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Root Canal Configuration Using Cone Beam Computed Tomography in Mandibular Incisors of Pakistani Individuals

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ABSTRACT

A thorough understanding of root canal morphology is crucial for successful endodontic therapy. Variations in root canal anatomy, including differences in configuration and disposition, can significantly affect treatment outcomes, emphasizing the importance of population-specific investigations. **Objectives:** To assess and identify anatomical variations in the root canal morphology of mandibular incisors among Pakistani individuals using cone beam computed tomography imaging. **Methods:** In this retrospective cross-sectional study, 440 cone beam computed tomography scans of mandibular incisors from 115 patients were analyzed. Data on patient demographics (age and gender), tooth characteristics (central or lateral incisors), root count, and root canal morphology were recorded. Statistical analysis using Chi-squared and Kruskal-Wallis tests was performed to explore associations between demographic variables and root canal configurations. **Results:** Out of 115 patients, 110 cone beam computed tomography scans were included, while five were excluded due to missing teeth. The mean age of participants was 36.49 years, with a gender distribution of 43.6% female and 56.4% male. Type I and Type III configurations were the most prevalent. Statistically significant gender differences were found in lateral incisors ($p<0.01$), with male more frequently exhibiting Type III configurations in central incisors, while female displayed Type I configurations in lateral incisors. No significant age-related differences were observed. **Conclusions:** It was concluded that mandibular incisors in Pakistani individuals exhibit notable anatomical variations, primarily Type I and Type III configurations. These findings underscore the importance of using advanced imaging tools like bone beam computed tomography for population-specific studies, enabling more tailored and effective endodontic treatments.

INTRODUCTION

The root canal is the space within the root of a tooth that houses the pulp and extends from the pulp chamber to the root apex. Root canal systems are integral to maintaining tooth vitality, and their complexity requires a detailed understanding of effective endodontic treatment. Endodontic therapy can present a challenge for dental practitioners if the structure of the root canal is not fully comprehended. The root canal morphology is complex, as it varies among teeth, and the shape alters from simple, straight to complex, and tortuous canals. Additionally, discrepancies in the location, shape, and number of accessory canals and apical foramina add to this complexity, necessitating a thorough understanding of each tooth's unique anatomy to ensure successful treatment outcomes [1]. Maxillary incisors, which are typically single-rooted with one canal, are among the most commonly treated teeth in endodontics. However, their morphology often deviates from the typical structure,

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making treatment more complex. Mandibular incisors, while typically exhibiting a single root canal, demonstrate a higher frequency of anatomical variations when compared to their maxillary counterparts [2]. Mandibular incisors typically exhibit a straighter and shorter root canal morphology, with an average length of around 15-17 mm. However, studies indicate that approximately 40% of mandibular incisors and 25% of maxillary incisors exhibit alterations in their root canal anatomy [3]. These variations include additional canals, lateral canals, and apical deltas, which significantly complicate treatment [1, 4]. This highlights the inherent complexity of root canal systems, which can vary not only in shape but also in the number and location of accessory canals. Understanding these morphological variations is crucial, as it can directly impact the debridement process and the overall success of endodontic treatment. Research conducted on populations such as those in Saudi Arabia has further emphasized unique morphological patterns in permanent maxillary and mandibular incisors, which can influence the outcomes of root canal therapy within specific demographic groups [5, 6]. Thus, knowledge of these anatomical differences is essential for tailoring treatment strategies to meet the unique needs of each population, ultimately optimizing patient care and treatment outcomes. To ascertain the anatomy of root canals, various methods have been employed. Most notable among them were cross-sections, clearing techniques and radiographic evaluations. Recently, Cone-beam computed tomography (CBCT) has appeared as a valuable noninvasive tool for visualizing the morphology of root canals in three dimensions [7]. CBCT provided an accurate and comprehensive understanding of root canal morphology by presenting precise imaging with reduced radiation exposure [8]. The advent of CBCT has significantly improved the field of endodontics, allowing clinicians to tailor their treatment strategies to the precise anatomical configuration of each tooth, thereby improving treatment outcomes and patient care [9]. The ability to visualize the full complexity of the root canal system enables endodontists to better plan and execute treatments, reducing the risk of complications and improving overall success rates. Despite the advancements in imaging technology and the growing body of literature on root canal morphology, there remains a gap in understanding the specific variations in certain populations [10]. Root canal treatment strategies must be tailored to address these population-specific variations to optimize patient outcomes.

