ORIGINAL ARTICLE

Investigating the Link Between Mandibular Arch Form and Intermental Foramina Measurements with Advanced CBCT Imaging

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Abstract

Background: The mandibular arch form and intermental foramina (IMF) dimensions are critical anatomical parameters influencing prosthetic stability, orthodontic outcomes, implant safety, and surgical planning.

Objectives: To investigate the association between mandibular arch form and intermental foramina measurements using CBCT imaging.

Materials and Methods: This cross-sectional analytical study was conducted at the Department of Prosthetics, Fatima Memorial Hospital, Lahore, from July 2024 to Jan 2025. A total of 200 patients who underwent CBCT scans were included in the study. Mandibular arch form was categorized as ovoid, square, or tapered. The interforaminal distance was measured bilaterally and analyzed according to arch type and gender.

Result: The mean age of participants was 34.7 ± 10.2 years, with 54% males and 46% females. Ovoid arch form was most common (46%), followed by square (30.5%) and tapered (23.5%). The overall mean IMF distance measured 26.9 ± 2.7 mm. Statistically significant differences were found among the three arch forms ($p < 0.001$), with square arches demonstrating the greatest IMF distance (28.4 ± 2.7 mm), ovoid arches showing intermediate values (26.8 ± 2.5 mm), and tapered arches presenting the narrowest spacing (25.1 ± 2.3 mm). Gender analysis revealed that males had significantly larger IMF distances than females (27.4 ± 2.8 mm vs 26.2 ± 2.5 mm; $p = 0.04$). Additionally, IMF distance increased progressively with age, ranging from 26.1 ± 2.4 mm in the 18–29-year group to 27.6 ± 2.9 mm in participants aged ≥50 years ($p = 0.03$).

Conclusion: Mandibular arch form significantly influences intermental foramina distance, with square arches associated with the widest spacing and tapered arches with the narrowest. Males demonstrated larger IMF distances compared to females. CBCT imaging provides precise evaluation of these anatomical relationships, enhancing surgical safety and individualized treatment planning in prosthodontics, orthodontics, and implantology.

Keywords: *Mandibular arch form, intermental foramina, cone-beam computed tomography, implantology*

Introduction

The human mandible exhibits a remarkable diversity in form and function, reflecting genetic, developmental, and environmental influences. Among its anatomical features, the mandibular arch form and the position of the mental foramina are of particular clinical and anthropological importance.[1] The mandibular arch form, broadly categorized as ovoid, square, or tapered, plays a central role in determining occlusal relationships, denture stability, and orthodontic treatment outcomes.[2]

On the other hand, the mental foramina, located on the anterolateral aspect of the mandible, are vital landmarks for surgical safety and effective anesthetic administration.[3] Their bilateral presence, through which the mental nerve and associated vessels exit, demands precise localization to avoid neurovascular complications during surgical and implant-related procedures.[4] Traditionally, radiographic methods such as panoramic radiography and periapical films have been used to assess mandibular anatomy. However, these two-dimensional imaging techniques are prone to distortion, magnification errors, and anatomical superimpositions, often limiting the accuracy of landmark identification.[5]

In recent years, cone-beam computed tomography (CBCT) has revolutionized maxillofacial imaging by providing high-resolution, three-dimensional views of bony structures with relatively low radiation doses compared to conventional CT. [6] CBCT enables clinicians to visualize subtle variations in bone morphology, measure intermental foramina distances with precision, and correlate these findings with different mandibular arch forms. The clinical significance of investigating the link between mandibular arch form and intermental foramina dimensions lies in its broad applicability across dental and surgical disciplines. [7] In prosthodontics, arch form directly impacts denture base extension, occlusal balance, and long-term stability. [8] An arch form that does not harmonize with prosthetic design may predispose patients to instability, resorption, or discomfort. [9]

In orthodontics, mandibular arch shape influences crowding, arch expansion strategies, and long-term retention outcomes. Furthermore, in implantology and oral surgery, knowledge of the mental foramina's spatial relationships is indispensable. Misjudging their location can result in iatrogenic injury to the mental nerve, leading to paresthesia, dysesthesia, or long-term sensory deficits.[10] By correlating foramina positions with arch morphology, clinicians may be better equipped to predict and avoid high-risk zones during surgical interventions.[11]

Beyond clinical dentistry, the relationship between mandibular arch form and intermental foramina has anthropological and forensic implications. Variations in arch form and foramina positions have been associated with population-specific traits, gender dimorphism, and even age-related changes. These parameters can therefore contribute to personal identification in forensic investigations and help in the study of population diversity.[12]

