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Biology and morphology of the C Shaped Root Canals in Endodontics- An Original Research

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Abstract

Introduction: The C-shaped root canal system is an anatomical variant of the root canal structure in which a continuous slit or web connects individual root canals. Hence in the present study we aim to investigate biology and morphology of the c shaped root canals in endodontics by using cone-beam computed tomographic (CBCT) images.

Material and methodology: Three-dimensional CBCT images of 92 mandibular second molars having C-shaped root canals were analysed to determine their configuration using a modification of Melton's classification, as well as the thinnest walls and their location. Associations between configuration type and distance from the canal orifice to the apex, as well as associations between the directional orientation of the thinnest root wall and distance from the canal orifice to the apex, were assessed by Fisher's exact test.

Results: The most common configuration types were Melton's type I in the coronal region and Melton's type III in the apical region. Mean thicknesses of the thinnest root canal walls were 1.39 ± 0.38, 0.85 ± 0.25 and 0.77 ± 0.20 mm in the coronal, middle and apical regions, respectively. The thicker the root canal walls at the orifice region, the greater the decrease in thickness towards the apical region (P <0.05), with the linguo-central root area being the thinnest. The pattern of decreasing thickness from the orifice to the apex formed a nonlinear cubic curve.

Conclusions: The most prevalent configuration types were Melton's type I (coronal region) and type III (apical region). The linguo-central root area was the thinnest in C-shaped root

canals of mandibular second molars. These anatomical variations should be considered during surgical or nonsurgical endodontic procedures.
Keywords: C-shaped canal, minimum wall thickness, orientation.

Introduction

The C-shaped root canal system is an anatomical variant of the root canal structure in which a continuous slit or web connects individual root canals. This morphology is most frequently seen in the mandibular second molars. The failure of Hertwig's epithelial root sheath to fuse onto the buccal or lingual root surface may be the main cause of the C-shaped root formation.[1-5] The prevalence of C-shaped canal systems has been reported to range from 2.7% to 44.5% in mandibular second molars, depending on the population. Root canal treatment of mandibular second molars may be challenging because of the presence of unique C-shaped canal systems, characterized by a narrow isthmus and a thin wall. Therefore, it is important that the configuration of C-shaped canals is understood. Furthermore, precautions should be taken to avoid instrumentation mishaps and achieve successful root canal treatment outcomes based on a thorough understanding of the root canal internal anatomy, including the thickness of the canal wall and the related position of the thinnest wall.[6-9]
Limited-volume CBCT can provide noninvasive 3D images or simultaneously axial, coronal and sagittal 2D sections of target objects that can be applied in endodontic diagnosis, morphologic analysis and endodontic epidemiologic investigation and clinical outcome study. Because there is a strong correlation between the data acquired by CBCT and histology, CBCT is a precise, nondestructive technique for endodontic research that allows the canal system to be explored both qualitatively and quantitatively.[10]
Hence in the present study we aim to investigate biology and morphology of the c shaped root canals in endodontics by using cone-beam computed tomographic (CBCT) images.

Materials and methods

Of the patients who visited the department Hospital from August 2019 to July 2020 for implant surgery and surgical removal of impacted teeth (including third molars and supernumerary teeth), 216 CBCT images of mandibular second molars (108 subjects), which had completely formed roots and had not received previous endodontic treatment, posts or crowns, were screened, and then finally 92 C-shaped root canals were selected. The mean age of the patients was 25 years, ranging from 19 to 45 years.
The CBCT system used in this study Three-dimensional images of the mandibular second molars were displayed using OnDemand3D software. The presence of C-shaped canal systems and their configurations were evaluated from the pulp orifice to the apex as axial tomographic slices were viewed at 1-mm intervals (Figs. 1 and 2). Measurements were initiated from two directions of the canal orifice (level 1) and 1 mm from the apex (level 11). Because the root lengths differed amongst specimens, measurements were standardized by analysing both sides concurrently. In short roots, the data of a specific level at middle area were left empty because both sides from canal orifice and root apex were analysed preferentially (Fig. 3). The minimum thickness from the inner wall of the canal to the outer root surface in the C-shaped canal system was measured in the same section of each tooth (Figs. 1 and 2). The orientation of the thinnest location and the groove was analysed simultaneously (Figs. 1 and 2). The root canal configuration was analysed and classified according to Melton's classification with the modifications proposed by Fan *et al.* (2004). The canals were classified as follows: type I (continuous C-shaped canal), characterized by a C-shaped outline with no separation; type II (semicolon-shaped canal), canal configurations

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in which the dentine separated one distinct canal from another C-shaped buccal or lingual canal; type III (separated canals), two or more discrete and separate canals; and type IV, a single round or oval canal. All the images were analysed by one endodontist, and assessments were made twice during a 2-week interval.