This study aims to investigate the root canal anatomy of permanent mandibular incisors in Pakistani individuals using CBCT imaging. By analyzing canal morphology, variations, and configurations, this study will provide valuable insights into the specific anatomical characteristics of the local population. This knowledge will, in turn, allow for the development of more precise, population-specific endodontic treatment strategies, optimizing care and ensuring better outcomes for patients.

METHODS

A retrospective cross-sectional study was conducted from April 2024 to June 2024 to review CBCT images of mandibular incisors in patients presenting with orthodontic and maxillofacial concerns. Ethical approval was obtained from the Institutional Ethical Committee (Ref: UCD/ERCA/24/182), with patient consent obtained for the use of CBCT data, and all images were anonymized to ensure patient confidentiality. The sample size for this study was calculated using the formula for cross-sectional studies based on a finite population [11]. The expected prevalence of root canal variations in mandibular incisors was estimated at 30%, based on previous studies [12]. The sample size was calculated using the following formula: n=Z2.P(1-P)/E2. Where: n is the sample size, Z is the Z-score corresponding to a 95% confidence level (1.1), P is the expected prevalence of root canal variations (0.3) and E is the margin of error (0.05). Using this formula, the calculated sample size was 110, rounded up to 115 to account for potential dropouts or incomplete data. This sample size provides a confidence level of 95% with a margin of error of 5%, ensuring that the study has sufficient power to detect significant differences in root canal morphology. Images were obtained from patients aged 18-50 years, including both genders from four different dental hospitals, namely, University College of Dentistry Lahore, Pakistan Institute of Medical Sciences Islamabad, Multan Medical and Dental College, and Peshawar Dental Hospital. CBCT images were acquired using a Planmeca Pro Max 3D Max (Planmeca OY Asentajankatu 6, 00880 Helsinki, Finland) unit with a voxel size of 0.4mm, and a field of view of 5 x 5.5 cm or 10 x 9 cm for high-resolution imaging. CBCT images were analyzed using Planmeca Romexis software. The coronal, axial, and sagittal sections of each mandibular incisor were carefully examined to determine the root canal configuration according to the Vertucci classification system. To ensure consistent image analysis, a calibration session was conducted for the three trained assessors (two general dental practitioners and one endodontist) to familiarize them with the Vertucci classification system. Each assessor independently reviewed the images, and discrepancies between the assessors were resolved through consensus. Images with poor image quality, incomplete root formation, or evidence of previous endodontic treatment were excluded. The classification of root canal morphology was determined according to the Vertucci classification system, which categorizes root

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canals into eight distinct types based on their anatomical configuration [13]. Type I: Single canal with a single foramen, Type II: Two separate canals merging into a single foramen, Type III: One canal dividing and reuniting into a single foramen, Type IV: Two separate canals each having one foramina, Type V: One canal bifurcating into two separate foramina, Type VI: Two separate canals first merge and then split into two foramina, Type VII: One canal first divides then reunites and finally terminates in two foramina and Type VIII: Three separate canals with three foramina. Classification of the root canal system is shown (Figure 1).

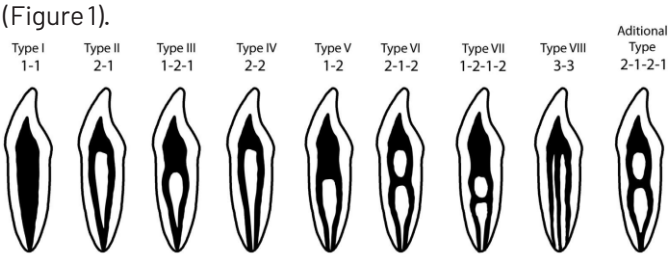

Figure 1: Classification of Root Canal Systems: Vertucci's 8 Types

Data were entered and analysed using SPSS version 29.0. Quantitative data were interpreted by Mean + SD and qualitative data were represented in the form of frequencies and percentages. The chi-square test was used to analyse the association between qualitative variables (gender, types of root configuration). The Kruskal-Wallis test was carried out to find the association between age and root configuration. $p<0.05$ was considered statistically significant, with two-tailed tests used for all analyses.

