types and clinically balanced skeletal pattern in sagittal direction.
Materials and Methods: Sixty adult patients were assigned into three groups according to FMA angle. Groups were created as 20 high-angle (HA), 20 normal-angle (NA) and 20 low-angle (LA). Mandibular foramen location (MFL) as linearly and proportionally, mandibular foramen width (MFW), ramus height (RH), ramus width (RW) and whether there was a statistically significant difference between right and left measurements were determined using CBCT images.
Results: In the LA group, MFL was observed to be closest to the mandibular notch on the right and left sides, however, it was statistically significant on the left and furthest from the posterior border of the ramus (PB) on both sides ($p < .000$). MFW was smaller in the LA group. ($p < .000$). The ramus width measurements were found to be insignificant among the groups ($p > 0.05$).
Conclusions: Low-angle patients presented more superior and anterior location for mandibular foramen.

***Keywords*:** Mandible, sagittal split ramus, cone-beam computed tomography, vertical dimension

Farklı Dikey Büyüme Modellerinde Mandibular Foramen ve Mandibular Ramus'un Morfometrik Özelliklerinin Değerlendirilmesi: Bir CBCT Çalışması

Araştırma Makalesi

Süreç

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ÖZ

Amaç: Bu çalışmanın amacı, farklı dikey yüz tiplerine ve sagital yönde klinik olarak dengeli iskelet yapısına sahip, büyüme dönemi tamamlanmış hastalarda mandibular ramus bölgesi ve mandibular foramenin morfometrik özelliklerini ortaya koymaktır.
Gereç ve Yöntemler: Altmış yetişkin hasta, FMA açısına göre üç gruba ayrılmıştır. Gruplar; 20 yüksek açılı (YA), 20 normal açılı (NA) ve 20 düşük açılı (DA) olarak oluşturulmuştur. Konik Işınlı Bilgisayarlı Tomografi (CBCT) görüntüleri kullanılarak; mandibular foramenin konumu (MFK) doğrusal ve orantısal olarak, mandibular foramen genişliği (MFG), ramus yüksekliği (RY), ramus genişliği (RG) değerlendirildi ve sağ-sol ölçümleri arasındaki istatistiksel fark incelendi.
Bulgular: Düşük açılı (DA) grupta MFK, sağ ve sol tarafta mandibular çentiğe en yakın konumda gözlendi; bu fark sol tarafta istatistiksel olarak anlamlıydı. Ayrıca MF, ramusun arka sınırına (PB) en uzak konumdaydı ($p < .000$). MFG, LA grubunda daha küçük ölçüldü ($p < .000$). Ramus genişliği ölçümleri gruplar arasında anlamlı fark göstermedi ($p > 0.05$).
Sonuçlar: Düşük açılı bireylerde mandibular foramen daha süperior (üstte) ve anterior (öne doğru) konumlanma eğilimindedir.

***Anahtar Kelimeler*:** Mandibula, sagittal split ramus, konik-ışınlı bilgisayarlı tomografi, dikey boyut

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Introduction

Sagittal split ramus osteotomy (SSRO) is a surgical method used for the management of mandibular dentofacial deformities and designed by Obweseger in 1957. In the course of time, certain changes have been made on the procedure.[1]This technique has certain advantages such as short healing period, post-operative early function and easy replacement of mandibular distal segments.[2] However, the procedure has two major complications. Firstly, incorrect positioning of the condyle in the mandibular fossa results in immediate occlusion shift. Secondly, there is a high risk for damaging inferior mandibular neurovascular bundle (INVB).[3] IVNB passes into the mandible through the mandibular foramen.[4] INVB is the major blood supplier and essential for the innervation of the mandible, teeth, periodontium, lips, chin, and mental region. The mandibular canal contains from inferior to superior; nerve, artery, and vein.[5] The most frequently complication regarding INVB is arterial

hemorrhage; however, inferior alveolar nerve desensitization is also reported.[6]

Many studies are conducted to identify the mandibular foramen location (MFL) and mandibular ramus morphology by ethnicity, age, gender, dentulous-edentulous jaws and malocclusions in the sagittal direction.[7-11] However, few studies were carried out to determine the MFL and ramus morphology in different vertical facial types.[9] Correa et al. reported closer location to the mandibular notch (MN) in high-angle (HA) and dolichocephalic patients, controversially, Epars et al. suggested closer location to MN for low-angle (LA) patients.[8,9]

The purpose of the present retrospective cross-sectional study is to assess whether the vertical growth pattern has an effect on the MFL and morphometric characteristics of the mandibular ramus area. The null hypothesis is that MFL and ramus morphology are not associated with vertical growth pattern.

