

Alternative Landmarks of the Mandibular Foramen to Prevent Nerve Injury during Ramus Surgery

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Objective: To investigate the mandibular foramen (MF) position in relation to other bony landmarks on the mandibular ramus (MR) to better understand the anatomical landmark during the ramus surgery.

Material and Method: Ninety-two adult mandibles were studied by measuring four linear parameters: AB, the distance from the posterior limit of the MF (point A) to the posterior border of the MR (point B), BC, the MR width (Point C was located at the anterior border of the MR), DE, the distance from the lingula tip (the highest and the most anterior limit of the MF) (point D) to the mandibular notch (point E), and the MR height (EF, point F was located at the mandibular inferior border). Lines BC and EF were drawn through points A and D and parallel to the inferior and posterior borders of the mandible, respectively. These measurements were analyzed to determine the mean parameters related to the MF location.

Results: The mean lengths of AB, BC, DE, and EF were 12.7 ± 2.3 , 35.0 ± 4.0 , 17.5 ± 3.5 , and 52.7 ± 5.2 mm, respectively. The ratios between AB/BC and DE/EF were 0.36 ± 0.05 and 0.33 ± 0.05 , respectively. This study indicated that the MF located slightly anterior to the posterior third of the MR width and at the superior third of the MR height.

Conclusion: Anatomical consideration of this area is useful to prevent neurovascular injury when performing the bony cut made in a ramus osteotomy; however, pre-operative examinations with appropriate radiographic analysis are also recommended.

Keywords: Mandibular foramen, Ramus osteotomy, Mandibular ramus, Nerve injury

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A number of mandibular surgical techniques have been developed and modified to correct mandibular developmental disorders and disease, such as internal derangement, mandibular prognathism, mandibular retrognathia, and laterognathia. Mandibular surgery can restore masticatory and speech function, esthetics, and the function of the temporomandibular joint⁽¹⁾. Two of the most widely used techniques for repositioning the mandibular dental arch are vertical ramus osteotomy (VRO)⁽²⁻⁵⁾ and sagittal split ramus osteotomy (SSRO)⁽⁶⁻⁹⁾. During VRO surgery, the osteotomy is performed through the lateral surface of the mandibular ramus, dividing the mandibular ramus from the mandibular notch down to the angle of the mandible^(10,11). The antilingula is the most commonly used landmark in this surgery^(12,13). The osteotomies performed in SSRO consist of a horizontal or medial cut, a sagittal cut, and a vertical cut. The medial cut is

made just above and posterior to the lingula, which is the key landmark for this operation⁽¹⁴⁾.

When an osteotomy is needed in the position close to the neurovascular bundle, it is generally recommended to perform 5 mm away from it (a safety zone) to reduce the incidence of nerve trauma. Even if the nerve is only slightly compressed, neurapraxia will occur^(15,16). In VRO and SSRO, the antilingula and lingula, respectively, need to be identified to avoid nerve injury. However, the positions of these landmarks are variable and they are often not sufficiently prominent to precisely locate the osteotomy site^(17,18). Numerous techniques have been proposed to locate the antilingula, lingula, or mandibular foramen, such as the anatomic study of their locations or the use of additional landmarks (e.g., the midwaist of the mandibular ramus or the midpoint between the coronoid process and gonion), panoramic radiograph tracing, or computed tomography (CT) scan⁽¹⁷⁻²⁴⁾. When performing mandibular ramus surgery, the surgeon should not depend on only one technique to identify the correct surgical site. Anatomic and radiographic evaluation are usually used together to

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provide the needed surgical information. Therefore, the identification of landmarks on the mandibular surface to specify the location of the mandibular foramen is important to avoid injury to the inferior alveolar neurovascular bundle. However, limited data are available on the location of the mandibular foramen in relation to surrounding structures for ramus osteotomy. In addition, racial variation exists in metric characteristics of the mandible.

The aim of the present study was to investigate the position of the mandibular foramen in relation to other bony landmarks on the mandibular ramus to determine a reliable safe area for mandibular ramus osteotomy to be performed without injury to the inferior alveolar neurovascular bundle. Differences in the parameters were assessed between mandible side, sex, and age groups. Comparisons with previous studies of various racial groups were also made.

Material and Method

The present study was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, and the Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand.