RESULTS

The study consisted of 115 CBCT images, procured from dental hospitals across Pakistan. Out of these, five cases were excluded owing to the absence of teeth, calcified canals, and external resorption. Therefore, 110 CBCT images were included in the analysis. The mean age of the sample population was 36.49 ± 14.04. Most of them were male 62 (56.4%) whereas females were 48 (43.6%). The predominant root anatomy of mandibular incisors was predicted. Among the samples, two left permanent central incisors, one left permanent lateral incisor, two right permanent central and one right permanent lateral incisor were missing (Table 1).

Table 1: Root Canal Configurations by Tooth Type

Root Configuration	Left Permanent Lateral Incisor n (%)	Left Permanent Central Incisor n (%)	Right Permanent Central Incisor n (%)	Right Permanent Lateral Incisor n (%)
Type I	67 (60.9%)	69 (62.7%)	71 (64.5%)	69 (62.7%)
Type II	2 (1.8%)	2 (1.8%)	1 (0.9%)	2 (1.8%)
Type III	33 (30%)	33 (30%)	32 (29.1%)	34 (30.9%)
Type IV	5 (4.5%)	-	-	-
Type V	1 (0.9%)	4 (3.6%)	3 (2.7%)	4 (3.6%)
Type VI	1 (0.9%)	-	-	-
Additional Type	-	-	1 (0.9%)	-

An additional root type was observed in the central incisor. As compared to female, more male was observed with type III canal configuration in left central (72.7% vs 27.3%) and right central incisors (71.9% vs 28.1%). On the contrary, when compared to male, more female patients had type I in the left lateral incisor (43.3% vs 56.7%) and right lateral incisor (44.9% vs 55.1%). The bivariate analysis revealed statistically significant associations between differences in root configurations between male and female for left lateral incisors (χ^2=16.19, $p<0.01$) and right lateral incisors (χ^2=12.41, $p<0.01$). However, no significant gender-based differences were observed in central incisors (Table 2).

Table 2: Gender-Wise Association of Root Configuration

Root Configuration	Left Lateral n (%)		Left Central n (%)		Right Central n (%)		Right Lateral n (%)	
	Male	Female	Male	Female	Male	Female	Male	Female
Type I	29 (46.8%)	38 (80.9%)	33 (55%)	36 (75%)	35 (58.3%)	36 (75%)	31 (50%)	38 (80.9%)
Type II	2 (3.2%)	0 (0%)	1 (1.7%)	1 (2.1%)	0 (0%)	1 (2.1%)	1 (1.6%)	1 (2.1%)
Type III	26 (41.9%)	7 (14.9%)	24 (40%)	9 (18.8%)	23 (38.3%)	9 (18.8%)	26 (41.9%)	8 (17%)
Type IV	4 (6.5%)	1 (2.1%)	-	-	-	-	-	-
Type V	1 (1.6%)	0 (0%)	2 (3.3%)	2 (4.2%)	2 (3.3%)	1 (2.1%)	4 (6.5%)	0 (0%)
Type VI	0 (0%)	1 (2.1%)	0 (0%)	0 (0%)	0 (0%)	1 (2.1%)	0 (0%)	0 (0%)
Additional type								
p-value	0.006*		0.128		0.124		0.006*	

Note: * denotes p-value is significant

Upon investigating the association between patient age and the different root configuration types, non-significant results were obtained (Table 3).

Table 3: Association of Age with Root Configuration among Different Types of Teeth

Type of Tooth	p-value
Right Central Incisor	0.26
Right Lateral Incisor	0.06
Left Central Incisor	0.08
Left Lateral Incisor	0.32

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Type I was the predominant canal configuration observed in both central and lateral incisors, followed by Type III (Figure 2).