For instance, differences in mandibular morphology between ethnic groups highlight the importance of region-specific anatomical data, rather than relying solely on generalized reference charts.[13] Despite the known importance of mandibular arch form and mental foramina location, literature integrating these two variables remains

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sparse. Most studies to date have examined arch form in isolation for prosthetic or orthodontic relevance, while others have focused primarily on the variability of foramina positions in relation to dentition or alveolar crest height. [14]

However, the potential association between mandibular arch form and intermental foramina spacing has not been systematically explored using CBCT. Such an investigation may reveal predictive patterns, enhancing both diagnostic and treatment planning strategies.[15] Advanced CBCT imaging offers an unprecedented opportunity to bridge this gap by allowing simultaneous assessment of arch morphology and foramina positions in a single dataset.[16] Its multiplanar reconstructions and volumetric analysis can eliminate guesswork, providing reproducible measurements. Moreover, CBCT imaging facilitates the collection of normative data, which can guide the establishment of population-specific reference standards for clinicians working in diverse demographic settings.[17] To investigate the association between mandibular arch form and intermental foramina measurements using CBCT imaging.

Material and Methods

This cross-sectional analytical study was conducted at the Department of Prosthetics, Fatima Memorial Hospital, Lahore, from July 2024 to January 2025 and ethical approval was obtained from Fatima Memorial Hospital under ethical number **FMH-21/07/2025-IRB-1689.** A total of 200 patients who underwent CBCT scans were included in the study. The sample size was calculated using the formula for comparing mean differences among three groups, assuming a minimum detectable difference of 1.5 mm in IMF distance, a standard deviation of 3.0 mm, 95% confidence level, and 80% power.[18] The required sample size was approximately 189, which was rounded up to 200 participants to ensure adequate statistical validity. Non-probability consecutive sampling was employed to recruit participants who met the inclusion and exclusion criteria.

Patients aged 18 years and above with fully erupted permanent mandibular dentition from premolar to molar region, undergoing CBCT scans for diagnostic or treatment planning purposes were included in the study. Patients with missing teeth in the mandibular anterior region, with mandibular fractures, pathology, or developmental anomalies and with a history of orthodontic treatment or surgical interventions altering mandibular arch form and poor quality CBCT scans with motion artifacts or incomplete visualization of the mental foramina were excluded from the study.

All participants underwent CBCT imaging using a standardized protocol. The scans were acquired with patients seated upright, maintaining maximum intercuspation, and ensuring head stabilization to minimize motion artifacts. CBCT images were reconstructed in sagittal, coronal, and axial planes using proprietary imaging software. Mandibular arch form was determined by plotting the dental arch curve across the lower anterior teeth, classifying arch shapes as ovoid, square, or tapered according to established criteria. Intermental foramina measurements were obtained by identifying the mental foramina bilaterally and measuring the linear distance between them. Additionally, the vertical position of the foramina relative to the alveolar crest and inferior mandibular border was recorded to validate measurements.

All data were entered into SPSS version 26.0. Quantitative variables such as interforaminal distance were expressed as mean ± standard deviation, while categorical variables such as arch form were presented as frequencies and percentages. The association between mandibular arch form and intermental foramina measurements was assessed using one-way ANOVA and post-hoc tests for multiple comparisons. A p-value of <0.05 was considered statistically significant.

Results

Data were collected from 200 patients. The mean age of participants was 34.7 ± 10.2 years, with males slightly older (35.9 ± 10.4 years) than females (33.2 ± 9.8 years), though this difference was not statistically significant (p = 0.12). The sample included 108 males (54.0%) and 92 females (46.0%). With respect to arch form, ovoid was the most common (46.0%), followed by square (30.5%) and tapered (23.5%). The distribution of arch forms was nearly identical across genders, with no significant differences (p > 0.05 for all). The overall mean intermental foramina (IMF) distance was 26.9 ± 2.7 mm, with males demonstrating larger distances (27.4 ± 2.8 mm) compared to females (26.2 ± 2.5 mm), and this difference was statistically significant (p = 0.04) as shown in table 1.