Materials and Methods

This study was approved by the Ethics Committee of Akdeniz University Health Science Institute (ethic approval no: 2023/640). All participants signed the written consent for CBCT examination.

Power analysis was performed using G*Power software (version 3.1.9.2; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Based on the calculated power values, each group included at least 16 cbct scans to achieve 95% confidence (1-α), 95% test power (1-β), and effect size (f) of 1.4673.

This retrospective cross-sectional study examined 190 CBCT scans from April 2018 to July 2023 who visited the Akdeniz University Faculty of Dentistry, Antalya, Turkiye. Sixty out of 190 CBCT scans were compatible with the criteria and included in the study. CBCT radiographs were taken using Veraview X800 CBCT device (J. Morita Mfg. Corp., Kyoto, Tokyo, Japan) according to the manufacturer's instructions (image field: 15x 15x 14.1; 4.8 mA; 99 kvP and 35.8 sec). The patients were assigned into three different groups according to the FMA angle; normal- angle (NA), LA and HA groups. Groups were created as 20 with NA (FMA ranging from 27° to 19°), 20 with HA (FMA > 27°), and 20 with LA (FMA < 19°). Subjects were between 20 and 34 years of age when the CBCT images were taken. The patients with hypodontia, syndromes, obvious asymmetry (more than 5 mm) and treated with orthopedic appliances were excluded.

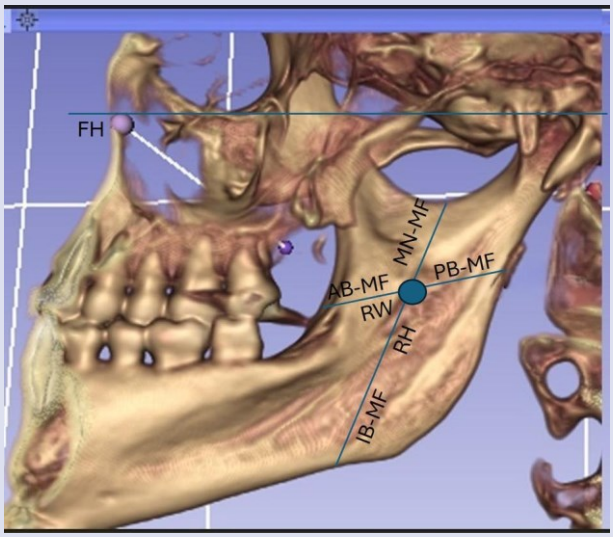

Figure 1. CBCT presentation showing reference points and distances for identifying the mandibular foramen width (MFW), ramus height (RH), ramus width (RW). Distance from the anterior border of the ramus to the mandibular foramen (AB-MF), distance from the posterior border of the ramus to the mandibular foramen (PB-MF), distance from the mandibular notch to the mandibular foramen (MN-MF), distance from the inferior border of the ramus to the mandibular foramen (IB-MF), Frankfort horizontal plane (FH).

CBCT Analysis

Frankfort horizontal line was adjusted to be coincide with the horizontal plane.

The horizontal and vertical measurements were performed by BB on the medial part of the ramus based on the parameters suggested by *da* Fontoura et al.[12]

To determine the MFL, following parameters were measured in the medial parts of each mandibular ramus on both sides by using 3D Slicer software, version 4.1120210226 (Surgical Planning Lab, Harvard University, Cambridge, USA). The measured parameters on CBCT are shown in Figure 1.

