Original Article

Mandibular second molars' C-shaped canal frequency in the Pakistani subpopulation: A retrospective cone-beam computed tomography clinical study

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Abstract

Introduction: The adequate knowledge of the canal configuration can improve the quality and prognosis of endodontic treatment. The aim of the study was to determine the frequency of C-shaped root canal in the mandibular permanent second molars among a Pakistani subpopulation sample by utilizing cone-beam computed tomography images.

Materials and Methods: Cone-beam computed tomographic images of 360 patients with 720 mandibular second molars were analyzed for the presence of C-shaped canal configuration. The root canal system was classified according to Fan's classification at three distinct levels. Unilateral or bilateral presence of C-shaped root canals and the location of the longitudinal groove were assessed. Moreover, the correlation of frequency of C-shaped canal with the gender was measured using the Chi-square test. The data were analyzed using SPSS version 23.

Results: Of 720 mandibular second molars of 360 patients, 10% of teeth were found to have C-shaped canals in 48 patients. The most commonly noted C-shaped canal configurations in the coronal and middle third were C1 (41.7%) and C3 (37.5%), respectively, whereas C2 (33.3%) and C4 (33.3%) configurations were commonly found in the apical third. Twenty-four of 48 patients had bilateral C-shaped root canals. Overall, 37.5% of the teeth were right-sided teeth and 62.5% were left-sided teeth. The frequency of C-shaped canals was significantly higher in females as compared to males, 15.6% and 4.2%, respectively ($P = 0.03$). The longitudinal groove was most commonly located on the lingual surface (66.7%).

Conclusions: The frequency of C-shaped canal configuration in the Pakistani subpopulation was 10% in the mandibular second molar teeth.

Keywords: Cone-beam computed tomography, C-shaped canal, mandibular second molar, Pakistan, root canal configuration

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INTRODUCTION

The inhabitation of microorganisms within the root canal system has been established as the principal contributing factor for irreversible pulpitis, pulp necrosis, and apical periodontitis. Comprehensive endodontic therapy is pivotal for the microbial eradication from the root canals. The success of the endodontic treatment has been attributed to an array of factors, which include the significant knowledge of morphological variations in the root canals.[1] Anatomical diversity of the canal system presents a unique challenge to the clinician during the cleaning, shaping, and obturation of the canals. Therefore, an adequate understanding of the canal configurations and their frequency in a population before initiating the endodontic treatment enhances the quality of the treatment and results in a better long-term prognosis.[1-3]

C-shaped anatomically variant canals were first documented in the mandibular permanent second molar teeth with single root in a case series by Cox and Cooke, the authors documented continuous C-shaped orifices for two, three, and four root canals.[4] The formation of the C-shaped canal morphology is associated with the fusion failure of the epithelial root sheath of Hertwig (ERSH). Lingual or buccal groove is formed due to the fusion failure of ERSH, on the buccal or lingual side, respectively.[5] There is a racial predilection in the frequency of C-shaped configuration; therefore, variations of the root canal systems are thought to be related to ethnicity and genetic makeup.[6]

Melton *et al*. classified the C-shaped canal morphology according to shape on the axial cross-section of teeth.[7] Subsequently, Fan *et al*. modified the Menton's classification and identified five categories based on micro-computed tomography (CT) analysis. The categories identified were (i) C1: continuous "C" with no division or separation, (ii) C2: semi-colon canal shape associated with an interruption in the continuity of "C" outline with either "α" or "β" angle should be no <60°, (iii) C3: 2 or 3 individual root canals with both "α" and "β" angles <60°, (iv) C4: one root canal with an oval or round in horizontal cross-section, and (v) C5: absence of canal lumen, usually noted near the apex.[8]

Endodontic therapy of C-shaped variant of mandibular second permanent molars is a challenging procedure, secondary to the presence of thin walls and narrow isthmuses.[9] Therefore, a detailed understanding of the canal morphology is important both at the diagnostic stage and the treatment stage.[10] Multiple methods have been utilized to investigate the internal anatomical variations of root canal systems, including digital and conventional radiography of extracted teeth, clearing technique with dye injection into the root canals, micro-CT, and spiral computerized tomography.[11-14]

