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ORIGINAL ARTICLE

A CBCT-BASED STUDY ON THE OCCURRENCE AND ANATOMICAL VARIATIONS OF C-SHAPED CANALS IN LOWER SECOND MOLARS

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ABSTRACT

Objective: *This study aims to determine the prevalence and anatomical characteristics of C-shaped canal configurations in mandibular second molars using cone-beam computed tomography in a Pakistani population.*

Methodology: *This CBCT-based cross-sectional study was conducted using scans obtained from patients presenting to dental imaging center. Mandibular second molars were evaluated for the presence of C-shaped canal configurations. Morphological parameters were assessed, and data were analyzed descriptively.*

Results: *Out of the evaluated mandibular second molars, 58 teeth exhibited a C-shaped canal configuration, yielding a prevalence of 26.36%. Bilateral occurrence was observed in 89.7% of cases. Radiographically, all teeth demonstrated fused roots. The C3 configuration was the most prevalent canal pattern. The mean total tooth length was 17.93 ± 2.20 mm. Longitudinal grooves were present on both buccal and lingual surfaces in 29.3% of cases, with the mean lingual groove length exceeding the buccal groove length. A long root trunk was observed in 24.1% of teeth, with a mean trunk length of 2.9 ± 0.5 mm. The mean thinnest dentin thickness was 1.39 ± 0.54 mm, most frequently located on the buccal surface.*

Conclusion: *C-shaped canal configurations in mandibular second molars were relatively common in the studied population, with a high rate of bilateral occurrence and considerable anatomical complexity. CBCT proved to be a valuable tool for detailed assessment of canal morphology, emphasizing the importance of careful preoperative evaluation to minimize procedural complications during endodontic treatment.*

Keywords: *C-shaped canals; Mandibular second molars; Cone-beam computed tomography; Root trunk; Dentin thickness*

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INTRODUCTION

Successful endodontic treatment depends largely on a thorough understanding of root canal morphology and its variations[1]. Complex anatomical configurations can compromise adequate cleaning, shaping, and disinfection of the root canal system, leading to missed canals[2], persistent infection, and eventual treatment failure. Mandibular second molars are known to exhibit a wide range of anatomical variations, among which the C-shaped canal system represents one of the most challenging configurations for endodontic management[3].

The C-shaped canal system is characterized by a continuous or semilunar canal morphology in cross-section, often accompanied by fins, webs, and longitudinal grooves[4]. This configuration is believed to result from failure of fusion of Hertwig's epithelial root sheath during root development, frequently associated with root fusion and external grooves[5]. Such anatomical

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features create areas of thin dentin, increasing the risk of procedural errors such as strip perforation and excessive dentin removal during instrumentation[6].

C-shaped canals are reported most commonly in mandibular second molars, with a higher prevalence in Asian populations. Previous studies have reported prevalence rates ranging from 2.7% to 40%[7], indicating significant ethnic[8] and geographical variation. These variations highlight the importance of population-specific studies to improve diagnostic accuracy and clinical outcomes.

Conventional two-dimensional radiographs have limitations in detecting complex root canal anatomy due to superimposition and distortion. Cone-beam computed tomography (CBCT) provides three-dimensional visualization of teeth and surrounding structures, allowing accurate assessment of canal morphology, dentin thickness, root fusion, and groove patterns. CBCT has therefore become a valuable tool for evaluating complex canal systems such as C-shaped canals[9].

Despite the clinical significance of C-shaped canals, limited data are available on their prevalence and detailed morphological characteristics in the Pakistani population, particularly regarding dentin thickness, groove patterns, and canal configuration[10]. Therefore, the present CBCT-based study was conducted to evaluate the prevalence and anatomical variations of C-shaped canal systems in mandibular second molars, with the aim of providing clinically relevant information that may aid in improved diagnosis and safer endodontic treatment planning.

METHODOLOGY

This cross-sectional study was conducted in the Department of Operative Dentistry at Foundation University College of Dentistry & Hospital (FUCD&H) after obtaining ethical approval from the Ethical Review Committee. The study was carried out over a period of three months from 10 August to 10 November in the year 2025.

Sample size was calculated using OpenEpi software. Based on a previously reported prevalence of C-shaped canals of 15.54% in a Pakistani population, with a confidence level of 95% and power of 80%, a minimum sample size of 201 CBCT scans was required. To account for possible exclusions and suboptimal image quality, a total of 220 CBCT scans were evaluated.

Inclusion criteria were CBCT scans of patients aged 18 years and above with fully developed bilateral mandibular second molars and adequate image quality for diagnostic evaluation.

Patients with previous endodontic treatment, incomplete root development, root caries, fractures, resorptive defects, posts, extensive restorations, absence of bilateral mandibular second molars, or poor-quality CBCT images were excluded.

CBCT scans were analyzed using Planmeca Romexis 3D software on a 30-inch monitor (1280 × 1024 resolution) in a dark room. A voxel size of 200 µm was used, and 1-mm thick cross-sections were evaluated. Axial CBCT sections were evaluated at three levels: coronal (2 mm below the pulpal floor), middle (mid-root level), and apical (2 mm above the apex).

