

Review Article

C-Shaped Root Canal Anatomy: A Literature Review

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ABSTRACT: Recognition of unusual variations in the root canal system is critical because it has been established that the root with a single tapering canal and apical foramen is the exception rather than the rule. C-shaped canal system is a variation that has a racial predilection and is commonly seen in mandibular second molars. The intricacies present in this variation of canal morphology can pose a challenge to the clinician during negotiation, debridement and obturation. The early recognition of these configurations facilitates cleaning, shaping, and obturation of the root canal system. "C" configuration, which is an important anatomic variation, presents a thin fin connecting the root canals. Knowledge of the C-shaped canal system is essential to achieve success in endodontic therapy. Radiographic and clinical diagnoses can aid in identification and negotiation of the fan shaped areas and intricacies of the C-shaped anatomy. The aim of this review is to discuss the etiology, incidence, classification, diagnosis and management of the C-shaped canal system.

KEYWORDS: Anatomic variation, C-shaped canal, Endodontic treatment, Mandibular second molars, Root canal system

INTRODUCTION

A thorough knowledge and understanding of the root canal anatomy and its variations is required for achieving success in root canal therapy, along with diagnosis, treatment planning and clinical expertise.^{1,2,3,4} In fact, it is important to be familiar with variations in tooth anatomy and characteristic features in various racial groups also because such knowledge can aid location and negotiation of canals as well as their subsequent management.⁵ In clinical practice, dentists frequently encounter these anatomically aberrant cases. One such variation of the root canal system is the Cshaped canal configuration. This condition was first described by Cooke and Cox⁶ in 1979, It is named so because of the Cshaped cross sectional anatomical configuration of the root and root canal.⁷ Numerous incidence studies prove the racial predilection of this variation.^{1,7,8,9,10,11,12,13,14,15,16} Though most commonly found in mandibular second molars,^{1,7,8,9,10} the Cshaped canal configuration may also occur in mandibular premolars,⁹ maxillary molars,⁹ and mandibular third molars.^{3,9} The Cshaped canal configuration presents with variations in both the number and location of the canal(s), as the canal(s) courses from the coronal to the apical third.¹⁷ Below the orifice level, the root structure shows a wide range of anatomic variations.

These can be classified into two basic groups: (1) those with a single, ribbon-like, C-shaped canal from orifice to apex and (2) those with three or more distinct canals below the C-shaped orifice.¹⁸ C-shaped canal, in mandibular molars, is commonly a single ribbon-shaped orifice with a 180° arc (or more), which, starts at the mesio-lingual line angle and sweeps around the buccal to the end at the distal aspect of the pulp chamber.¹⁹ Typically, this canal configuration is found in the teeth with fusion of the roots either on its buccal or lingual aspect. In such teeth, the floor of the pulp chamber is usually situated deeply and may assume an unusual anatomic appearance.²⁰ The main anatomic feature of C-shaped canals is the presence of a fin or web connecting the individual root canals. Roots containing a C-shaped canal often have a conical or square configuration.^{17,18,21} Early recognition of a C shaped canal configuration before treatment can facilitate effective management, which will prevent irreparable damage that may put the tooth in severe jeopardy.^{8,11} If not, the complexity of this canal configuration proves to be a challenge for complete debridement and adequate obturation mainly because it is unclear whether the C-shaped orifice found on the floor of the pulp chamber actually continues to the apical third of the root²² which may possibly affect the prognosis of root canal

therapy.^{4,17} Because of the great challenges in the diagnosis and treatment of C-shaped configuration, the aim of this review article is to address its etiology, incidence, classification, diagnosis, and management.