Ninety-two adult Thai (the Mongoloid population in Southeast Asia) dry mandibles (184 sides) of known sex and age were selected from the collections of the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University, and the Department of Anatomy, Faculty of Dentistry, Chulalongkorn University. The sexes and ages of the dry mandible specimens were identified from the demographic records of the institutes. All mandibles were dentated, containing at least anterior teeth, and had no evidence of atrophy or deformity. The rami on both sides of each mandible were evaluated.

The mandibular foramen in the present study was localized using the lingula as the highest and the most anterior limit of the foramen and the posterior point of the mandibular foramen was used as the lowest and most posterior limit of the mandibular foramen. Bony landmarks that are always clearly identifiable in an operative approach to the mandibular ramus were chosen as the reference points. Six landmarks (points A-F) were identified on each mandibular ramus (Fig. 1). Point A was defined as the posterior limit of the mandibular foramen, whereas points B and C were located at the posterior and the anterior borders of the mandibular ramus, respectively, on a line parallel to the inferior mandibular border going through point A. Point D was located at the tip of the lingula. Points E

and F were located at the mandibular notch and the inferior border of the mandible, respectively, on a line parallel to the posterior border of the mandible going through point D. All measurements were performed using sliding calipers (Mitutoyo, Japan) capable of measuring to the nearest 0.01 mm.

The gonial angle and the angle of the mandibular canal were also measured (Fig. 2). With the mandible on a horizontal plane, a rigid probe was inserted down the mandibular canal as far as possible and a photograph of the lateral mandible was taken with a digital camera (Camedia E-10, Olympus Optical

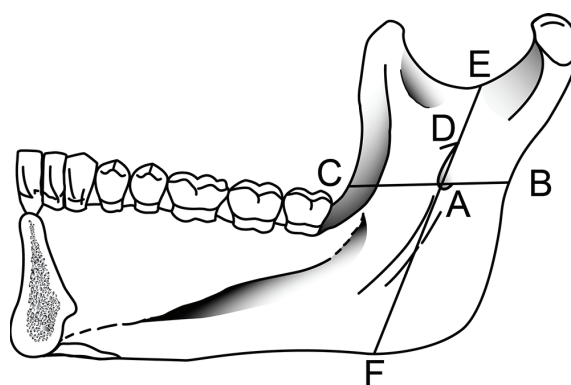


Fig. 1 Diagram of the internal surface of the mandible, showing anatomical landmarks for measuring the position of the mandibular foramen. A) the posterior limit of the mandibular foramen, B) the posterior border of the mandibular ramus, C) the anterior border of the mandibular ramus, D) the tip of the lingula, E) the point located in the mandibular notch, and F) the point located in the inferior border of the mandible. BC and EF are lines drawn parallel to the inferior border and the posterior border of the mandible, respectively (adapted from Jansisyanont et al, 2009)⁽¹⁷⁾.

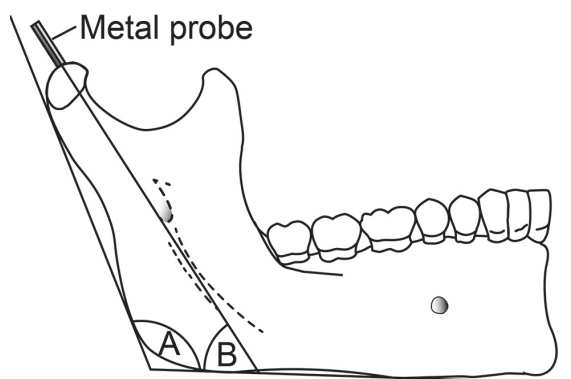


Fig. 2 The measurement of the gonial angle (A) and the angle of the mandibular canal (B).

Co., Ltd.) at a right angle to the mandibular body. The data were transferred to a computer. The standard basal plane and rameal planes were drawn on the photographs and angles were measured using computer software (UTHSCSA Image Tool for Windows version 3.0). The gonial angle was the angle formed between the standard basal and rameal planes, whereas the angle of the mandibular canal was measured between the standard basal plane and the metal probe indicating the mandibular canal direction.

To test the reproducibility of the measurements, 20% of the mandibles were randomly selected and re-measured two weeks later. The differences between each measurement on the two occasions were determined by the paired t-test.

