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Assessment of Mandibular Ramus Thickness and Depth for Safe Miniscrew Placement in an Iranian Population: A Cone-Beam Computed Tomography Study

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ABSTRACT

Objectives: This study assessed the mandibular ramus for safe miniscrew placement in an Iranian population using cone-beam computed tomography (CBCT).

Materials and Methods: This cross-sectional study was conducted on 212 CBCT scans. The mandibular ramus thickness and depth were measured as the distance between the buccal and lingual surfaces, and the distance between the anterior border of the ramus and the mandibular canal, respectively, at the occlusal plane level and 5mm and 10mm above it. Two-way ANOVA was applied to analyze the effects of gender and presence of third molars on ramus depth and thickness. The right and left sides were compared by paired t-test (alpha=0.05).

Results: As moving from the occlusal plane to 5 and 10mm above it, ramus depth increased while its thickness decreased. In presence of third molars, ramus thickness and depth in males were greater than those in females at both sides. Ramus depth was significantly greater in the right side than the left side at all levels (P<0.001). Presence of third molars (P=0.001, P=0.053) and gender (P<0.001, P=0.052) significantly affected the left-side ramus depth at the occlusal level and 5mm above it. Gender significantly affected the right-side ramus depth at 5 and 10mm levels (P=0.013).

Conclusion: Presence of third molars increased ramus depth and thickness. Ramus depth and thickness were greater in males than females. Miniscrew placement is recommended at 5mm above the occlusal level due to sufficient depth and thickness of the ramus at this region.

Keywords: Cone-Beam Computed Tomography; Mandibular Condyle; Orthodontic Anchorage Procedures

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INTRODUCTION

Anchorage control is essential for successful fixed orthodontic treatment of dental and skeletal malocclusions [1]. Miniscrews are widely-used temporary anchorage devices that offer easy insertion and removal, low cost, and small size. They also require minimal patient cooperation. However, potential complications include root contact, nerve injury, sinus perforation, soft tissue problems, and fracture during placement or removal [2-5].

Adequate bone at the insertion site is crucial for miniscrew stability [6]. Primary stability, mainly determined by cortical bone quality and quantity, is a key factor for long-term success, while secondary stability develops after osseointegration [7]. Factors such as insertion site characteristics, miniscrew design, and applied forces can also influence stability [8-12]. Depending on treatment requirements,

miniscrews may be placed in various regions, including the palate, infrazygomatic crest, retromolar region, and maxillary and mandibular cortical plates [4,13]. Morphological differences in the mandibular ramus are clinically relevant for determining safe insertion sites, as well as for gender determination [14].
Two-dimensional radiographs provide limited information about interradicular space, root morphology, cortical bone thickness, and the position of the inferior alveolar nerve [15,16]. Cone-beam computed tomography (CBCT) offers reliable, three-dimensional images with acceptable radiation dose and minimal artifacts, making it suitable for preoperative assessment of miniscrew insertion [17,18]. The complications of miniscrew insertion can be minimized by thorough evaluation of the morphology and structural properties of bone [19]. Considering the limited data on mandibular ramus anatomy in the Iranian population, this study aimed to evaluate the mandibular ramus for safe miniscrew placement using CBCT.

MATERIALS AND METHODS

This cross-sectional study was conducted on 212 eligible CBCT scans of Iranian patients retrieved from the archives of a private radiology clinic. The CBCT scans had been taken for purposes not related to this study. The study protocol was approved by the ethics committee of the university (IR.SHAHED.REC.1402.006).

Sample size:

The minimum sample size was calculated to be 53 from each sex in each group according to a study by Nucera et al, [5] using the confidence interval for the mean in PASS 11 and assuming alpha=0.05, mean standard deviation of 1.8mm for the ramus thickness at 10mm level from the occlusal plane, and confidence interval of 0.5mm. Accordingly, a total of 212 eligible CBCT scans were selected by convenience sampling.

Eligibility criteria:

The inclusion criteria were good-quality radiographs visualizing the ramus area with optimal resolution, presence of erupted mandibular second molars, no genetic syndromes, no craniofacial anomalies, absence of periapical lesions and periradicular pathologies (with either endodontic or periodontal origin), no history of orthognathic surgery, no mandibular ramus anomalies, no horizontal bone resorption (normal alveolar crest within 1.5to 2mm apical to the cementoenamel junction, with a flat contour parallel to the cementoenamel junction), and no vertical bone loss at the site.