ETIOLOGY

Various etiological factors have been reasoned for formation of c-shaped canal. Earlier, teeth with Cshaped roots were thought as taurodonts.¹⁸ Manning also stated that the C shaped anatomy with separate canals could be the result of age changes due to deposition of dentin on the walls of the canal.¹⁸ However, this theory was rejected because separate canals in roots were observed even in patients under 40 years of age with c-shape anatomy.¹² The failure of fusion of Hertwig's epithelial sheath is the most accepted explanation for the formation of the Cshaped canal configuration.²³ The shape and the number of roots are determined by Hertwig's epithelial sheath, which bends in a horizontal plane below the cemento enamel junction and fuses in the center leaving openings for roots.²³ Failure of the Hertwig's epithelial root sheath to fuse on the lingual or buccal root surface will result in the formation of a buccal groove or a lingual groove respectively and the formation of a conical or prism shaped root.¹⁸ As this fusion is not uniform and a thin interradiacal ribbon connects the two roots together.^{11,24} It is attributed to trauma, such as radiation or chemical interference, but following the literatures of racial predilection, it is more likely to be of genetic origin.^{18,25}

INCIDENCE

The Cshaped canal configuration shows an ethnic predilection. These morphologies are known to be common in Asians, but are relatively rare amongst Europeans and Americans. HelvacioğluYigit & Sinanoğlu (2013) reported that there were no significant differences in the distribution of Cshaped root canals between males and females. Furthermore, Cshaped root canals have been reported to occur in maxillary second deciduous molars (Ballal *et al.* 2006, Ahmed 2013). However, reports of Cshaped roots and root canals in permanent teeth are predominant. This configuration has been shown to have a high prevalence in mandibular second molars with a percentage ranging between 2.7%45.5%.^{1,5,7,9,10,11} It has also been reported in maxillary first molars (0.12%), maxillary third molars (4.7%), mandibular third molars (3.5%4%), mandibular second premolars (1%), maxillary first molars and maxillary lateral incisors.^{3,19} C-shaped canals have been reported bilaterally in 70% to 81% patients.²⁶

CLASSIFICATION¹⁹

The C-shaped canal system shows many variations in its configuration. A comprehensive classification can help in true diagnosis and management.²⁰

A. MELTON'S CLASSIFICATION

Melton *et al.*² in 1991 proposed the following classification of

C-shaped canals based on their cross-sectional shape:

1. Category I: continuous C-shaped canal running from the pulp chamber to the apex defines a C-shaped outline without any separation (i.e., C1 in Fig. 1).
2. Category II: the semicolon-shaped (;) orifice in which dentine separates a main C-shaped canal from one mesial distinct canal (i.e., C2 in Fig. 1).
3. Category III: refers to those with two or more discrete and separate canals: subdivision I, C-shaped orifice in the coronal third that divides into two or more discrete and separate canals that join apically; subdivision II, C-shaped orifice in the coronal third that divides into two or more discrete and separate canals in the midroot to the apex; and subdivision III, C-shaped orifice that divides into two or more discrete and separate canals in the coronal third to the apex (i.e., C3 in Fig. 1).

In this classification, they noted that the second type of C-shaped canal is the most common.

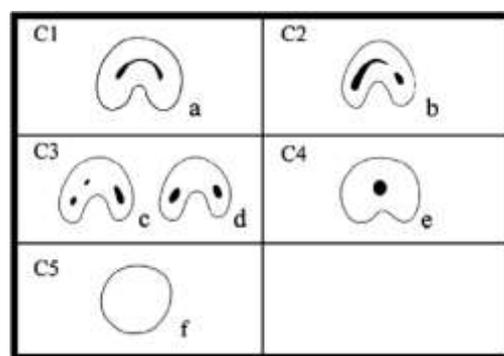


Figure 1. Classification of C-shaped canal configuration

B. Fan's Classification (Anatomic Classification)

Fan *et al.*²⁰ in 2004 modified Melton's method into the following categories:

1. Category I (C1): the shape was an interrupted "C" with no separation or division (Fig. 1A).
2. Category II (C2): the canal shape resembled a semicolon resulting from a discontinuation of the "C" outline (Fig. 1B), but either angle α or β (Fig. 2) should be no less than 60° .
3. Category III (C3): 2 or 3 separate canals (Fig. 1C and D) and both angles, α or β were less than 60° (Fig. 3).
4. Category IV (C4): only one round or oval canal in that cross section (Fig. 1E).
5. Category V (C5): no canal lumen could be observed (which is usually seen near the apex only) (Fig. 1F).