The presence of C-shaped canal configuration was recorded and classified according to Fan et al. classification (C1–C5) at each level, as shown in Figure 1.

The trunk length was measured as the distance from the cemento-enamel junction (CEJ) to the floor of the pulp chamber in a sagittal section. The thinnest dentin thickness was measured on the axial section at the point of minimum dentin width, as shown in Figure 2.

Figure 1: Axial CBCT sections showing Fan's classification of C-shaped canal configurations

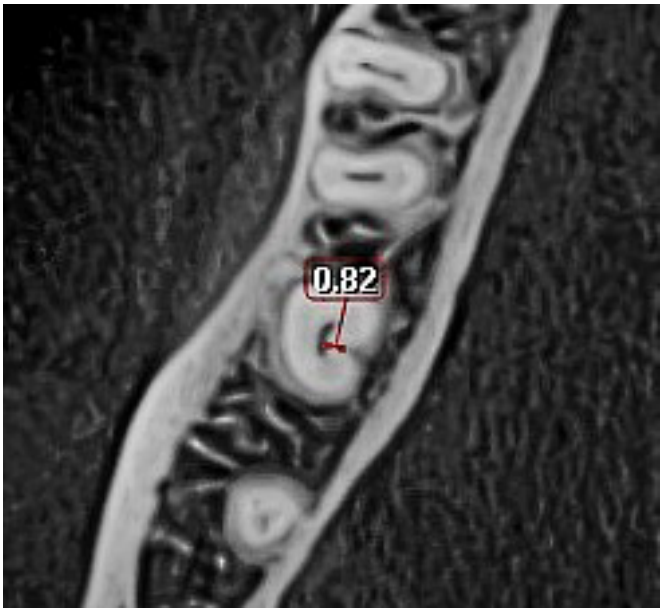

Figure 2: Measurement of thinnest dentin thickness on CBCT

Data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to calculate frequencies, percentages, means, and standard deviations. Gender distribution and laterality (right vs left side) of the C-shaped canal configuration were assessed descriptively. Interobserver reliability was evaluated using Cohen's kappa test. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 58 mandibular second molars with C-shaped canal configuration were included in the study, yielding a prevalence of 26.36%. All scans were of diagnostic quality, and no missing data were observed for dentin thickness, trunk length, or tooth length. The data is tabulated in Table 1.The mean total tooth length was 17.93 ± 2.20 mm. Grooves were present on both the buccal and lingual surfaces in 29.3% of cases. Isolated lingual grooves were observed in 25.9%, while buccal grooves alone were noted in 20.7%. The mean buccal groove length was 1.84 ± 0.83 mm, while the mean lingual groove length was 2.15 ± 0.76 mm. A total of 24.1% presented with long root trunk, average root trunk was 2.9±0.5 mm.

The mean thinnest dentin thickness was 1.39 ± 0.54 mm. The thinnest dentin was most frequently located on the buccal surface, 62.1%, followed by the lingual surface, 37.9%. Bilateral occurrence of C-shaped canal configuration was 89.7%, 10.3% showed unilateral involvement, as presented in Table 2. Radiographic evaluation revealed fused roots in all teeth, and a long trunk was observed in 24.1% teeth, as shown in Figure 3. According to the canal configuration classification, C3 was the most common pattern, as shown in Figure 4.

DISCUSSION

A thorough understanding of root canal morphology is essential for successful endodontic treatment, particularly in teeth with complex anatomical variations such as C-shaped canal systems. The present CBCT-based study evaluated the prevalence and morphological characteristics of C-shaped canals in mandibular second molars in a Pakistani population.

In the current study, a prevalence of 26.36% of C-shaped canals was observed in mandibular second molars. This finding is within the higher range of reported prevalence in Asian populations and supports previous literature indicating ethnic variation in canal morphology[11]. Prevalence values have been reported in CBCT-based studies conducted in Chinese and Middle Eastern populations, suggesting that C-shaped canals are relatively common in this region[12].

TABLE 1: MORPHOMETRIC CHARACTERISTICS OF C-SHAPED MANDIBULAR SECOND MOLARS

	Trunk Length	Thinnest Dentin	Tooth Length	Buccal Groove Length	Lingual Groove Length
Mean±SD(mm)	2.9±0.5	1.39±0.5	17.93±2.20	1.84±0.83	2.15±0.76
Range (mm)	1.6-4.1	0.78-3.21	14.2-23.6	0.50-3.90	0.82-3.67