Data collection:

All CBCT scans had been taken with NewTom VGi Evo CBCT scanner (Quantitative Radiology, Verona, Italy) with a 12 x 8cm field of view, 6.18mA tube current, 110kVp tube potential, and 4.3s time. The images were categorized based on the gender of patients and presence/absence of mandibular third molars. To assess the mandibular ramus quantity, its thickness and depth were measured. The ramus thickness was measured as the distance between the buccal (external) and lingual (internal) walls of the mandibular ramus (Fig. 1).

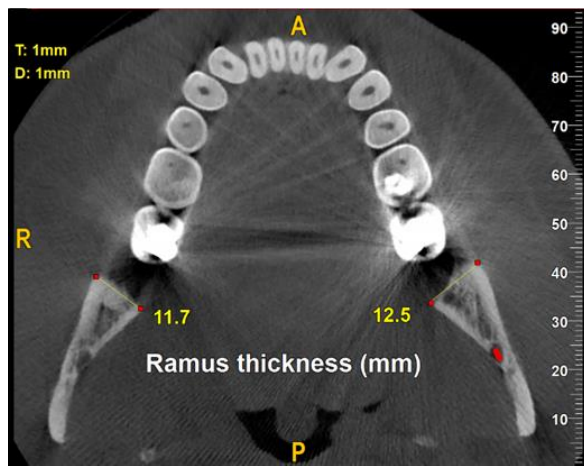

Fig. 1. Measuring the ramus thickness on CBCT scans.

The ramus depth was measured as the distance between the anterior border of the ramus and the mandibular canal [20] (Fig. 2). To find an ideal location for miniscrew insertion, the occlusal plane was used as the reference for ramus thickness. The ramus thickness and depth were measured at 3 levels bilaterally, namely at the level of the occlusal plane and 5mm and 10mm above the occlusal plane, using NNT viewer software.

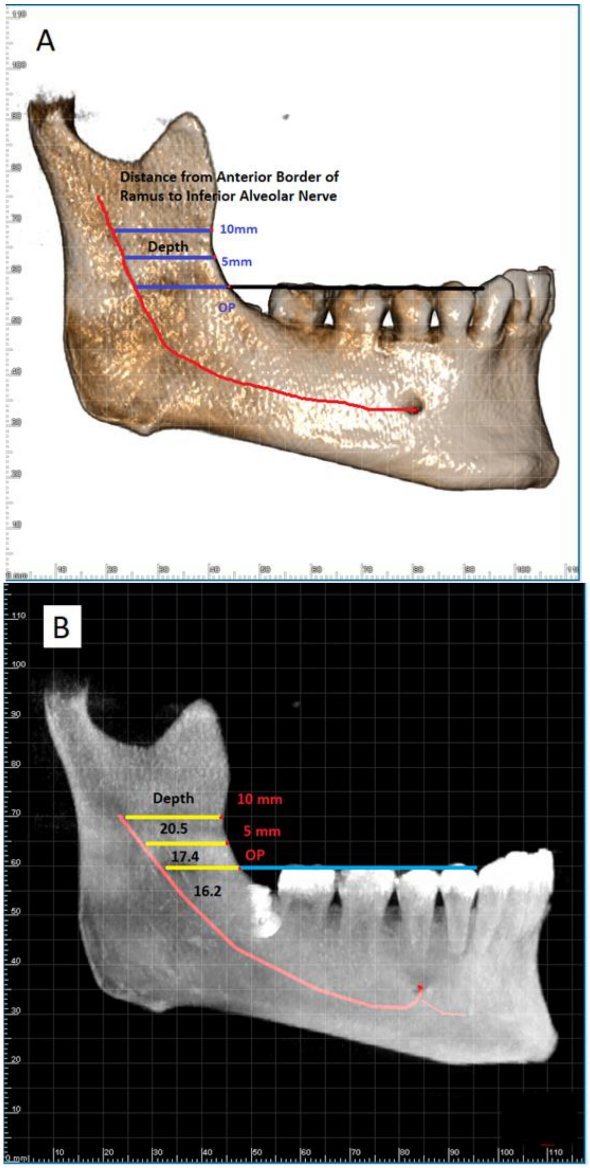

Fig 2. Ramus depth measurement; A: Schematic illustration; B: Measuring the ramus depth on CBCT scan.