Statistical analyses were performed using the R statistical language (R Foundation for Statistical Computing, Vienna, Austria), and *P*-values <0.05 were considered statistically significant.

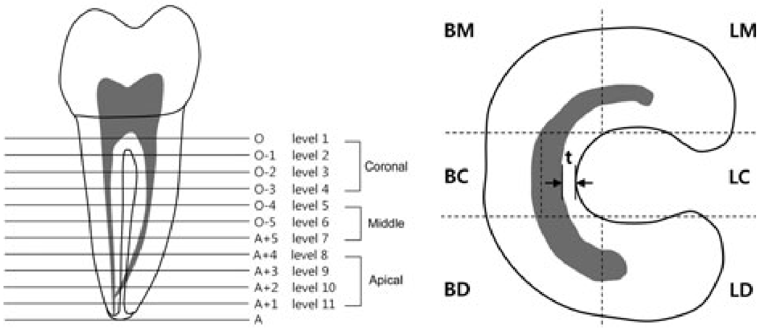

Figure 1 Measurement locations in 1-mm intervals from the orifice to the apex of mandibular second molars with C-shaped canal systems. Levels 1 and 11 were the starting points for measurement (left). Six sections were assessed and measured for the thinnest area (right). O, orifice; A, apex; t, thickness; BM, bucco-mesial direction; BC, bucco-central direction; BD, bucco-distal direction; LM, linguo-mesial direction; LC, linguo-central direction; LD, linguo-distal direction.

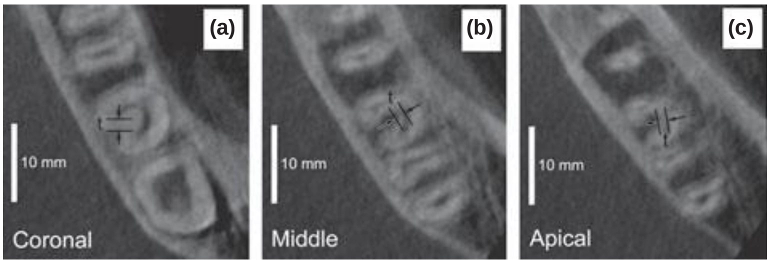

Figure 2 Example of cone-beam computed tomography axial images of a tooth with C-shaped canal configuration. (a) coronal third level, (b) middle third level, (c) apical third level.

Results

Amongst the 216 CBCT images of mandibular second molars examined, the prevalence of C-shaped canals was 42.6% (n = 92). Cross-sectional shapes of the 92 C-shaped canals at serial 1-mm intervals of the root are shown in Table 1. In the coronal region of the tooth, Melton's type I canals were the most frequent, whereas configuration types II and III were prevalent in the middle root area. The occurrence of type IV canals was rare, and type III canals were most common in the apical region.

Figure 3 shows the change in wall thickness in the thinnest areas at different levels in 92 C-shaped canals. The mean thicknesses of the thinnest root canal walls were 1.39 ± 0.38, 0.85 ± 0.25 and 0.77 ± 0.20 mm at the coronal, middle and apical regions, respectively. A strong

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correlation (*r* =)0.913) was observed between the root wall thickness (intercept, 1.95 ± 0.37 mm) at the orifice (level 1) and the decrease in the root wall thickness along the orifice–apical axis (slope,)0.13 ± 0.04) amongst individuals ($P < 0.05$). Thus, the wall thicknesses of the 92 C-shaped canals were similar (0.65 ± 0.14 mm) at the apical level (level 11; Fig. 3). The area 3 mm from the canal orifice (level 4) exhibited a thickness of <1 mm, and the pattern of decreasing thickness formed a nonlinear cubic curve (Fig. 3).