All measurements and ratios of the data were tabulated and separated according to side, sex, and age groups. The Statistical Package for Social Science (version 11.5) was used for the analyses. The mean, standard deviation (SD), and range for each measurement was assessed. The values of all measurements were compared between sides using the paired t-test, whereas the unpaired t-test was used when comparing measurements between sexes and age groups (25 years old and below and over 25 years old). Differences between groups were considered statistically significant at *p*-value less than 0.05.

Results

The 92 mandibles (184 sides) investigated in the present study comprised 58 males (63%) and 34 females (37%) with a mean age of 42.4±15.2 years (range, 18-83 years). There was no significant

difference in age between males (42.6±14.8 years) and females (42.0±16.0 years) (*p* = 0.859).

The location of the mandibular foramen in relation to the mandibular ramus landmarks was shown in Table 1. The mean lengths of lines AB, BC, DE, and EF were 12.7±2.3, 35.0±4.0, 17.5±3.5, and 52.7±5.2 mm, respectively. The horizontal (AB/BC) ratio was 0.36±0.05, indicating the mandibular foramen was located slightly anterior to the posterior third of the mandibular ramus width (distance BC). The value of the vertical (DE/EF) ratio was 0.33±0.05, revealing the mandibular foramen was located at approximately the superior third of the mandibular ramus height (distance EF). The means of the gonial angle and the angle of the mandibular canal were 122.2±8.2 and 25.1±5.6 degrees, respectively. Concerning the reliability of the measurements, no significant variations in the measurements were found (*p* of AB = 0.577, *p* of BC = 0.544, *p* of DE = 0.510, *p* of EF = 0.356, *p* of AB/BC = 0.352, *p* of DE/EF = 0.241, *p* of the gonial angle = 0.616, and *p* of the angle of the mandibular canal = 0.633).

The measurements and ratios used to locate the mandibular foramen were compared between sides, sexes, and age groups. There were no significant differences between any measurements and ratios used to locate the foramen when compared by side (data not shown). In contrast, there were significant differences in many of the measurements used to locate the foramen when compared by sexes (*p* of AB, BC, and EF <0.0001), except DE (*p* = 0.134), AB/BC (*p* = 0.407), and DE/EF (*p* = 0.165) (Table 1). The gonial angle and the angle of the mandibular

Table 1. Measurements of the location of mandibular foramen compared between sexes

Parameters	Total (n = 184)		Male (n = 116)		Female (n = 68)		<i>p</i> -value
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	
Distances (mm)							
AB	12.7±2.3	6.6-19.0	13.2±2.3	7.4-19.0	11.9±2.1	6.6-17.7	<0.0001
BC	35.0±4.0	25.7-45.1	36.1±3.5	28.6-45.1	33.2±4.0	25.7-43.9	<0.0001
DE	17.5±3.5	11.0-33.3	17.8±3.6	11.0-33.3	17.0±3.3	12.5-24.3	0.134
EF	52.7±5.2	41.9-71.4	54.1±5.0	42.0-71.4	50.3±4.3	41.9-60.4	<0.0001
Ratio							
AB/BC	0.36±0.05	0.18-0.52	0.37±0.05	0.21-0.48	0.38±0.06	0.19-0.52	0.407
DE/EF	0.33±0.05	0.22-0.48	0.33±0.05	0.23-0.48	0.34±0.05	0.22-0.43	0.165
Angles (degrees)							
Gonial angle	122.2±8.2	99.5-143.9	120.2±8.3	99.5-143.9	125.6±6.9	108.0-141.8	<0.0001
Angle of the mandibular canal	25.1±5.6	11.1-49.9	26.1±5.9	11.1-49.9	23.4±4.6	13.9-35.0	0.001

AB = distance from the mandibular foramen to the posterior border of the mandibular ramus; BC = distance from the posterior to the anterior borders of the mandibular ramus; DE = distance from the lingula tip to the mandibular notch; EF = distance from the mandibular notch to the inferior mandibular border

canal were significantly different between sexes (p of the gonial angle <0.0001 and p of the angle of the mandibular canal = 0.001) (Table 1). No significant differences were found between age groups (p of AB = 0.225, p of DE = 0.880, p of EF = 0.812, p of AB/BC = 0.948, p of DE/EF = 0.922, p of the gonial angle = 0.388, and p of the angle of the mandibular canal = 0.749), except BC in the over 25-year-old group was significantly longer than that in the 25-year-old or less group ($p = 0.040$) (Table 2).