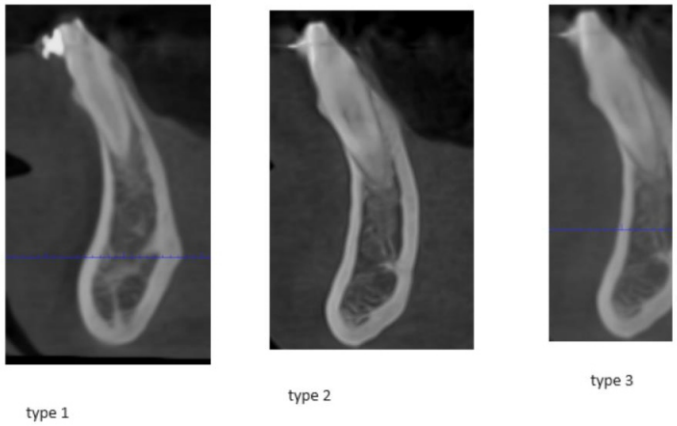

Figure 2: Root Canal Morphology Visible on CBCT

DISCUSSION

Traditionally, root morphology has been examined through invasive staining and clearing techniques. However, CBCT offers a revolutionary and non-invasive method for exploring and understanding root canal anatomy, providing a more comfortable and efficient experience for patients [14]. The integration of CBCT technology in this study permitted a precise and non-invasive examination of variation in root canal anatomy, which will help in tailoring effective treatments for better patient outcomes [15]. Previous studies have exhibited a significant range of anatomical variations, mandibular incisors exhibit complex root canal morphology, with diverse configurations, shapes, and sizes, posing challenges for endodontic treatment [16]. In this study, the Type I root canal was the predominant anatomical configuration in both central and lateral mandibular incisors, followed by Type III. These findings are comparable with with studies that have been conducted in three geographically diverse locations Saudi Arabia, China, and Turkey. Hence, it is a suggestion of a homogeneous pattern across different populations [17-19]. A rare anatomical variation in the current study was observed a noteworthy finding of the central incisor presenting with an additional root type. This finding is of great importance, as it spotlights the impact of comprehensive review and accurate diagnosis in root canal treatment. Similar findings were manifested by Alqahtani et al., reporting the incidence of additional root canals in central incisors and supporting our results [20]. From our study, it was observed that gender significantly influenced the occurrence of root canal configurations in mandibular incisors, with notable differences between males and females. Peculiarly, males displayed a greater percentage of Type III root canals in mandibular central incisors, while females showed a greater frequency of Type I canal morphology in mandibular lateral incisors. Interestingly, a recent study conducted on the Chinese population by Zhu et al., 2022 showed indistinguishable results, with males exhibiting a greater proportion of Type III root canal patterns in central incisors, mirroring our results [21]. However, this study did not depict a notable gender-based difference in lateral incisors, contrary to our results. Differences in sample size and demographics may explain the divergent findings between the two studies. Both studies highlighted the significance of believing gender is an important factor in understanding root canal morphology, which can lead to the perception of more diversities and tailoring more effective endodontic treatment strategies accordingly. Contrary to our apprehension, the difference in the root configuration of incisors between different gender groups was insignificant in the present study. Additionally, no significant relationship was observed between the patient's age and different types of root configurations. Nearly similar results were reported by Zhu et al., [21]. The present research emphasized that age may not play a significant role in shaping root canal anatomy. Similarly, a recent study analyzing the interrelation between age and root canal anatomy in mandibular incisors found no significant association between them. However, a greater frequency of alterations in root canal morphology in older individuals was observed which was not evident in our study. The observed dissimilarity between the two studies may be attributed to discrepancies in sample size and demographic characteristics. Despite these dissimilarities, both studies focused on the importance of considering individual alterations in root canal morphology, rather than only depending on age or gender as predictors, to ensure accurate diagnosis and treatment [20].

CONCLUSIONS

It was concluded that this research provided considerable insight into the pulp canal anatomy of mandibular incisors in a Pakistani population, exhibiting a greater prevalence of Type I and Type III root canal patterns. These inventions concentrated on improving the existing knowledge, highlighting the need for continued research for morphological variations and personalized treatment approaches to enhance patient care and improve treatment outcomes.

Authors Contribution

Conceptualization: SS
Methodology: AF, AA, IH, IR
Formal analysis: KT, AA, SS, IH
Writing review and editing: AF, SS, KT, AC

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All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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