The utilization of cone-beam CT (CBCT) for the investigation of root canal anatomy has been noted in multiple studies.[15] CBCT offers a three-dimensional, cross-sectional analysis of the complex anatomy of root canals with a low radiation dose.[16] Moreover, it is noninvasive, more accurate method as compared to the CT and conventional two-dimensional intraoral periapical radiographs when investigating the possible presence of morphological variants of roots and canal systems that include the number of roots and presence of apical deltas, accessory canals, and canal calcifications.[17]

Numerous studies have been conducted by utilizing the CBCT to ascertain the C-shaped canals' frequency in mandibular second permanent molars.[15,16] However, to date, no relevant study has been conducted in Pakistan. Consequently, there is a dearth of literature on the Pakistani population, in this respect. Therefore, the objective of the current study was to determine the C-shaped root canals' frequency in the mandibular second permanent molars among the Pakistani subpopulation by utilizing CBCT images. In addition, the presence of bilateral C-shaped canals, longitudinal grooves' location, and gender-based differences in frequency of C-shaped canals were investigated.

MATERIALS AND METHODS

The current cross-sectional study was conducted at the Department of Endodontics, College of Dentistry, Riphah International University, Islamabad, Pakistan, from August to December 2019. The ethical approval was obtained from the Institutional Review Board of Dental Faculty at Riphah International University (Reference no: IIDC/IRC/2017/004/002). The archived CBCT radiographs of 720 mandibular permanent second molars from 360 patients who underwent diagnostic scanning, from January 2015 to January 2017 were obtained from a large private diagnostic facility, Islamabad Diagnostic Center. Random sampling technique was utilized. The sample size was calculated using the Australian Bureau of Statistics sample size calculator.[18] Estimating an anticipated population proportion of 50% with a confidence level of 99% and confidence interval of 0.05, a sample size of 664 teeth was calculated. For the purpose of this study, a sample of 720 mandibular second molars was used. The scans containing mandibular second molars bilaterally with closed apices were included in the study. Conversely, the teeth with sclerosed canals, open apices, periapical periodontitis, endodontic treatment, and crown were excluded from the study.

CBCT machine utilized was "Planmeca Promax-3D max" (Planmeca, Finland) with a voxel size of 200 μm, field of view of 5–26 cm, KVp = 96, and mA = 9. CBCT images were evaluated using PLANMECA ROMEXIS Version 4.6.0.R viewer software in a Hewlett Packard Pavilion dv6 laptop with 16" liquid-crystal display screen, with a resolution of 1366 × 768 pixels in a dark room. The contrast and brightness of the image was adjusted using the image processing tool in the software to ensure optimal visualization. Before commencing evaluation, calibration was done among the two evaluators, both endodontists with a clinical experience of more than 5 years, to exclude inter-evaluator bias and enhance intra-evaluator reliability. Inter-evaluator reliability was determined by analyzing the initial 30 mandibular permanent second molars for the presence of C-shaped canal. Intra-evaluator reliability was assessed by the reevaluation of the same teeth sample after a week. The kappa test was utilized to determine the intra- and inter-evaluator reliability. In case of differences of interpretation among the two evaluators, the CBCT image was analyzed by the consultant radiologist. The cross-sections of the C-shaped canals were analyzed at three levels: (a) coronal: "2 mm" below the canal orifice, (b) middle: the root length from canal orifice to radiographic apex divided by two, and (c) apical: coronal to radiographic apex by 2 mm. Then, these root canals were classified based on the Fan *et al*. classification.[8] In addition, the longitudinal groove on the lingual or buccal surface of the root was also evaluated.

Statistical analysis

The data were analyzed by using SPSS 23 (IBM Corp,32 Armonk, N.Y., USA). Frequency of the different morphological types of C-shaped canal variations was determined according to the Fan's classification[8] and their correlation with gender was measured by utilizing the Chi-square test. Furthermore, the longitudinal grooves' location was noted on CBCT scans. The significance level was set at $P < 0.05$.

