Original Article

Morphometric Assessment of the Mandible and Mandibular Foramen in the Pakistani Population

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Abstract

Objective: Mandibular size and foraminal anatomy vary from population to population because they provide passage to important anatomical structures that have great importance during clinical procedures. Through a comprehensive literature review, we found that no existing morphometric data are available for the Pakistani population. This cross-sectional analysis is performed on 86 dry adult mandibles (from Rawalpindi Medical University) to identify key mandibular dimensions and foraminal positions in a Pakistani sample.

Methods: Each mandible was measured twice with digital Vernier calipers (0.01 mm precision). Paired (left vs. right) parameters included mandibular body length, ramus height, and distances from the mandibular foramen to the anterior and posterior borders of the ramus. Unpaired parameters (bicondylar width and bigonial width) were measured across specimens. Morphological variants (e.g., accessory mental foramina) were also observed. Statistical comparison of sides used paired two-tailed t-tests or Wilcoxon signed-rank tests (significance set at $p<0.05$).

Results: Out of 100 mandibles examined, 86 were suitable for analysis. Significant side-to-side differences were found for mandibular body length, the distance from the anterior border to the mandibular foramen, and mandibular notch distance to angle ($p<0.05$). No accessory mental foramina were observed. Unpaired measurements such as bicondylar width (114.53 ± 5.44 mm), bigonial width (94.47 ± 6.93 mm), and symphysis menti height (28.57 ± 4.45 mm) were recorded.

Conclusion: The findings offer population-specific morphometric data on the mandible and foramina in Pakistan and may serve as a reference for anatomical and clinical research.

Keywords: Mandible; Mandibular Canal; Population; Anatomy, Cross-Sectional; Pakistan.

Contributions:
MH, AM, DZ, DF, MS, AR - Conception, Design
MH, AM, DZ, DF, MS, AR - Acquisition, Analysis, Interpretation
MH, AM, DZ, DF, MS, AR - Drafting
MH, AM, DZ, DF, MS, AR - Critical Review

All authors approved the final version to be published & agreed to be accountable for all aspects of the work.

Conflicts of Interest: None
Financial Support: None to report
Potential Competing Interests: None to report

Institutional Review Board Approval
263/IREF/RMU/2025
08-07-2025
Rawalpindi Medical University

Review began 08/05/2025
Review ended 27/12/2025
Published 30/12/2025
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How to cite this article: Hina M, Maryam A, Zahra D, Dua Fatima, Sardar M, Rasheed A. Morphometric Assessment of the Mandible and Mandibular Foramen in the Pakistani Population. JRMC. 2025 Dec. 31;29(4).

https://doi.org/10.37939/jrmc.v29i4.2988

Introduction

Bony landmarks are essential for identifying different anatomical structures during surgical procedures. A thorough understanding of these landmarks helps minimize the risk of neurovascular bundle injury.[1]. Among these, the cutaneous facial foramina— the mental foramen, which is an important landmark of the mandible—hold significant importance in anesthesia and surgery because they transmit the mental nerve and artery. The mental nerve plays a crucial role in nerve blocks during anesthesia. The position of this important bony landmark is determined by palpation of the symphysis menti, the inferior border of the ramus, the canine-premolar line, and the mandibular premolars. However, due to ethnic variations, the position of the mental foramen may differ, increasing the risk of nerve injury and complications during anesthesia, dental implant placement, or reconstructive procedures.[2]

The morphology of the mandible is highly variable due to factors such as age, sex, and functional adaptations. These variations can influence tooth eruption, masticatory forces, and overall mandibular function. Functional factors also play a significant role, as the mandible undergoes continuous remodeling and resorption throughout life.[3]. Bone remodeling is primarily influenced by the activity of muscles attached to craniofacial structures, such as the masseter, buccinator, temporalis, and pterygoid muscles. The loss of functional stimuli, such as reduced mastication, can lead to underdevelopment of the mandibular body, ramus, coronoid process, condylar process, alveolar process, and mental region due to inadequate remodeling. [4,5]

Additionally, studies have shown that mandibular variations can also be influenced by genetic and environmental factors.[6]. The growth of the mandible is particularly important in both dentistry and forensic science. In dentistry, understanding normal mandibular growth aids in the treatment of developmental disorders such as micrognathia and condylar hypoplasia. In forensic science, mandibular landmarks are widely used for age determination. [7]

A thorough understanding of mandibular morphology helps reduce the risk of alveolar root damage and bone injuries.[8]. Mandibular growth is mainly influenced by vertical skeletal factors and masticatory function. However, to our knowledge, no study has specifically examined these parameters in the Pakistani population. The existing literature on the three-dimensional shape and variation of the mandible is found to be incomplete. Our study determines the anatomical landmarks, overall dimensions, and morphological characteristics of the mandible in the Pakistani population. Additionally, anatomical variations in the mandibular foramen are also assessed. The clinical implications of the measured parameters are also discussed.