- The closest distance of the anterior boundary of the ramus (AB) to the anterior edge of the MF, parallel to the mandible inferior border. (MF-AB)
- The distance of the posterior edge of the MF to the closest point of the PB, parallel to the mandible inferior border. (MF-PB)
- The distance of the most inferior point of the MN to the MF, parallel to the mandible posterior border. (MF-MN)

- The distance of the most convex part of the inferior boundary of the ramus (IB) to the MF, parallel to the mandible posterior border. (MF-IB)
- Mandibular foramen width (MFW)
- The linear measurement of the line that passing in the middle of the MF which is between the closest points of the AB and PB, parallel to the mandible inferior border. (Ramus Width)
- The linear measurement of the line that passing in the middle of the MF which is between the MN and IB, parallel to the mandible posterior border (Ramus Height) Based on the mentioned parameters, the following values could be calculated.
- Distance of the nearest point of the AB to the midpoint of the MF = MFW/2 + (AB-MF Distance)
- Distance of the nearest point of the PB to the midpoint of the MF = MWF/2 + (PB-MF Distance)
- To determine the quadrant of the MFL in the medial mandibular ramus, following formula was obtained.

For horizontal location % = (MFW/2) + (AB-MF Distance)/Ramus Width x 100

For vertical location % = (MN-MF Distance)/Ramus High x 100

Statistical Method

In order to determine the differences between the study groups, non-parametric tests were preferred since the sample size was below 30 in at least one group. Accordingly, the Mann-Whitney U test was applied in two independent group comparisons, and the Kruskal Wallis H test was applied in more than two independent group comparisons. Depending on the results of the Kruskal Wallis H test, the Dunn Test and Post-Hoc Bonferroni correction were applied. The chi-squared test was used to assess the quartiles in all directions for study groups. Intra class variation was studied using intra-class correlation coefficients (ICC) with 95% confidence intervals. Analyses were carried out in IBM SPSS 25 program (SPSS Inc., Armonk, New York, USA). The level of statistical significance was determined to be $p < 0.05$.

Results

The intra-rater correlation analysis, indicating excellent consistent and reliable results. Table 1. The values of linear distances to determine MFL on the left and right sides for study groups and the MFW on both sides were shown in Table 2. The MF-AB measurements were not statistically significant among study groups on both sides. ($p > 0.05$). In the LA group, MFL was observed to be closest to the mandibular notch on the right and left sides, however it was statistically significant on the left. MFL was furthest from the PB on both sides in low-angle group and significantly greater compared to normal-angle group. Significant differences were observed among groups in terms of the MF-IB dimensions on both sides; it was found to be significant in the low angle group, compared to high-angle. The mean value of the MFW was significantly smaller in the low- angle group compared to the high- angle and normal- angle groups. ($p < .000$).

The values of the ramus width-to-height ratio were presented in Table 3. The ramus width measurements were found to be statistically insignificant among study groups ($p > 0.05$) The mean value for the ramus height measured as shorter in the high- angle group compared to the normal-angle and low- angle groups, however it was statistically significant on the right side in high- angle group compared to normal-angle.

The values of the anteroposterior and superoinferior ratios of the MFL were presented in Table 4. A significant difference was observed between low-angle, high-angle and normal-angle groups in the anteroposterior direction on the right side. The mean value of the superoinferior ratio was found to be lower in the low-angle group on both sides.

Analysis regarding whether there is a statistically significant difference between the right and left side measurements were conducted separately for the three study groups (Table 5). According to the analysis results, no statistically significant difference was observed in any parameter between the right and left measurements in the NA study groups ($p > 0.05$). In the high-angle group; MF-MN ($p = 0.033$), in the low-angle group; FM-AB ($p = 0.007$) and superoinferior ratio ($p = 0.017$) were the parameters with significant differences on the right and left measurements.

The quartiles of the MFL in the anteroposterior and superoinferior directions for all study groups were shown in the Table 6. The MFL was frequently found in the third and second quartiles in the horizontal and vertical directions, respectively. There was not statistically significant difference between groups in terms of quartiles of MFL in the anteroposterior and superoinferior quadrants.

Table 1. Intraclass correlation coefficients of the variables

Variables	ICC	Lower Bound	Upper Bound
Right MFW	>0.999	0.999	1.000
Right MF-AB	>0.999	1.000	1.000
Right MF-MN	>0.999	1.000	1.000
Right Ramus Height	>0.999	1.000	1.000
Right Ramus Width	>0.999	0.999	1.000
Left MFW	0.993	0.984	0.997
Left MF-AB	>0.999	1.000	1.000
Left MF-MN	>0.999	1.000	1.000
Left Ramus Height	>0.999	1.000	1.000
Left Ramus Width	>0.999	0.999	1.000

MFW; Mandibular foramen width, MF; Mandibular foramen, AB; Anterior border, MN; Mandibular notch.