All measurements were made by one operator (oral radiologist), and repeated after 1 month to ensure optimal intra-examiner reliability.

Statistical analysis:

Data were analyzed using SPSS version 25 (SPSS Inc., IL, USA). The mean and standard deviation of ramus thickness and depth at the occlusal plane level and 5mm and 10mm above it in the right and left sides were reported and analyzed separately for males and females, and also based on presence/absence of mandibular third molars. Two-way ANOVA was applied to analyze the effects of gender and presence/absence of mandibular third molars on the ramus depth and thickness at different levels and also in the right and left sides. The right-side and left-side ramus depth and thickness were compared by paired t-test. Level of significance was set at 0.05.

RESULTS

Table 1 shows the measures of central dispersion for the ramus depth at different levels in the right and left sides in males and females. Two-way ANOVA showed significant effects of presence/absence of third molars on the left-side ramus depth at 0mm ($P=0.001$) and 5mm ($P=0.053$) from the occlusal plane. Also, gender had a significant effect on the left-side ramus depth at 0mm ($P<0.001$) and 5mm ($P=0.052$) from the occlusal plane. Gender had a significant effect on the right-side ramus depth only at the occlusal plane level ($P=0.013$).

Table 2 presents the measures of central dispersion for the ramus thickness at different levels in the right and left sides in males and females. Two-way ANOVA showed significant effects of presence/absence of third molars on the left-side ($P=0.014$) and right-side ($P=0.001$) ramus thickness at the occlusal plane level. Also, presence/absence of third molars had a significant effect on the left-side ($P<0.001$) and right-side ($P=0.001$) ramus thickness at 5mm above the occlusal plane. Gender had a significant effect on the left-side ($P=0.002$) and right-side ($P=0.006$) ramus thickness at 10mm above the occlusal plane.

Table 3 compares the right-side and left-side mandibular ramus depth and thickness at different levels from the occlusal plane irrespective of gender and presence/absence of third molars. Paired t-test showed significant differences in ramus depth in the right and left sides at the occlusal plane and 5 and 10mm above it ($P<0.0001$). However, no significant difference was found in ramus thickness at the right and left sides at 0 ($P=0.13$) and 5mm ($P=0.92$) levels. But the right-side ramus

Table 1. Measures of central dispersion for ramus depth at different levels in the right and left sides in males and females in presence and absence of mandibular third molars (in millimeters)

Third molars	Gender	Side	Level from occlusal plane (mm)	Mean± SD	Minimum	Maximum
Absent	Female	Left	0	14.84±2.39	7.60	18.50
			5	16.52±2.71	9.40	21.00
			10	18.81±2.66	13.50	22.80
		Right	0	15.70±1.81	12.00	19.30
			5	17.63±2.00	14.20	22.50
			10	19.91±2.11	16.60	25.00
	Male	Left	0	15.73±1.48	12.70	18.10
			5	16.93±1.44	14.70	19.50
			10	19.57±2.49	16.60	33.70
		Right	0	16.37±1.86	12.50	19.80
			5	17.67±2.25	12.90	22.30
			10	19.65±2.41	14.20	25.50
Present	Female	Left	0	15.61±1.97	13.20	20.00
			5	17.32±2.31	13.70	23.80
			10	19.48±2.97	15.00	27.70
		Right	0	16.05±2.77	11.70	24.10
			5	17.95±2.88	13.70	26.10
			10	20.52±3.41	15.50	30.60
	Male	Left	0	16.98±2.60	11.00	23.20
			5	18.27±3.36	11.80	25.60
			10	19.57±3.63	11.50	28.30
		Right	0	17.09±3.21	10.00	25.70
			5	18.31±3.41	11.50	29.10
			10	20.27±4.01	12.50	32.80

SD: Standard deviation

thickness was significantly greater than the left-side ramus thickness at 10mm from the occlusal plane (P=0.005).