At the canal orifice, the thinnest area was most commonly found in the mesiolingual area ($P < 0.05$), whereas the linguo-central direction was most often the thinnest at all levels except for the orifice level (Table 2). All C-shaped root canals were grooved in the lingual direction.

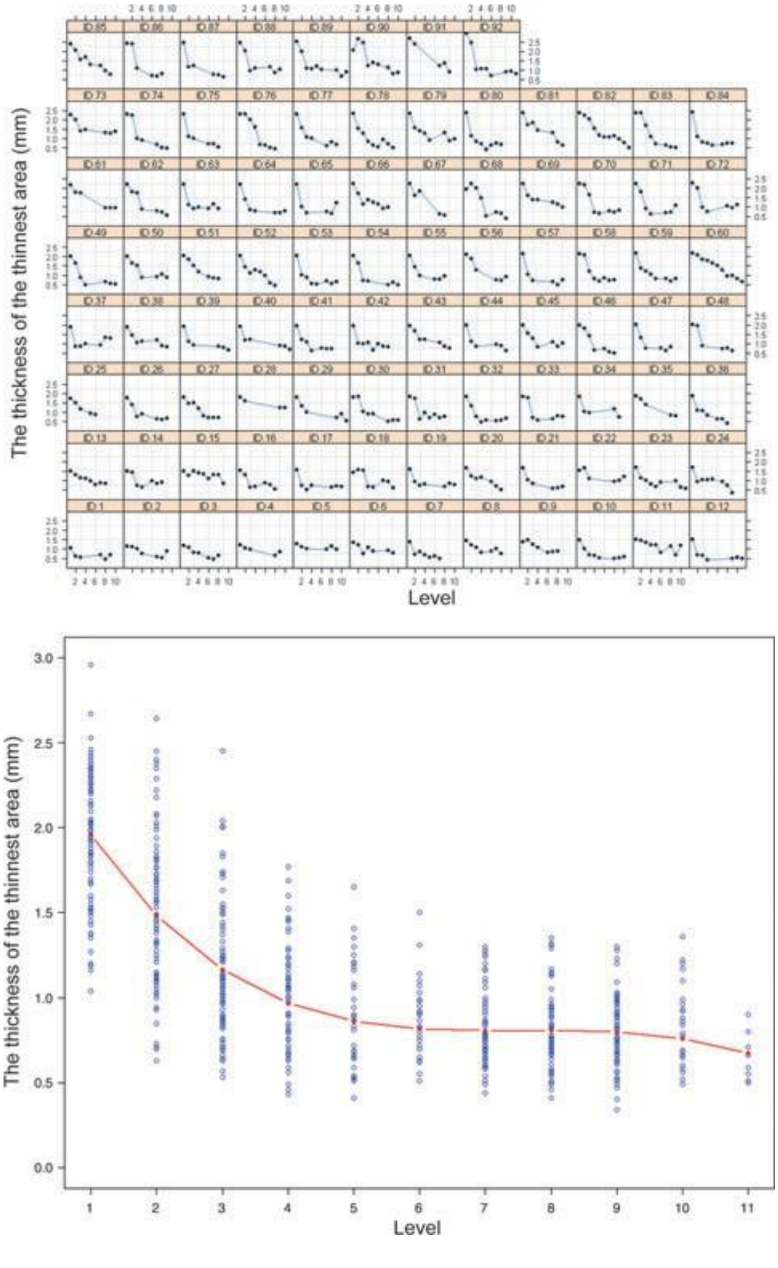

Figure 3 Changes in the thickness of the thinnest areas from the orifice to the apex for each individual C-shaped canal system (top). Correlations are shown between the thinnest canal wall and the root level from the canal orifice to the apex. The circles at each level indicate the tooth analysed for thickness amongst the 92 C-shaped root canals (bottom).

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Table 1 Configuration type and frequency for the 92 C-shaped root canals at the coronal and apical cross-sectional levels

	Coronal region				Apical region			
Type	Level 1	Level 2	Level 3	Level 4	Level 8	Level 9	Level 10	Level 11
Type I	68	49	29	12	17	9	8	3
Type II	11	25	37	21	17	18	3	2
Type III	8	13	20	29	46	33	10	2
Type IV	5	5	5	4	3	4	4	2
Total	92	92	91	66	83	64	25	9

Type I, continuous C-shaped canal; Type II, semicolon-shaped canal; Type III, separated canal; Type IV, one round or oval-shaped canal. Types are based on the classification of Fan *et al.* (2004).