Table 2. Comparison of the linear distances determine the position of the right and left side Mandibular Foramen for study groups

	Right			Left		
	Mean ± SD (Med)	**Min-Max**	**p**	**Mean ± SD (Med)**	**Min-Max**	**p**
MFW			**<0.001**			**<0.001**
HA	6.093 ± 1.256 (6.16)	4.31-8.71		6.738 ± 1.135 (6.954)	4.796-8.832	
LA	4.836 ± 0.533 (4.925)	3.82-5.8		5.009 ± 0.628 (4.915)	3.1-5.945	
NA	6.718 ± 1.288 (6.915)	3.82-8.34		6.939 ± 1.201 (6.965)	4.89-8.74	
Post-Hoc Anaysis	LA-HA (p = 0.006); NA-LA (p < 0.001)			LA-HA (p < 0.001); NA-LA (p < 0.001)		
MF- AB			0.290			0.456
HA	13.304 ± 2.652 (12.86)	8.29-18.87		14.157 ± 3.291 (14.21)	9.12-20.06	
LA	13.956 ± 1.223 (14.5)	11.9-15.59		15.449 ± 2.213 (15.225)	12.05-19.95	
NA	14.107 ± 1.708 (14.115)	11.81-17.24		14.914 ± 2.435 (15.31)	8.25-17.88	
MF- MN			**0.001**			**<0.001**
HA	16.66 ± 3.66 (17.06)	9-24.43		18.85 ± 3.12 (17.88)	11.34-24.84	
LA	15.96 ± 2.22 (16.12)	11.28-19.16		15.32 ± 1.84 (15.49)	11.64-18.3	
NA	19.46 ± 3.07 (20.1)	11.9-23.84		19.65 ± 2.86 (19.38)	14.34-24.4	
Post-Hoc Analysis	NA-LA (p=0.001); HA-NA (p = 0.013)			LA-HA (p = 0.001); NA-LA (p<0.001)		
MF- PB			**<0.001**			**0.012**
HA	7.2 ± 3.01 (7.53)	2.05-13.12		5.98 ± 3.51 (6.25)	0.49-13.01	
LA	9.52 ± 1.79 (9.53)	7.01-13.23		8.49 ± 2.67 (9.23)	3.65-12.21	
NA	5.75 ± 2.11 (6.06)	2.05-10.19		5.54 ± 3.19 (5.18)	0.28-11.2	
Post-Hoc Analysis	NA-LA (p < 0.001); HA-LA (p = 0.036)			NA-LA (p = 0.018)		
MF- IB			**0.013**			**0.001**
HA	27.65 ± 3.4 (27.26)	20.49-33.9		26.29 ± 5.53 (27.02)	11.63-33.77	
LA	31.63 ± 3.73 (30.45)	26.27-38.88		32.55 ± 3.81 (32.29)	26.84-43.4	
NA	29.55 ± 5.36 (28.47)	20.73-37.84		27.99 ± 4.81 (26.69)	22.43-37.96	
Post-Hoc Analysis	HA-LA (p = 0.010)			HA-LA (p = 0.001); NA-LA (p = 0.006)		

[ξ]Kruskal-Wallis H Test, Dunn Test, Post-Hoc Bonferroni Correction
MFW; Mandibular foramen width, MF; Mandibular foramen, AB; Anterior border, MN; Mandibular Notch, PB; Posterior border, IB; Inferior border

Table 3. Comparison of the right and left side width-to-height ratio of the ramus for study groups