DISCUSSION

This study assessed the mandibular ramus for safe miniscrew placement in an Iranian population using CBCT. The results showed that the ramus depth increased while its thickness decreased from the occlusal plane to 5 and 10mm above it, which was similar to the results of Mehta et al [20]. Due to the optimal ramus depth and thickness at 5mm above the occlusal plane, this area was considered optimal for miniscrew insertion in the present study. Chang et al. [21] reported that ramus miniscrews with 2mm diameter and 14mm length had the best adaptation to the anatomy of the mandibular ramus region. They suggested ramus miniscrews with >14mm length when the clinician wants to affect the thick mucosa covering the anterior border of the ramus as well.

According to the present results and those of Mehta et al, [20] ramus depth increased from the occlusal plane to 5 and 10mm above it; thus, greater depth is available for miniscrew insertion at 5 and 10mm levels above the occlusal plane, minimizing the risk of inferior alveolar nerve damage. Therefore, a suitable imaging modality is required for safe insertion of ramus miniscrews. On the other hand, the thickness of the soft tissue covering the mandibular ramus also has several variations in different individuals, which should be taken into account when interpreting the

Table 2. Measures of central dispersion for ramus thickness at different levels in the right and left sides in males and females in presence and absence of mandibular third molars (in millimeters)

Third molars	Gender	Side	Level from occlusal plane (mm)	Mean± SD	Minimum	Maximum
Absent	Female	Left	0	8.67±2.13	5.10	17.80
			5	7.05±1.39	4.50	9.70
			10	5.52±1.31	3.20	7.70
		Right	0	8.45±1.71	5.40	12.60
			5	7.06±1.54	4.50	10.60
			10	5.82±1.61	3.10	9.60
	Male	Left	0	8.74±2.81	6.10	21.20
			5	6.76±1.17	5.00	9.50
			10	6.12±1.24	3.70	8.80
		Right	0	8.30±1.76	4.80	11.00
			5	6.84±1.32	4.10	9.10
			10	6.44±1.42	3.90	8.70
Present	Female	Left	0	9.24±2.13	6.30	14.30
			5	7.40±1.73	4.20	11.00
			10	5.88±1.75	3.40	10.00
		Right	0	9.03±1.66	6.10	14.00
			5	7.44±1.56	4.70	11.40
			10	5.96±1.68	3.30	10.10
	Male	Left	0	9.77±2.28	6.70	21.30
			5	7.92±1.11	5.90	10.00
			10	6.47±1.25	4.10	9.30
		Right	0	9.24±1.47	7.00	13.40
			5	7.77±1.23	4.50	10.00
			10	6.51±1.34	4.70	9.70

SD: Standard deviation

Table 3. Comparison of the right and left mandibular ramus depth and thickness at different levels from the occlusal plane irrespective of gender and presence/absence of third molars

variable	Level from occlusal plane (mm)	Left Mean	Right Mean	Mean Difference (Right-Left)	P value
Depth	0	15.79	16.30	0.51	<0.001
	5	17.26	17.89	0.63	<0.001
	10	19.36	20.09	0.74	<0.001
Thickness	0	9.11	8.76	-0.35	0.13
	5	7.28	7.28	0.01	0.92
	10	5.99	6.18	0.19	0.005

results. Clinical assessment of soft tissue thickness covering the ramus is beneficial prior to miniscrew insertion.

Bone thickness has a fundamental role in miniscrew success. The initial success of miniscrews highly depends on their primary stability, which is influenced by the miniscrew diameter, anatomical site, and bone quantity. It has been reported that the primary stability of miniscrews increases following an increase in miniscrew diameter [22]. Miyawaki et al. [23] evaluated the success rate of three different miniscrews with variable lengths and diameters in 51 patients, and reported the success rate to be 0% (all failed) for miniscrews with 1mm diameter, 83.9% for those with 1.5mm diameter, and 85% for those with 2.3mm diameter. Thus, 2mm diameter miniscrews are more suitable for placement in the mandibular ramus and have a lower fracture rate. Nonetheless, greater ramus thickness would be preferred for placement of miniscrews with a larger diameter, because sufficient bone would be available around the miniscrews [20].