RESULTS

The inter-evaluator reliability, determined by utilizing the Cohen kappa coefficient for the initial 30 teeth evaluated was 85.6% that was an acceptable outcome. CBCT image analysis of 720 mandibular second molars of 360 patients, 183 females (366 teeth) and 177 males (354 teeth), were conducted. Seventy two teeth (10%) of 48 patients were found to have C-shaped root canal configuration. Twenty four of 48 patients had bilateral mandibular second permanent molar teeth with the C-shaped canals [Figure 1]. Overall, 37.5% of C-shaped canals were found in right-sided teeth and 62.5% in left-sided teeth. The patients' age ranged between 17 and 70 years. The C-shaped canals' frequency was higher in females as compared to males, 15.6% and 4.2%, respectively. A statistically significant difference ($P = 0.003$) was noted in the incidence of the C-shaped canals on the basis of gender. In addition, the canal configurations at three cross-sectional levels (coronal, middle, and apical thirds) were evaluated. The uniform canal morphology from coronal to apical one-third was noted in six teeth. The remaining 66 teeth exhibited variations of Fan's classification along the root length at different cross-sectional levels [Figure 2]. The most commonly noted C-shaped canal configurations in the coronal and middle third were C1 (41.7%) and C3 (37.5%), respectively, whereas C2 (33.3%) and C4 (33.3%) configurations were commonly found in the apical third [Table 1]. The longitudinal groove of mandibular second permanent molar teeth with a C-shaped canal was most commonly located on the lingual side in 48 teeth (66.7%) and least frequently located on the buccal side in 9 teeth (12%). The buccal and lingual presence of LG accounted for 21% ($n = 15$) of the teeth with C-shaped canals in the current study.

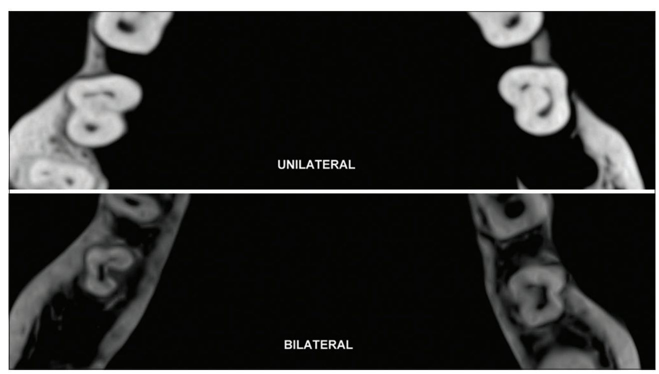

Figure 1: Cone-beam computed tomography radiographic images showing the unilateral/bilateral presence of C-shaped canals in mandibular second permanent molars

Table 1: The frequencies of variants of C-shaped root canal configuration at different axial root sections

C-shaped canal subtypes	Axial root section		
	Coronal third (%)	Middle third (%)	Apical third (%)
C1	30 (41.7)	24 (33.3)	6 (8.3)
C2	21 (29.2)	15 (20.8)	24 (33.3)
C3	15 (20.8)	27 (37.5)	18 (25.0)
C4	6 (8.3)	6 (8.3)	24 (33.3)
C5	0	0	0

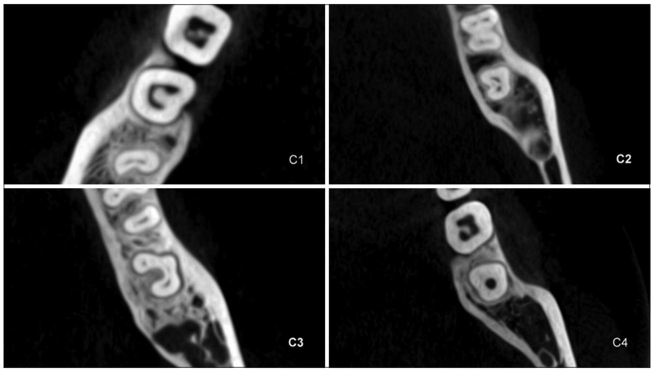

Figure 2: Axial sections of mandibular second molars exhibiting the C-shaped canals' subtypes in the current study sample

DISCUSSION

Missed root canals and subsequent inadequate intracanal debridement most commonly lead to the failed endodontic treatment.[19] The positive outcome of endodontic treatment can be anticipated only if all the canals are located, thoroughly cleaned, and obturated three dimensionally.[19] Therefore, it is essential that the clinician should be cognizant of the canal morphology of a specific tooth and its variations in different ethnic groups. This allows the clinician to optimally identify and negotiate the teeth with anatomical variations with achievement of positive treatment outcomes.[20] The possibility of incurring procedural error is significantly increased in teeth with an atypical root canal system. The errors include canal perforation, ledge formation, and apical zipping.[20]