	Right			Left		
	Mean ± SD (Med)	**Min-Max**	**p**	**Mean ± SD (Med)**	**Min-Max**	**p**
Ramus Height			**0.016**			0.154
HA	44.32 ± 4.99 (43.87)	36.89-57.16		45.13 ± 4.57 (45.46)	35.62-53.2	
LA	45.79 ± 3.38 (45.53)	41.03-51.98		47.87 ± 3.7 (47.94)	41.09-55.3	
NA	49.01 ± 6.56 (49.77)	34.57-60.3		47.64 ± 5.35 (48.11)	40.18-61.25	
Post-Hoc Analysis	HA-NA (p = 0.014)					
Ramus Width			0.229			0.060
HA	26.57 ± 3.46 (27.5)	16.7-30.1		26.88 ± 3.66 (26.84)	19.1-33.41	
LA	28.31 ± 2.13 (28.08)	25.19-33.3		28.95 ± 1.8 (29.2)	25.27-31.55	
NA	26.58 ± 2.95 (26.61)	19.88-30.85		27.39 ± 2.68 (28.07)	22.35-31.95	

[ξ]Kruskal-Wallis H Test, Dunn Test, Post-Hoc Bonferroni Correction

Table 4. Comparison of the right and left sides Mandibular Foramen Location in the anteroposterior/ superoinferior direction according to side R/L for study groups

	Right			Left		
	Mean ± SD (Med)	**Min-Max**	**p**	**Mean ± SD (Med)**	**Min-Max**	**p**
Anteroposterior %			**0.001**			0.167
HA	61.81 ± 8.59 (61.94)	44.37-80.64		65.47 ± 10.38 (68.06)	43.17-80.3	
LA	57.97 ± 4.19 (57.72)	48.79-65.04		62.17 ± 8.14 (60.47)	49.7-75.67	
NA	65.96 ± 5.92 (65.75)	56.23-76.84		67.4 ± 10.02 (68.03)	48.99-84.82	
Post-Hoc Analysis	NA-LA (p = 0.001)					
Superoinferior %			**0.043**			**<0.001**
HA	37.42 ± 5.98 (37.33)	21.59-48.04		42.21 ± 9 (41.19)	27.17-67.34	
LA	35.14 ± 5.62 (35.9)	23.66-46.69		32.07 ± 3.97 (32.17)	21.51-39.19	
NA	39.89 ± 5.44 (39.75)	30.15-50.18		41.41 ± 5.64 (42.22)	32.31-52.1	
Post-Hoc Analysis	NA-LA (p = 0.036)			LA-HA (p < 0.001); NA-LA (p < 0.001)		