TABLE 2: BILATERAL AND UNILATERAL OCCURRENCE OF C-SHAPED CANALS

	Bilateral C-shaped Canals	Unilateral C-shaped Canals
Percentage	89.7%	10.3%

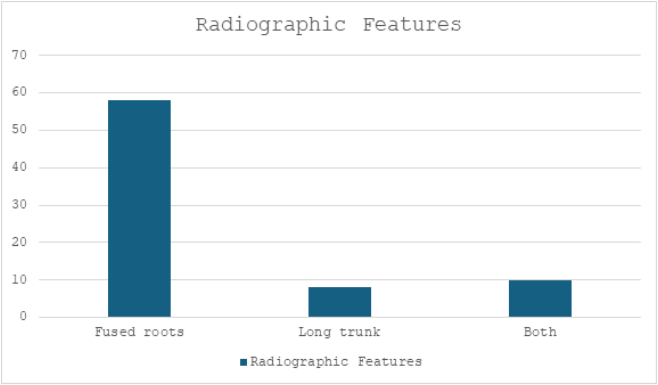

Figure 3: Distribution of radiographic features associated with C-shaped mandibular second molars

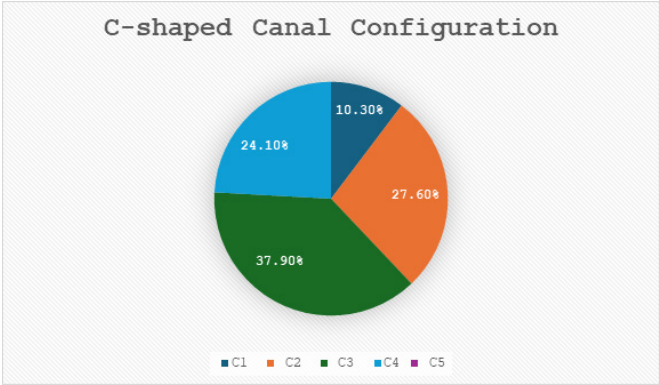

Figure 4: Distribution of C-chaped canal configurations according to Fan's classification

Bilateral occurrence was noted in 89.7% of cases, indicating a strong tendency for symmetry in C-shaped canal systems. This observation is consistent with previous studies that have reported a high incidence of bilateral presentation, emphasizing the importance of careful evaluation of the contralateral tooth when a C-shaped canal is identified clinically[13].

Regarding canal configuration, C3 was the most prevalent pattern, 38%, followed by C2, C4, and C1. These findings align with those of Fan et al. who reported that discontinuous canal configurations (C2 and C3) were more commonly encountered at different root levels due to canal separation along the root length. The predominance of the C3 configuration highlights the complexity of canal morphology and the potential challenges faced during cleaning and shaping procedures. No C5 configuration was observed in this study.

The mean thinnest dentin thickness observed in this study was 1.39 ± 0.54 mm, with the thinnest dentin most frequently located on the buccal surface (62.1%). This finding has important clinical implications, as excessive dentin removal during instrumentation or post-space preparation may increase the risk of strip perforation, particularly in the buccal aspect of mandibular second molars with C-shaped anatomy. Similar observations regarding dentin thinning and groove-related vulnerability have been reported in previous CBCT studies[14]. Conversely, other investigations have reported the lingual surface as the area of minimum dentin thickness, suggesting that dentin distribution may vary with root level and measurement methodology[15].

Longitudinal grooves were identified in a considerable proportion of teeth, with both buccal and lingual grooves present in 29.3% of cases. The presence of grooves, especially on the lingual surface, has been associated with root fusion and increased anatomical complexity. In the present study, the mean lingual groove length exceeded the buccal groove length, a finding consistent with earlier studies reporting deeper, more pronounced lingual grooves in C-shaped mandibular molars[16]. However, contradictory findings in the literature have described a predominance of buccal grooves, highlighting anatomical variability among different populations[17].

Radiographically, fused roots were the most common finding, supporting the widely accepted concept that root fusion is a key feature associated with C-shaped canal systems[18]. The presence of a large pulp chamber in the remaining cases further reflects developmental variations contributing to this morphology.

The use of CBCT imaging allowed for three-dimensional assessment of canal anatomy, overcoming the limitations of conventional two-dimensional radiography. CBCT has been shown to be a reliable and non-destructive tool for identifying complex canal systems, making it particularly useful in the evaluation of C-shaped canals[19,20].

This study has certain limitations. Given the retrospective, single-center design, the findings may not be generalizable to the entire population. One limitation of the present study is the absence of demographic data, as the CBCT scans were obtained in anonymized form from the imaging center. Therefore, age- and gender-based analysis of C-shaped canal prevalence could not be performed. Additionally, although CBCT provides high diagnostic accuracy, it does not offer the resolution of micro-CT. Future multicenter studies with larger sample sizes and correlation with clinical outcomes are recommended.

CONCLUSION

Within the limitations of this CBCT-based study, C-shaped canals were relatively prevalent in mandibular second molars, with frequent bilateral occurrence. The C3 configuration was the most common, and the buccal aspect most often exhibited the thinnest dentin, representing a potential danger zone during instrumentation. Associated features such as root fusion and longitudinal grooves underscore the anatomical complexity of these canals. CBCT-based assessment may aid in accurate diagnosis, treatment planning, and prevention of procedural complications.

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