Table 2 Number of cases and locations of the thinnest wall from the coronal and apical region of the 92 C-shaped canals

	Coronal region				Apical region			
Location	Level 1	Level 2	Level 3	Level 4	Level 8	Level 9	Level 10	Level 11
LM	49	31	25	13	15	11	7	1
LC	33	54	60	50	63	46	13	4
LB	10	7	5	3	2	4	2	1
BC	0	0	0	1	3	3	2	2
Total	92	92	90	67	83	64	24	8

LM, linguo-mesial direction; LC, linguo-centre direction; LB, linguo-buccal direction; BC, bucco-centre direction.

Discussion

Regarding the configurations of C-shaped canals, the highest prevalence of Melton's type I (73.9%) was noted at the orifice, which was similar to the results of other studies. The most frequent configuration type at the apical root canal region was Melton's type III. Thus, during treatment procedures, it is essential to recognize that C-shaped canal systems have an increased frequency of individual canal types with a narrow isthmus and fins directed towards the apex, and in this case, ultrasonic irrigation, negative pressure technique or using the self-adjusting file can be useful to remove debris and necrotic tissue from the root canal system.[11-13] If endodontic surgery (intentional replantation) is indicated in the case of nonsurgical root canal failure, it should be well understood that separate canal types (with or with- out isthmus and fins) are often encountered at the 3-mm apical level (level 9), where root resection is performed.

The thinnest canal walls in C-shaped roots appear to be thicker than the thickness of the danger zone in normally shaped root canals. However, strip perforation may occur if canal preparation is excessive or not controlled.[14] In the present study, the 92 C-shaped canals had considerable diversity in the thinness of the canal walls (Fig. 3). A strong correlation was

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found between the decrease in thickness and the thickness of walls at the orifice (level 1). This suggests that the thicker the root canal wall at the orifice region, the greater the decrease in thickness towards the apical region, indicating that the thick- ness of the apical root wall tends to be within a uniformly narrow range (0.65 ± 0.14 mm) despite the larger variation in root wall thicknesses at the orifice area amongst individuals. Furthermore, the thinnest root canal wall was most frequently observed in the mesiolingual direction at the orifice level, whereas the root canal wall was thinnest in the linguo-central direction below the orifice level, which was consistent with data in a previous report. However, artefacts related to misalignment, an imperfect geometric system alignment during the CBCT scan, are well known.[15-17]

Methods that include the sectioning or micro-CT of extracted teeth and clinical observations have been performed to assess mandibular second molar C-shaped configurations. Micro-CT is nondestructive and offers more precision with up to 2 lm resolution compared to CBCT which has typically voxel size of 0.08–0.4 mm^3. However, disadvantages of the micro-CT method include the amount of time required and the fact that the technique is applicable only in *ex vivo* studies. The main limitation of clinical observation is that only the orifice level is available for the *in vivo* assessment of tooth morphology. In contrast, CBCT scanners are less expensive than CT hardware, accurate for the evaluation of root canals and their morphology and able to obtain images in a relatively short exposure time.[18] Although CBCT could help over- come some of the limitations of intraoral radiographs and may be a valuable diagnostic tool for endodontic treatment, it cannot be used routinely in all cases of nonsurgical endodontic treatment. Cone-beam computed tomography uses ionizing radiation and is not without risk. Therefore, patients' exposure to radiation should be kept *as low as reasonably achievable* (ALARA), and evidence-based selection criteria for CBCT should be developed.[19,20] Thus, limited-volume CBCT with low radiation dose and high resolution should be considered for endodontic fields when conventional radiographic views yield limited information and that further radiographic details are required for proper diagnosis, treatment planning, endodontic epidemiologic investigation and clinical outcome studies.

Conclusion

This *in vivo* retrospective study revealed that Melton's type I configuration was more prevalent in the coronal region, whereas the type III configuration tended to occur in the apical region of C-shaped canals in mandibular second molars, and the linguo-central root area had the thinnest walls. These anatomical variations should be considered during surgical or nonsurgical endodontic procedures of mandibular second molars.

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