Materials And Methods

This cross-sectional observational study examined 100 dry mandibles obtained from skeletal remains in the Department of Anatomy, Rawalpindi Medical University. Based on the exclusion criteria, 14 mandibles were

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excluded, leaving 86 mandibles for analysis. Specimens were selected using convenience sampling, ensuring that only well-preserved, complete mandibles without congenital or acquired deformities were included. Fully ossified, intact mandibles with identifiable anatomical landmarks were included, while those with fractures, severe wear, pathological changes, or surgical interventions were excluded. Each parameter was measured twice by the same observer to minimize error, and the average value was recorded. Measurements were taken using a digital Vernier caliper with a precision of 0.01 mm. This study was approved by the Institutional Ethical Review Board of Rawalpindi Medical University (Ref. No. 263/IREF/RMU/2025; approval date: 08 July 2025)

Morphometric Parameters:

Morphometric parameters included both paired and unpaired measurements.

Unpaired parameters (Figure 2):

- Qq – Height of mandible at the symphysis menti: vertical height measured at the symphysis menti.
- Pp – Bigonial width: distance between the most lateral points on both gonial angles.
- Oo – Bicondylar width: distance between the highest points of both mandibular condyles.

Paired parameters (Figure 3):

- AO – Mandibular body length: distance from the mental protuberance to the angle of the mandible.
- PQ – Ramus height (head to base): vertical distance from the highest point of the mandibular condyle to the base of the mandible.
- MO – Coronoid ramus height: vertical distance from the tip of the coronoid process to the angle of the mandible.
- NO – Mandibular notch distance: distance from the deepest point of the mandibular notch to the angle of the mandible.
- RS – Width of the ramus: distance between the anterior and posterior borders of the ramus at its widest point.

In addition, the position of the mandibular foramen was recorded in relation to the base of the mandible, the mandibular notch, and the anterior and posterior borders of the ramus. All mandibles were also examined for the presence of accessory mandibular foramina.

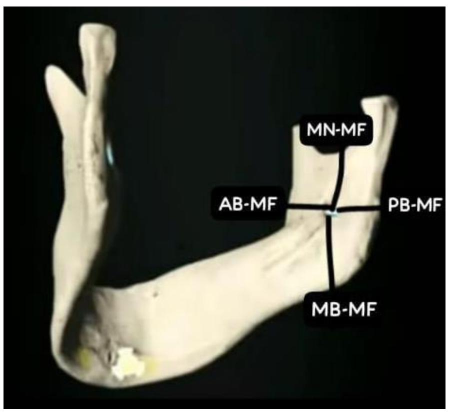

Figure1: Location of mandibular foramen (MN-MF: Mandibular notch to Mandibular foramen, MB-MF: Mandibular base to Mandibular foramen, AB-MF: Anterior border of ramus to Mandibular foramen, PB-MF: Posterior border of ramus to Mandibular foramen)

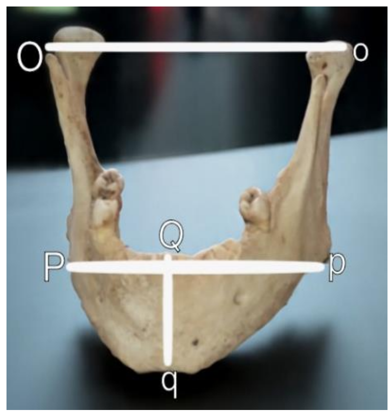

Figure 2: Unpaired morphometric measurements (Qq: height of mandible at symphysis menti, Pp: Bigonial width, Oo: Bicondylar width at head)

Figure 3: Paired morphometric measurements (RS: width of ramus, MO: coronoid ramus height from angle, NO: Mandibular notch distance from angle, PQ: Ramus height from head to base, AO: mandibular body length)

Data were initially assessed for normality of paired difference variables using the Shapiro–Wilk test. For parameters where the difference scores were normally distributed ($p > 0.05$), paired *t*-tests were conducted to compare the left and right sides. These parameters included body length, ramus height, mandibular foramen to notch, and base. Conversely, for parameters that did not conform to a normal distribution ($p < 0.05$), the nonparametric Wilcoxon signed-rank test was applied. This test was used for ramus height (head–base), notch to angle, ramus breadth, mandibular foramen distance from anterior, and posterior border of ramus. A significant level of $p < 0.05$ was employed throughout the analyses. Additionally, three linear measurements, bicondylar width at the head, bigonial width, and symphysis menti height, were summarized descriptively using mean ± standard deviation (SD) and range.