A CBCT scan enables the clinician to evaluate tooth anatomy in three planes: (a) sagittal, (b) axial, and (c) coronal. The planes can be visualized in thin slices, enhancing the CBCT scan's precision for the identification of variations in the canal system and peri-apical tissues that was unattainable previously.[21] Furthermore, the CBCT is noninvasive in comparison to the alternative *in vitro* methodologies like the clearing technique.[12]

The frequency of C-shaped canal configuration in the mandibular second permanent molars is high among the Asian population in comparison with other ethnicities.[13] A considerable number of studies have documented the frequency of C-shaped root canals in mandibular second molars and ethnic variation in the C-shaped canals frequency is evident.[22-29] The C-shaped canal is most prevalent in the Korean population ranging from 31% to 45%.[9]

The frequency of C-shaped canal was 10% in the present study. The findings were comparable to the results reported by Wadhwani *et al.* (9.6%) in the Indian Population[22] and in line with those documented in Saudi and Turkish population by Alfawaz *et al.* (9.1%) and Helvacioglu-Yigit and Sinanoglu (8.9%), respectively.[23,24] Conversely, the high frequency of C-shaped canals was reported by Kim *et al.* (40%) in the Korean population and Janani *et al.* (21.4%) in the Iranian population.[15,16] On the other hand, the low frequency was noted in the Israeli (4.6%) and Brazilian (3.5%) population.[25,26]

The outcome of the current study suggested that if the mandibular second permanent molar presented a C-shaped canal anatomy, the probability of the similar variation in the contralateral quadrant was 50%, consistent with the findings of Alfawaz *et al.* (46.2%).[23] Conversely, Janani *et al.* (57.1%) and Zheng *et al.* (81%) noted a higher frequency of bilateral C-shaped canals in the Iranian and Chinese population, respectively.[16,27]

Literature has quite a few studies evaluating the correlation between gender and C-shaped canal frequency.[16] The current study noted a statistically significant difference between the frequency of C-shaped canals in the male (4.2%) and female (15.6%) subjects ($P < 0.05$) with women having a significantly higher frequency. The results are similar to the findings reported by other researchers.[23,28] Contrary to this, no significant correlation was found between the Chinese and Turkish population.[24,27] In addition, the axial cross-sectional form was assessed at the apical, middle, and coronal thirds. Six teeth (8.3%) showed a similar configuration at all three levels that were in line with the results reported by Janani *et al.*[16] The most commonly noted C-shaped canal configurations in the apical, middle, and coronal third were C4/C2, C3, and C1, respectively, that was different from the findings of Alfawaz *et al.* and Kim *et al.* who reported the C3 configuration as the most prevalent configuration at all root levels.[15,23]

Moreover, the present study also assessed the location of longitudinal groove. In 67% of the teeth with C-shaped canal configuration, the groove was found to be on the lingual side. The studies reported similar findings in the Portuguese, Turkish, and Saudi population.[23,24,28] The knowledge of longitudinal groove location is of significant importance as it enables the clinician to avoid strip perforation during root canal instrumentation.[29]

This is the first study conducted on the Pakistani subpopulation to assess the frequency of C-shaped canal configuration in the mandibular second molar teeth using CBCT. The results of the study can be applied to the clinical endodontic practice for enhancing the quality of patient care and reducing treatment failures. The main limitation of the current research is that the CBCT images were evaluated at a single center. Future multicenter studies are recommended with a larger sample size both in Pakistan and in other ethnic groups where the data are lacking in this regard.

CONCLUSIONS

The outcome of the current study noted considerable morphological variations at distinct cross-sections of the teeth roots with C-shaped canal morphology. Within the study limitations, the utilization of CBCT technique is useful for assessing the location of longitudinal groove, frequency, and morphology of C-shaped canal system. Therefore, when the preoperative intraoral periapical radiograph suggests the presence of C-shaped canal, the clinician should consider the utilization of CBCT imaging technique for a better understanding of the canal morphology.

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Conflicts of interest
There are no conflicts of interest.

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