Table 1. Demographic and Baseline Characteristics of Patients (N = 200)

Variable	Total (N = 200)	Male (n = 108)	Female (n = 92)	p-value
Age, years (mean ± SD)	34.7 ± 10.2	35.9 ± 10.4	33.2 ± 9.8	0.12
Gender, n (%)	200	108 (54.0)	92 (46.0)	–
Arch form, n (%)				
• Ovoid	92 (46.0)	50 (46.3)	42 (45.7)	0.94
• Square	61 (30.5)	34 (31.5)	27 (29.3)	0.73
• Tapered	47 (23.5)	24 (22.2)	23 (25.0)	0.65
Intermental foramina distance, mm (mean ± SD)	26.9 ± 2.7	27.4 ± 2.8	26.2 ± 2.5	0.04
Arch Form				
Ovoid	92 (46.0)	50 (46.3)	42 (45.7)	0.94
Square	61 (30.5)	34 (31.5)	27 (29.3)	0.73
Tapered	47 (23.5)	24 (22.2)	23 (25.0)	0.65

The mean IMF distance varied significantly with arch type. Square arches had the widest mean distance at 28.4 ± 2.7 mm (range 23.5–34.0 mm). Ovoid arches showed an intermediate distance of 26.8 ± 2.5 mm (range 22.0–32.1 mm), while tapered arches had the narrowest spacing at 25.1 ± 2.3 mm (range 20.8–30.4 mm). The overall IMF distance across all arch forms was 26.9 ± 2.7 mm (Table 2).

Table 2. Intermental Foramina (IMF) Measurements by Arch Form

Arch Form	Mean IMF Distance (mm ± SD)	Minimum (mm)	Maximum (mm)
Ovoid	26.8 ± 2.5	22.0	32.1
Square	28.4 ± 2.7	23.5	34.0
Tapered	25.1 ± 2.3	20.8	30.4
Overall	26.9 ± 2.7	20.8	34.0

ANOVA testing confirmed that the differences in IMF distances among the three arch forms were statistically significant (p < 0.001), with square arches showing greater distances compared to ovoid and tapered forms. Gender-based analysis demonstrated that males (27.4 ± 2.8 mm) had significantly larger IMF distances compared to females (26.2 ± 2.5 mm), with a p-value of 0.04.

When analyzed by age group, IMF distance showed a trend of gradual increase with advancing age. Patients aged 18–

Table 3. Comparison of Intermental Foramina Distance by Arch Form (ANOVA Test) *One-way ANOVA

Variable	Mean ± SD	p-value
Ovoid vs Square vs Tapered	26.8 ± 2.5 vs 28.4 ± 2.7 vs 25.1 ± 2.3	<0.001
Gender		
Male (n = 108)	27.4 ± 2.8	0.04
Female (n = 92)	26.2 ± 2.5	

Table 4. Intermental Foramina Distance Across Age Groups (N = 200)

Age Group (years)	n (%)	Mean IMF Distance (mm ± SD)	p-value*
18–29	62 (31.0)	26.1 ± 2.4	
30–39	58 (29.0)	26.8 ± 2.5	
40–49	46 (23.0)	27.4 ± 2.6	
≥50	34 (17.0)	27.6 ± 2.9	0.03

29 years had a mean IMF distance of 26.1 ± 2.4 mm, which progressively increased to 26.8 ± 2.5 mm in the 30–39 group, 27.4 ± 2.6 mm in the 40–49 group, and 27.6 ± 2.9 mm in those aged ≥50 years. This increasing trend was statistically significant (p = 0.03), indicating that IMF distance tends to widen slightly with age.