Results

Out of 100 dry mandibles, 14 were excluded because of damage, so 86 bones were assessed for paired and unpaired morphometric measurements. Table 1 shows there is no significant bilateral differences in the location of the mandibular foramen measured from the base of the mandible (right: 27.10 ± 3.26 mm; left: 27.34 ± 3.78 mm; P = .363) or from the mandibular notch (22.39 ± 4.52 mm vs. 21.95 ± 4.21 mm; P = .118) or the posterior border of the ramus (12.51 ± 2.34 mm vs. 12.84 ± 3.22 mm; P = .752). However, a Wilcoxon signed-rank test revealed a significant side-to-side difference in the distance from the anterior border of the ramus, with the left side being slightly greater (right: 16.68 ± 2.75 mm; left: 17.24 ± 2.60 mm; mean difference –0.56 ± 2.76 mm; P < .001).

Table 2 shows side-to-side comparisons of six paired mandibular dimensions (N = 86). A significant bilateral difference was found for maximum mandibular body length, which was slightly greater on the left (right: 85.88 ± 4.92 mm; left: 86.78 ± 4.81 mm; mean diff. –0.91 ± 3.60 mm; P = .022, paired t-test), and for mandibular notch distance to angle, which was also larger on the right (48.44 ± 4.72 mm vs. 47.49 ± 4.72 mm; median diff. .95 mm, P = .037, Wilcoxon signed-rank). No significant side-to-side differences were observed for ramus height from head to base

(65.57 ± 4.96 mm vs. 64.08 ± 4.32 mm; P = .102, Wilcoxon signed-rank), ramus height from coronoid to angle (62.16 ± 5.03 mm vs. 61.71 ± 5.25 mm; P = .096, paired t-test), or ramus breadth from anterior to posterior edge (32.41 ± 3.47 mm vs. 32.37 ± 4.69 mm; P = .517, Wilcoxon signed-rank). No accessory mandibular foramen was found.
Measurements of unpaired parameters include bicondylar width at the head 114.53 ± 5.44 mm (range: 103.19–129.00 mm), bigonial width 94.47 ± 6.93 mm (range: 81.38–109.48 mm), mandibular height at the symphysis menti was 28.57 ± 4.45 mm(range:19.61 to 37.60 mm. As these parameters were unpaired and no demographic or comparative grouping information (e.g., sex, side, age) was available, only descriptive statistics were applied.

Table 1: Location of Mandibular Foramen

Characteristics	Mean±SD (mm)		P value	Mean difference
	Right	Left		
Distance from the base of the mandible	27.10±3.26	27.34±3.78	.363	-.235±2.38
Distance from the mandibular notch	22.39±4.52	21.95±4.21	.118	.443±2.6
Distance from the posterior border of the ramus	12.51±2.34	12.84±3.22	.752	-.332±3.21
Distance from the anterior border of the ramus	16.68±2.75	17.24±2.6	<.001	-.559±2.76

Table 2 Mean ± SD, mean difference, and P- P-value of paired morphometric mandibular parameters.

N=86	Side	Mean	SD	Mean difference	P-value
Maximum mandibular body length	Right	85.88	±4.92	-0.91±3.6	.022
	Left	86.78	±4.81		
Ramus height from head to base	Right	65.57	±4.96	-1.48±3.98	.102
	Left	64.08	±4.32		
Ramus height from coronoid to angle	Right	62.16	±5.03	0.449±2.47	.096
	Left	61.71	±5.25		
Mandibular notch distance to angle	Right	48.44	±4.72	0.955±3.11	.037
	Left	47.49	±4.72		
Ramus breadth from the anterior to the posterior edge	Right	32.41	±3.47	0.037±4.27	.517
	Left	32.37	±4.69		