In the present study, the ramus thickness decreased from the occlusal plane to 5 and 10mm above it. In the current study, the minimum ramus thickness was 5.52mm noted in the left side of females at 10mm from the occlusal plane in absence of third molars. The greatest ramus thickness was 9.77mm in the left side of males in presence of third molars at the level of the occlusal plane. Since the diameter of ramus miniscrews is 2mm, and the ramus thickness decreases at higher levels above the occlusal plane, care should be taken in insertion of ramus miniscrews in the middle region and between the internal and external oblique ridges because if the miniscrew is placed eccentrically, it would result in insufficient amount of bone remaining around the miniscrew [20].

The decision of insertion of orthodontic miniscrews at certain areas depends on factors such as the used biomechanics (direct or indirect anchorage) and anatomy of the region, which varies in different individuals. However, some areas probably yield more reproducible results [4, 12, 24]. Thus, CBCT can be used to acquire data about the bone anatomy and its quality and quantity at different areas to find the best location for miniscrew insertion and assess the adjacent anatomical structures [4, 12, 24].

The present results showed significant effects of presence/absence of third molars and gender on the left-side ramus depth at 0 and 5mm from the occlusal plane; however, in the right side, only gender had a significant effect on the ramus depth at 0mm level. Presence/absence of third molars significantly affected the left-side and right-side ramus thickness at 0mm and 5mm levels, which can be due to the effect of the available space in case of presence/absence of third molars. Also, gender had a significant effect on the right-side and left-side ramus thickness at 10mm above the occlusal plane.

In presence of third molars, the ramus thickness at both sides was greater in males than females. Nonetheless, in absence of third molars, the ramus thickness in females was slightly greater than that in males in some cases. The same observations were recorded for the ramus depth as well, and in presence of third molars, the ramus depth in males was greater than that in females; whereas in absence of third molars, the ramus depth was greater in females than males in some cases.

Mehta et al. [20] evaluated the ramus parameters for miniscrew insertion and reported greater ramus thickness in males than females. Also, Humphrey et al. [25] reported that the size of mandible in females was averagely 92.4% of the size of mandible in males. Saini et al. [26] evaluated 116 dry mandibles and concluded that sexual dimorphism in the mandibular ramus was greater than that in the body of mandible. In the study by Mehta et al, [20] growing (adolescent) females had a greater ramus thickness than non-growing (adult) females except in the groups with a hyper-divergent face at 10mm distance from the occlusal plane. Also, growing (adolescent) males showed a greater ramus thickness than non-growing (adult) males. This topic was not evaluated in the present study to compare the results; but it should be noted that bone is a dynamic tissue, and bone formation exceeds bone resorption during the growth period [27].

In a study by Soltani et al, [28] the mandibular ramus width in males was greater than that in females. Also, the ramus width was greater in females than males in a study by Vinay et al [29]. Since the applied muscle forces differ in males and females, development of the masticatory muscles may possibly contribute to the differences in the mandibular ramus between the sexes [25, 30]. If functional capacity is the primary factor in differences in bone thickness, some gender-related differences in bone thickness should also be expected, as males have stronger masticatory forces and stronger masticatory muscles than females [30]. However, Schwartz-Dabney and Dechow [31] found no significant difference in mandibular cortical bone thickness of males and females. They believed that the maximum bite force is not a regular or habitual function like chewing, and that one should not expect that gender would have a significant role in the thickness of some bones [31]. The differences observed in the mandible of males and females may be explained by genetic factors, tooth size, and muscle force (lower in females than males). Dietary habits may also play a role in the differences observed on both sides [32, 33].