Discussion

Nerve injury is the most common and problematic complication in ramus osteotomy surgery. The incidence of nerve injury after 1 year following ramus surgery (VRO and SSRO) ranges from 5.3 to 38.0%⁽²⁵⁾. The locations of the lingula, antilingula, midwaist of the mandibular ramus, and midpoint between the coronoid process and the gonion were studied and reported as the determining determinant of the vertical ramus osteotomy position to avoid injury of the inferior alveolar neurovascular bundle during mandibular surgery^(17,18). The present study used anatomic landmarks that can be visualized intraoperatively as reference points to evaluate the location of the mandibular foramen in the mandibular ramus.

When performing lateral ramus surgery, the antilingula is typically used as an anatomic landmark corresponding to the location of the mandibular foramen^(12,13). However, in studies using dry mandibles, its ability to be identified ranged from 42% to 100%^(18,26-29). Furthermore, it is not always

located at the point precisely opposite the opening of the mandibular foramen. The antilingula has been reported to often be anterior and superior to the mandibular foramen^(18,26-28). Martone et al recommended using the midwaist point of the ramus to localize the mandibular foramen when the antilingula was not discernable⁽²⁷⁾. They claimed that this point was closer to the opening of the mandibular foramen than the antilingula. However, the opposite result was found in a subsequent study⁽¹⁸⁾. Therefore, surgeons have been encouraged to avoid the use of a single criterion and to obtain as many anatomic guide points as possible when performing mandible ramus osteotomy⁽¹³⁾. The identification of the anatomic positions of the lingula, the antilingula, and the mandibular foramen, as well as a preoperative radiographic assessment, will assist the surgeon in determining safe anatomic guidelines for mandibular surgery.

In the present study, the means of AB, BC, DE, and EF were 12.7±2.3 mm, 35.0±4.0 mm, 17.5±3.5 mm, and 52.7±5.2 mm, respectively. The horizontal and vertical ratios were 0.36±0.05 and 0.33±0.05, respectively. The means of the gonial angle and angle of the mandibular canal were 122.2±8.2 degrees and 25.1±5.6 degrees, respectively.

The mean of the mandibular ramus width in the present study (35.0±4.0 mm) is greater than the 31.03±3.9 mm⁽²¹⁾ and the 31.3±2.7 mm⁽²⁴⁾ reported for Brazilian and Asian mandibles, respectively. The distance from the posterior border of the mandibular foramen to the posterior border of the mandibular ramus in the present study (12.7±2.3 mm) is greater than the 10.04±1.8 mm found in Brazilians⁽²¹⁾. The

Table 2. Measurements of the location of mandibular foramen compared between age groups

Parameters	≤25 years (n = 30)		>25 years (n = 142)		p-value
	Mean ± SD	Range	Mean ± SD	Range	
Distances (mm)					
AB	12.3±2.1	8.5-17.1	12.8±2.4	6.6-19.0	0.225
BC	33.5±3.3	27.7-41.3	35.2±4.1	25.7-45.1	0.040
DE	17.5±3.6	12.1-24.3	17.6±3.5	11.0-33.3	0.880
EF	52.5±5.1	44.2-61.9	52.7±5.4	41.9-71.4	0.812
Ratio (%)					
AB/BC	0.37±0.05	0.27-0.46	0.37±0.06	0.18-0.52	0.948
DE/EF	0.33±0.05	0.23-0.43	0.33±0.04	0.24-0.48	0.922
Angles (degrees)					
Gonial angle	121.0±7.5	105.6-132.3	122.4±8.4	99.5-143.9	0.388
Angle of the mandibular canal	25.3±4.9	16.0-35.8	25.0±5.8	11.1-49.9	0.749

AB = distance from the mandibular foramen to the posterior border of the mandibular ramus; BC = distance from the posterior to the anterior borders of the mandibular ramus; DE = distance from the lingula tip to the mandibular notch; EF = distance from the mandibular notch to the inferior mandibular border

horizontal ratio (0.36 ± 0.05) in the present study is more than the 0.32 ± 0.05 seen in the Brazilian study⁽²¹⁾.