[ξ]Kruskal-Wallis H Test, Dunn Test, Post-Hoc Bonferroni Correction

Table 5. Right and left side measurements for the study groups

	Right		Left		
	Mean ± SD (Med)	**Min-Max**	**Mean ± SD (Med)**	**Min-Max**	**p**
HA					
MFW	6.093 ± 1.256 (6.16)	4.31-8.71	6.738 ± 1.135 (6.954)	4.796-8.832	0.086
MF-AB	13.304 ± 2.652 (12.86)	8.29-18.87	14.157 ± 3.291 (14.21)	9.12-20.06	0.478
MF-MN	16.66 ± 3.66 (17.06)	9-24.43	18.85 ± 3.12 (17.88)	11.34-24.84	**0.033**
MF-PB	7.2 ± 3.01 (7.53)	2.05-13.12	5.98 ± 3.51 (6.25)	0.49-13.01	0.201
MF-IB	27.65 ± 3.4 (27.26)	20.49-33.9	26.29 ± 5.53 (27.02)	11.63-33.77	0.620
Ramus Height	44.32 ± 4.99 (43.87)	36.89-57.16	45.13 ± 4.57 (45.46)	35.62-53.2	0.414
Ramus Width	26.57 ± 3.46 (27.5)	16.7-30.1	26.88 ± 3.66 (26.84)	19.1-33.41	0.968
Anteroposterior %	61.81 ± 8.59 (61.94)	44.37-80.64	65.47 ± 10.38 (68.06)	43.17-80.3	0.142
Superoinferior %	37.42 ± 5.98 (37.33)	21.59-48.04	42.21 ± 9 (41.19)	27.17-67.34	0.086
LA					
MFW	4.836 ± 0.533 (4.925)	3.82-5.8	5.009 ±0.628 (4.915)	3.1-5.945	0.495
MF- AB	13.956 ± 1.223 (14.5)	11.9-15.59	15.449 ±2.213 (15.225)	12.05-19.95	**0.007**
MF-MN	15.96 ± 2.22 (16.12)	11.28-19.16	15.32 ±1.84 (15.49)	11.64-18.3	0.231
MF-PB	9.52 ± 1.79 (9.53)	7.01-13.23	8.49 ± 2.67 (9.23)	3.65-12.21	0.529
MF- IB	31.63 ± 3.73 (30.45)	26.27-38.88	32.55 ± 3.81 (32.29)	26.84-43.4	0.478
Ramus Height	45.79 ± 3.38 (45.53)	41.03-51.98	47.87 ± 3.7 (47.94)	41.09-55.3	0.076
Ramus Width	28.31 ± 2.13 (28.08)	25.19-33.3	28.95 ± 1.8 (29.2)	25.27-31.55	0.211
Anteroposterior %	57.97 ± 4.19 (57.72)	48.79-65.04	62.17 ± 8.14 (60.47)	49.7-75.67	0.149
Superoinferior %	35.14 ± 5.62 (35.9)	23.66-46.69	32.07 ± 3.97 (32.17)	21.51-39.19	**0.017**
NA					
MFW	6.718 ± 1.288 (6.915)	3.82-8.34	6.939 ± 1.201 (6.965)	4.89-8.74	0.698
MF- AB	14.107 ± 1.708 (14.115)	11.81-17.24	14.914 ± 2.435 (15.31)	8.25-17.88	0.056
MF- MN	19.46 ± 3.07 (20.1)	11.9-23.84	19.65 ± 2.86 (19.38)	14.34-24.4	>0.999
MF- PB	5.75 ± 2.11 (6.06)	2.05-10.19	5.54 ± 3.19 (5.18)	0.28-11.2	0.968
Ramus Height	49.01 ± 6.56 (49.77)	34.57-60.3	47.64 ± 5.35 (48.11)	40.18-61.25	0.289
Ramus Width	26.58 ± 2.95 (26.61)	19.88-30.85	27.39 ± 2.68 (28.07)	22.35-31.95	0.495
Anteroposterior %	65.96 ± 5.92 (65.75)	56.23-76.84	67.4 ± 10.02 (68.03)	48.99-84.82	0.565
Superoinferior %	39.89 ± 5.44 (39.75)	30.15-50.18	41.41 ± 5.64 (42.22)	32.31-52.1	0.383

[μ]Mann Whitney U Test

MFW; Mandibular foramen width, AB; Anterior border, MF; Mandibular foramen, MN; Mandibular notch, PB; Posterior border, IB; Inferior border

Table 6. Anteroposterior and Superoinferior Quadrants for High Angle, Low Angle and Normal Angle groups

	HA				LA				NA				
	First Quadrant (n. %)	Second Quadrant (n. %)	Third Quadrant (n. %)	Fourth Quadrant (n. %)	First Quadrant (n. %)	Second Quadrant (n. %)	Third Quadrant (n. %)	Fourth Quadrant (n. %)	First Quadrant (n. %)	Second Quadrant (n. %)	Third Quadrant (n. %)	Fourth Quadrant (n. %)	p value
Anteroposterior MFL%													
Right	0 (0)	1 (5)	18 (90)	1 (5)	0 (0)	1 (5)	19 (95)	0 (0)	0 (0)	0 (0)	19 (95)	1 (5)	0.916
Left	0 (0)	2 (10)	15 (75)	3 (15)	0 (0)	1 (5)	18(90)	1 (5)	0 (0)	3 (15)	13 (65)	4 (20)	0.733
Superoinferior MFL %													
Right	1 (5)	19 (95)	0 (0)	0 (0)	1 (5)	19 (95)	0 (0)	0 (0)	0 (0.0)	19 (95)	1 (5)	0 (0.0)	0.808
Left	0 (0)	18 (90)	2 (10)	0 (0)	1 (5)	19 (95)	0 (0)	0 (0)	0 (0.0)	19 (95)	1 (5)	0 (0.0)	0.671