In the present study, in both presence and absence of mandibular third molars, the ramus depth at 10mm above the occlusal plane was greater than that at other levels; however, the ramus thickness was the lowest at 10mm level. The same was reported by Mehta et al [20]. In mesial impaction of mandibular second molars, a ramus miniscrew inserted at 5mm above the occlusal plane would have a higher position vertically and a more posterior position horizontally compared with impacted molars. This position has several biomechanical advantages to upright the impacted molars, because the forces are applied superiorly and posteriorly, causing a torque in a counterclockwise direction in molars, resulting in their uprighting movement. At 10mm above the occlusal plane, the direction of the applied forces causes strong loading in the vertical axis and extensive extrusion of mandibular molars. In the occlusal plane, the direction of the applied forces causes a strong loading of the horizontal axis, leading to large posterior movement of molar teeth. At 5mm above the occlusal plane, the direction of the applied forces causes a balance in the vertical and horizontal axes, resulting in correction of mesial tipping of second molars. According to the results of the present study, the morphology of the mandibular ramus differed depending on gender and presence/absence of third molars. Therefore, further research is required on the clinical success and failure of ramus miniscrews in male and female patients with/without mandibular third molars.

In the present study, the right-side ramus depth was significantly greater than the left-side ramus depth at all levels. However, these differences were not significant for the right-side and left-side ramus thickness at 0- and 5mm levels from the occlusal plane, but again at 10mm distance from the occlusal plane, the ramus thickness in the right side was significantly greater than that in the left side. However, this difference was 0.19mm, and did not seem to be of much clinical importance.

Since the presence of third molars was thought to be effective on anatomical characteristics of the ramus, the effects of this variable on ramus depth and thickness were also investigated in the present study. The results showed that presence/absence of third molars had significant effects on the ramus depth in the left side at 0 and 5mm from the occlusal plane. Also, presence/absence of third molars had significant effects on the ramus thickness at both the left and right sides at the occlusal plane level and 5mm above it. According to the present results, the ramus depth and thickness in presence of third molars were greater than the corresponding values in absence of third molars, although the differences were usually smaller than 1mm. This finding could be due to the effects of presence of dental mass in bone on growth and development of the mandible. The possible reason is that in a smaller mandible (with lower thickness and depth), obstruction and destruction of dental lamina occur and resultantly, third molars do not develop. Accordingly, Nucera et al. [5] evaluated the bone width, cortical bone thickness, and vestibulo-lingual bone dimensions at the retromolar trigone of the mandible and anterior ramus, and found no significant difference in these variables between patients with/without third molars. Their results were largely in agreement with the present findings.

Recent CBCT-based investigations have provided detailed anatomical guidelines for extra-alveolar mini-implant placement in mandibular regions. Fan et al. [34] reported that in the mandibular ramus, optimal insertion parameters included a height of 4–8mm above the occlusal plane, a site 4–8mm medial to the external oblique ridge, and insertion angles of approximately 120–150 degrees relative to the anterior surface of the ramus platform, which were associated with reduced risk of mandibular canal contact and molar interference. Similarly, Wang et al. [35] identified the mesial root of the mandibular second molar at 6–8mm from the alveolar ridge as the most favorable insertion site in the buccal shelf, recommending oblique insertion angles of 10–30 degrees relative to the root surface to minimize root contact. In addition, Alirezaei et al. [36] demonstrated that skeletal morphology, particularly gonial angle, significantly influenced bone thickness, depth, and angulation in the mandibular buccal shelf region, with inverse correlations suggesting improved stability potential in individuals with reduced vertical facial height. Although insertion angle was not directly evaluated in the present study, these findings collectively indicate that optimal angulation varies depending on the anatomical reference and insertion region. Therefore, individualized CBCT-based assessment remains essential to determine safe and stable mini-implant positioning.

The present study was a radiographic anatomical assessment based on CBCT images, and primarily focused on the anatomical characteristics of the mandibular ramus. Therefore, it did not evaluate several clinical and biological factors that may influence mini screw success, such as patient-related variables, soft tissue characteristics, and biomechanical loading conditions. In addition, the data were obtained from one single radiology center with specific inclusion criteria, which may limit the generalizability of the findings. Consequently, although the present findings provide useful anatomical information for miniscrew placement, they cannot alone fully predict clinical success rates.

CONCLUSION

Presence of third molars increased ramus depth and thickness. Ramus depth and Miniscrew placement is recommended at 5mm above the occlusal level due to the sufficient depth and thickness of the ramus at this region.thickness were greater in males than females.

CONFLICT OF INTEREST STATEMENT

None declared.

GENERATIVE AI IN SCIENTIFIC WRITING

None declared.

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