The mean height of the mandibular ramus in the present study (52.7 ± 5.2 mm) is greater than the 49.4 ± 4.2 mm reported in Brazilians⁽²¹⁾ and the 47.7 ± 7.1 mm observed in Asians⁽²⁴⁾. The distance from the lingula tip to the mandibular notch in the present study (17.5 ± 3.5 mm) is greater than the 15.8 ± 2.6 mm seen in Brazilians⁽²¹⁾ and the 16.2 ± 2.1 mm found in Asians⁽²⁴⁾. The vertical ratio (0.33 ± 0.05) in the present study is between the 0.31 ± 0.04 determined in Brazilians⁽²¹⁾, the 0.32 seen in Koreans⁽³⁰⁾, and the 0.35 ± 0.04 noted in Asian mandibles⁽²⁴⁾. All of these comparisons confirm the variation in the location of the mandibular foramen among racial groups, which have been noted in previous reports^(17,20,30-34).

When comparing the location of the mandibular foramen expressed as the horizontal and vertical ratios of the ramus obtained from the present study and from the study of Trost et al, there were no significant differences between side, sex, and age groups⁽³¹⁾.

When comparing the four distances (AB, BC, DE, and EF) according to sex, higher values were significantly found in males than in females, except for the distance from the lingula tip to the mandibular notch (Table 1). As a general trend, the distances in males were greater than or nearly equal to those found in females. This observation is consistent with the fact that males generally have larger mandibles than females⁽³²⁾. Comparing age groups, the mean distance from the posterior border to the anterior border of the mandibular ramus in the over 25-year-old group was longer than that in the 25-year-old and below group ($p = 0.040$) (Table 2).

The horizontal and vertical ratios determined the present study suggest that the posterior and superior thirds of the mandibular ramus should be considered as a "safe area" to make the vertical and horizontal cuts of a mandibular ramus osteotomy with a low incidence of inferior alveolar nerve injury.

Hetson et al used computer calculations to develop a linear equation from the measurements of the gonial angle and the narrowest antero-posterior ramal width to use in predicting the position of the mandibular foramen⁽³⁵⁾. They suggested that the degree of mandibular growth would be related to the gonial angle rather than to some arbitrary bony measurement. In the present study, the mean gonial angle (122.2 ± 8.2 degrees) was nearly equal to the 122 degrees reported by Hetson et al⁽³⁵⁾, but it is higher

than that identified in those of East Indian ethnic origin (right, 115.8 ± 11.0 and left, 116.1 ± 7.3 degrees)⁽³⁴⁾. The mean angle of the mandibular canal (25.1 ± 5.6 degrees) in the present study is smaller than that reported in East Indian ethnic origin individuals (right, 36.0 ± 10.1 and left, 37.0 ± 7.1 degrees)⁽³⁴⁾.

The limitation of the present study is that the investigation was performed on normal mandibles that might be different from those of patients with mandibular deformities. Fujimura et al studied and compared similar measurements to those used in the present study in 47 dry mandibles and 22 patients with prognathism⁽²⁴⁾. Their results showed that the position of the mandibular foramen varied among individuals with normal mandibles and among those with prognathism. Fujimura et al⁽²⁴⁾ found a significant difference between the dry mandible group and the patient group. However, the mandibular foramen was located slightly posterior to the center of the width of the mandibular ramus, and the lingula tip was located at approximately the superior third of the mandibular ramus height in both groups. In contrast, Tominaga et al suggested that the initial osteotomy point should be determined by their technique, using an individual point identified based on each patient's radiograph, and not based on statistical data such as the relationship of the midwaist point to the foramen⁽³⁶⁾. Therefore, the location of the mandibular foramen should be confirmed preoperatively by panoramic radiograph and axial CT images. Further modifications of ramus surgical technique and instrument development should make mandibular ramus osteotomy easier and safer.

In conclusion, although the exact position of the mandibular foramen in the present study was slightly variable among individuals with normal mandibles, it was usually localized slightly anterior to the posterior third of the mandibular ramus width, and at the superior third of the mandibular ramus height. From the horizontal and vertical ratios of our study, the authors suggest that the posterior and superior thirds of the mandibular ramus are a "safe area" to make the medial cut of the SSRO or the vertical cut of a mandibular ramus osteotomy with a low incidence of inferior alveolar nerve injury.