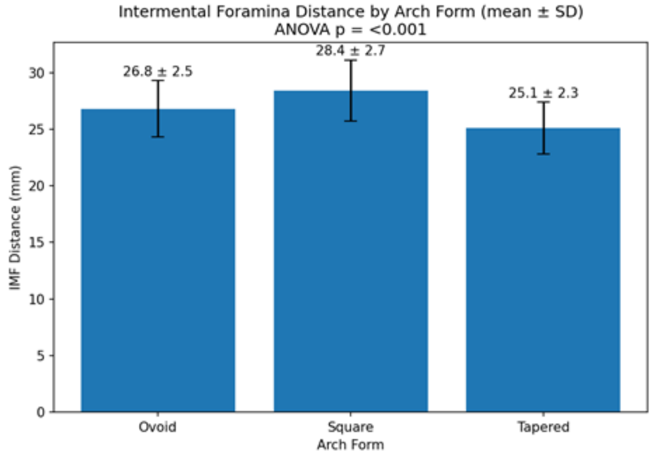

Figure 1. Intermental foramina distance by arch form

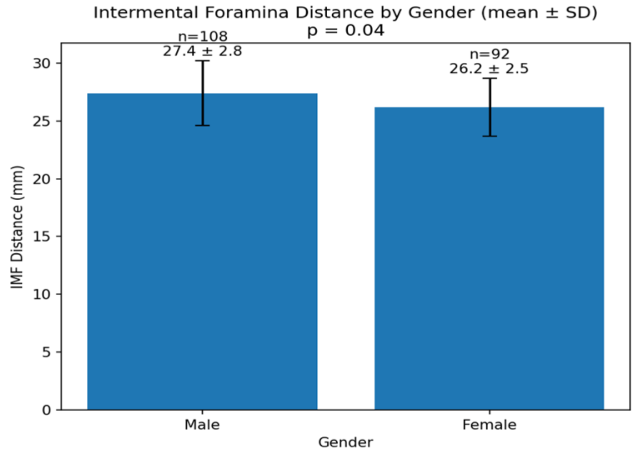

Figure 2 . Intermental foramina distance by gender

Discussion

The present study investigated the relationship between mandibular arch form and intermental foramina (IMF) measurements using advanced CBCT imaging in 200 patients. The findings revealed that ovoid arch form was the most prevalent, followed by square and tapered forms, which aligns with patterns commonly reported in previous research.

This predominance of the ovoid type is clinically significant, as it represents a balanced morphology often associated with prosthetic stability and orthodontic adaptability. One of the most notable findings was the significant variation in IMF distance across different arch forms. Patients with square arches demonstrated the greatest interforaminal width, while those with tapered arches exhibited the smallest measurements. These results suggest that mandibular morphology exerts a measurable influence on foraminal positioning.

Previous research has similarly demonstrated that skeletal form and dental arch configuration correlate with baseline mandibular dimensions, supporting the notion that wider arches tend to exhibit increased IMF spacing. Clinically, this implies that patients with square arches may present with safer zones for implant placement in the anterior mandible, whereas those with tapered arches may require greater caution due to narrower available bone. [19]

Gender-based analysis further showed that males had significantly greater IMF distances than females. This difference is consistent with prior anatomical studies reporting dimorphism in mandibular morphology, where males tend to have larger bone dimensions. Such findings emphasize the importance of accounting for patient-specific variables, including sex and arch form, during diagnostic and surgical planning. The role of CBCT imaging in this study proved invaluable.[20] Conventional radiography often suffers from distortion and anatomical superimposition, limiting the accuracy of IMF localization. In contrast, CBCT allowed precise three-dimensional visualization of foraminal anatomy and arch form in the same dataset, thereby improving measurement reliability.[21] Previous research has highlighted the superiority of CBCT in identifying foraminal variations, accessory foramina, and nerve pathways, underscoring its value in surgical safety and treatment predictability.[22]

The results of this study also have implications beyond dentistry. In forensic sciences, arch form and IMF measurements may contribute to population-specific databases useful for personal identification. Variations in arch form and foramina distances between populations highlight the need for regionally tailored anatomical reference data rather than relying solely on generalized standards.[23-24] Furthermore, the demonstrated association between arch form and foraminal distance underscores the interplay between functional morphology and neurovascular anatomy. Despite these contributions, this study has some limitations. The sample was restricted to patients undergoing CBCT for diagnostic purposes, which may introduce selection bias. Additionally, the study did not account for factors such as age-related bone remodeling or ethnic variations, both of which could influence mandibular morphology. Future research should incorporate larger, multi-center datasets, stratified analyses by age and ethnicity, and possibly longitudinal follow-up to assess how IMF distances may change over time with bone resorption or orthodontic interventions.

Conclusion

It is concluded that mandibular arch form has a significant influence on intermental foramina (IMF) measurements when assessed with advanced CBCT imaging. This study demonstrates that mandibular arch form significantly influences intermental foramina (IMF) distance, with square arches exhibiting the greatest width and tapered arches the narrowest. IMF distance also varied with gender and age, being larger in males and showing a gradual increase across older age groups. These findings highlight the importance of individualized assessment of mandibular morphology when planning prosthodontic, orthodontic, and implant procedures. CBCT imaging proved essential for accurately identifying these anatomical variations, supporting safer and more precise clinical decision-making.

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Author Contributions

1. **Muhammad Saboor Anees**: Conceptualization of the study, CBCT image analysis, and manuscript drafting.
2. **Zahid Iqbal**: Study supervision, clinical guidance, and critical review of the manuscript.
3. **Sohaib Nawaz**: Data analysis, measurements interpretation, and results compilation.
4. **Shehla Batool**: Literature review and assistance in manuscript preparation.
5. **Khadija Shahid**: Data collection, CBCT imaging support, and technical assistance.
6. **Maria Rafique** : Statistical analysis and final approval of the version to be published.