**Chi-squared test, p < 0.05. MFL; Mandibular foramen location*

Discussion

Kim et al.[13] reported that 5 out of 6 bleeding in orthognathic surgery occurred during SSRO. The injury of the mandibular foramen may cause hemorrhages that could cause airway obstruction.[14] It is reported that bleeding during the SSRO is not a major problem and mostly could manage perfectly, although if the origin is inferior alveolar vessels it is occasionally difficult to control due to limited access.[15] The frequency of inferior alveolar nerve injury is reported approximately 66 to 85 % after SSRO.[16] It is suggested that osteotomy lines should be placed at 5 mm away from the vital structures at minimum to prevent damage to the neurovascular bundles.[17] In light of these information, accurately determining the MFL is very important during surgeries of mandibular ramus area for preventing nerve injuries and hemorrhages.[18]

Linear measurements can be considered the most reliable procedures when performed on dry mandibles, but cadaveric samples may be inappropriate to assess the angular measurements for determining the vertical facial type. There are studies in literature that used panoramic radiography to determine the MFL.[19,20] However, it was reported that the major distortions in 2D images were

shown in the mandibular ramus area compared to 3D images.[21] Besides this, it was reported several disadvantages of panoramic radiographies due to ghost artefacts while determining MF location.[22] Thus, we used CBCT images for determining the accurate MFL in different vertical facial types.

When the literature on this subject is examined, several studies can be found.[4,8,9] Correa et al.[8] reported more posterior MFL in low- angle patients and more superior location in high-angle patients. Contrary to these findings, we found MFL closest to the MN and furthest from the PB in the LA group. These variabilities may be related to differences in ethnicity.[9] Therefore, our results can be considered as anatomical variation that is applicable only for Anatolian population and may not be compatible with other ethnicities.

The morphometric equilibrium of the craniofacial structures on the opposite sides of the medial sagittal plane is decisive for the presence of facial symmetry.[23] In our study, ramus width, ramus height, MFW and MFL were found more symmetrical in normal- angle group compared to low- angle and high- angle groups. Similar to our findings, one recent study identified that the values of the asymmetry index were found slightly higher for low- angle and high- angle groups compared to the normal- angle group.[24]

The MFW values between study groups were significantly different. The smallest MFW was observed in the LA group. It is well known that vertical growth pattern is a direct expression of muscular activity.[25] Therefore, skeletal characteristics occur depending on the occlusal forces, and this relationship is established between muscular forces and mandibular shape.[26] It is reported that form of the parietal foramina show variations depending on muscular tension and compressions.[27] Similar to parietal foramina, higher muscular forces on ramus areas may result smaller mandibular foramens.

In this study, ramus height was shorter in high- angle group when compared to normal- angle and low- angle groups, however it was statistically significant only on the right side compared to normal- angle group. Numerous investigators Sassouni, Muller and Schudy have also investigated that shorter ramus height was associated with increased vertical growth pattern.[28-30] No significant ramus widths were observed between study groups, while Magna et al.[31] found greater in low- angle group.

Although, several studies have been conducted to investigate the quadrant in which the mandibular foramen is located regardless of the vertical growth pattern, this is the first study to address the relationship between the quadrant in which the mandibular foramen is located and the vertical growth pattern. The most frequent localization of MF was the third anteroposterior ramus quadrant (82.5 % of HA, 92.5 of LA, 80 % of NA). Hayvard J et al.[32] reported similar results consistent with our findings. The most frequent localization of MF was the second superoinferior quadrant (92.5 % of HA, 95 % of LA, 95 % of NA) as suggested by Nicholson et al.[33]

This study has several limitations. It assessed only Anatolian people; therefore, it could not be generalized for all ethnicities. Additionally, we did not evaluate the impact of potential sex differences. Furthermore, due to low prevalence of existence, it was not possible to observe a statistically significant result for accessory mandibular foramen.

Conclusions

Our findings revealed that in patients with LA, the MF was closest to the MN and furthest from the PB. The MFW showed significantly smaller dimensions in LA group. The ramus height was significantly shorter in HA group compared to NA group on the right side.

It should always be considered that there would be a tendency to asymmetric location of the mandibular foramen and asymmetric structure of the ramus in LA and HA groups compared to NA group.

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Conflicts of Interest Statement

The authors declare that there is no conflict of interest relevant to this article. The final version of the manuscript has been seen and approved by all authors.

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