Importantly, the surgeon should avoid the use of a single criterion, but obtain as many anatomic guidelines as possible, to determine the location of the mandibular foramen and antilingula. Preoperative radiographic assessments such as panoramic radiographs, lateral cephalographs, or/and axial CT images of the mandibular foramen location should be

utilized to assist the surgeon in determining a safe anatomic location for mandibular ramus osteotomy procedures. The data presented here should be useful for surgeons to perform mandibular ramus osteotomy surgery precisely and without complication.

What is already known on this topic?

There were several anatomical studies about the location of the antilingula, the lingula, or the mandibular foramen. The use of additional landmarks and techniques was also reported such as the midwaist of the mandibular ramus or the midpoint between the coronoid process and gonion or the computed tomography. However, there is limited data on the location of the mandibular foramen in relation to the surrounding structures for mandibular ramus surgery.

What this study adds?

The information about the location of the lingula and mandibular foramen has a better understanding. From the present study, the mandibular foramen has been localized slightly anterior to the posterior third of the mandibular ramus width and at the superior third of the mandibular ramus height. They are slightly variable among individuals with normal mandibles so the surgeon should not use only single anatomical guideline to plan for the surgery.

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Potential conflicts of interest

None.

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จุดกำหนดทางเลือกของรูขากรไรกรล่างเพื่อป้องกันอันตรายต่อเส้นประสาทระหว่างการผ่าตัดขากรไรกรล่างส่วน
ท้ายฟันกราม

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วัตถุประสงค์: เพื่อศึกษาคำแหน่งของรูขากรไรกรล่าง (mandibular foramen, MF) ที่สัมพันธ์กับจุดกำหนดอื่นๆ ที่เป็นกระดูก
บนขากรไรกรล่างส่วนท้ายฟันกราม (mandibular ramus, MR) เพื่อเพิ่มความเข้าใจจุดกำหนดทางกายวิภาค (anatomical
landmark) ระหว่างการผ่าตัดขากรไรกรล่างส่วนท้ายฟันกราม

วัสดุและวิธีการ: ทำการศึกษาในขากรไรกรล่างผู้ใหญ่จำนวน 92 ชิ้น โดยการวัดเส้นตรง 4 ระยะ ได้แก่ AB; ระยะจากขอบหลัง
ของ MF (จุด A) ไปยังขอบหลังของ MR (จุด B), BC; ความกว้างของ MR (จุด C อยู่ที่ขอบหน้าของ MR), DE; ระยะจากจุด
สูงสุดและหน้าสุดของ MF (lingula tip) (จุด D) ไปยังส่วนเว้าขากรไรกรล่าง (mandibular notch) (จุด E) และความสูงของ
MR (EF; จุด F อยู่ที่ขอบล่างของขากรไรกรล่าง) เส้น BC และ EF ลากผ่านจุด A และ D และขนานกับขอบล่างและขอบหลัง
ของขากรไรกรล่างตามลำดับ วิเคราะห์ระยะที่วัดเพื่อกำหนดค่าเฉลี่ยที่เกี่ยวข้องกับตำแหน่งของ MF

ผลการศึกษา: ความยาวเฉลี่ยของ AB, BC, DE และ EF เท่ากับ 12.7 ± 2.3 , 35.0 ± 4.0 , 17.5 ± 3.5 และ 52.7 ± 5.2 มม. ตามลำดับ
อัตราส่วนระหว่าง AB/BC และ DE/EF เท่ากับ 0.36 ± 0.05 และ 0.33 ± 0.05 ตามลำดับ จากการศึกษาครั้งนี้ชี้ให้เห็นว่า MF อยู่ที่
ค่อนข้างทางหน้าต่อหนึ่งในสามของด้านหลังของความกว้างของ MR และอยู่ที่หนึ่งในสามของด้านบนของความสูงของ MR

สรุป: ข้อควรพิจารณาทางกายวิภาคของบริเวณนี้มีประโยชน์เพื่อป้องกันอันตรายต่อเส้นประสาทและหลอดเลือด เมื่อทำการตัดกระดูก
ในการผ่าตัดขากรไรกรล่างส่วนท้ายฟันกราม อย่างไรก็ตามการตรวจวิเคราะห์ด้วยภาพรังสีที่เหมาะสมก่อนการผ่าตัดก็จำเป็น