Discussion

This study was conducted on dry mandibles of the Pakistani population. The primary objective was to determine the anatomical location of the mandibular foramen in relation to various bony landmarks. This is clinically significant, as the mandibular foramen serves as the entry point for the inferior alveolar neurovascular bundle.[17], which plays a crucial role in dental procedures. Understanding its precise location is essential due to its variability based on race, gender, ethnicity, and individual anatomical differences. [18]For this study, demographic information such as the age and sex of the mandibular specimens under examination was unavailable. Since mandibular morphology is known to vary depending on age and sex, the ability to examine changes related to these factors is limited by the absence of such information.
The mean distance from the anterior border (AB-MF) was 16.68 ± 2.75 mm on the right and 17.24 ± 2.6 mm on the left side, with a statistically significant difference ($p < 0.001$). This finding aligns with previous studies by Singh et al. (2025) and Chaudhary et al. (2023), who reported similar values in North Indian populations, suggesting regional similarities in mandibular morphology across the subcontinent. The mean distance from the posterior border (PB-MF) in our study was 12.51 ± 2.34 mm on the right and 12.84 ± 3.22 mm on the left. These results are comparable with values reported by Tshite and Olaleye (2019) from South Africa and Chandimal et al. (2024) from Sri Lanka, indicating a relatively conserved posterior anatomical location of the MF across different populations.
Regarding the distance from the mandibular notch (MN-MF), our findings (22.39 ± 4.52 mm right, 21.95 ± 4.21 mm left) closely match those of Oguz and Bozkir (2002) in Turkey and Mbajiorgu (2000) in Zimbabwe. This parameter showed no statistically significant side difference ($p = 0.118$), suggesting symmetrical placement in the vertical plane, which may have clinical implications for regional anesthesia. The base of the mandible to the MF (MB-MF) was found to be 27.10 ± 3.26 mm on the right and 27.34 ± 3.78 mm on the left, again without significant side variation ($p = 0.363$). These values are among the highest reported across comparative studies, indicating a slightly lower placement of the MF in this population.
The maximum mandibular body length showed a statistically significant difference ($p = 0.022$), with the left side being slightly longer (86.78 ± 4.81 mm) than the right (85.88 ± 4.92 mm). When compared with the findings of Kumar et al.[19], who reported a mean mandibular body length of 75.31 ± 4.53 mm, our values are noticeably higher. This discrepancy may be attributed to ethnic, genetic, or nutritional differences, as well as potential variations in methodology. The ramus height from head to base in our study was 65.57 ± 4.96 mm on the right and 64.08 ± 4.32 mm on the left, showing no significant side difference ($p = 0.102$). These findings are slightly greater than those of Kumar et al., who reported 62.92 ± 5.3 mm on the right and 61.05 ± 5.72 mm on the left. Similarly, ramus height from coronoid to angle and mandibular notch distance to angle were assessed. The ramus breadth from the anterior to posterior edge was found to be comparable between sides without a statistically significant difference ($p > 0.05$). Our mean ramus breadth measurements are consistent with those reported by Sharma et al., who found a mean ramus breadth of 30.92 ± 2.55 mm in male subjects. Unpaired morphometric characteristics, bicondylar width at the head, had a mean of 114.53 ± 5.44 mm, an important metric in assessing facial width and prosthodontic planning. The bigonial width (94.47 ± 6.93 mm) represents lower facial breadth and is often sexually dimorphic.
Limitations:
This study has certain limitations that should be considered. A key limitation is the absence of demographic details, such as age and sex of the mandibles, which restricts subgroup analysis and reduces the generalizability of the findings. Another concern is that, although all measurements were performed twice by the same observer to minimize error, a formal statistical assessment of intra-observer reliability, such as the Intraclass

Correlation Coefficient, was not conducted. While the present data provide valuable anatomical reference values, further studies incorporating clinical and imaging-based approaches are necessary to confirm their practical relevance.

Conclusions

Overall, our findings are consistent with those from neighboring South Asian countries, with minor differences noted in comparison to African and European populations. These variations may be attributed to environmental, genetic, and ethnic factors influencing craniofacial growth and development. Although the present study was conducted on dry mandibles and did not directly evaluate clinical outcomes, the reference values generated here may indirectly assist oral surgeons, dentists, and anesthesiologists by providing anatomical benchmarks relevant to procedures such as mandibular nerve block. Further clinical research is warranted to validate the practical applications of these findings.

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