They considered that the single, round, or oval canal (C4 in their classification), which may be found near the apex, should be considered as a variation because other parts of the canal have shown the "C" configuration. In this classification, one of the canals in the C2 category would appear as an arc (with $\beta \geq 60^\circ$, Fig. 2) (i.e., the C2 canal would be more likely to extend into the fused area of the root where the dentin wall may be quite thin). They are more difficult to clean and shape than C3 canals.

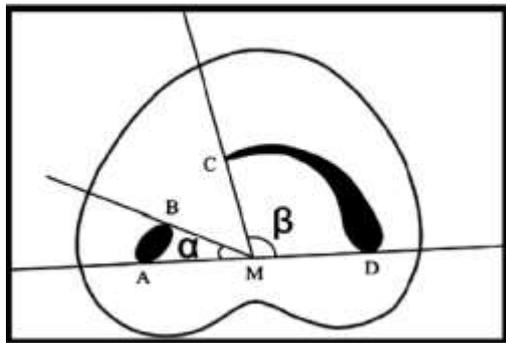


Figure 2. Measurement of angles for the C2 canal. Angle_ is more than 60°. (A and B) Ends of one canal cross-section, (C and D) ends of the other canal cross-section; M, middle point of line AD; α angle between line AM and line BM; β angle between line CM and line DM

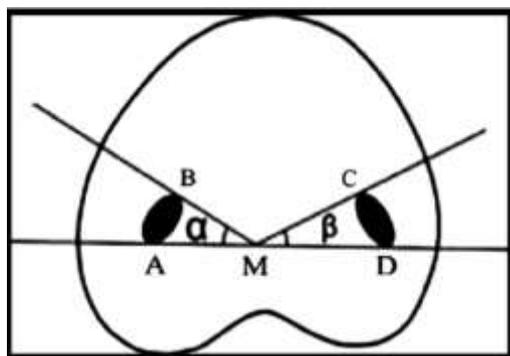


Figure3. Measurement of angles for the C3 canal. Both angle α and angle β are less than 60°. (A and B) Ends of one canal cross-section; (C and D) ends of another canal cross-section; M, middle point of line AD; α angle between line AM and line BM; β angle between line CM and line DM

C. Fan’s Classification (Radiographic Classification)

Fan et al.²¹ classified C-shaped roots according to their radiographic appearance into three types:

1. Type I: conical or square root with a vague, radiolucent longitudinal line separating the root into distal and mesial parts. There was a mesial and a distal canal that merged into one before exiting at the apical foramen (foramina) (Fig. 4A).
2. Type II: conical or square root with a vague, radiolucent longitudinal line separating the root into distal and mesial parts. There was a mesial and a distal canal, and the two canals appeared to continue on their own pathway to the apex (Fig. 4B).
3. Type III: conical or square root with a vague, radiolucent longitudinal line separating the root into distal and mesial parts. There was a mesial and a distal canal, one canal curved to and superimposed on this radiolucent line when running toward the apex, and the other canal appeared to continue on its own pathway to the apex (Fig. 4C).

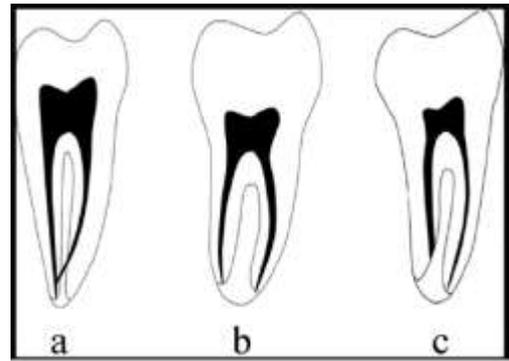


Figure 4. Radiographic types. (A) Type I, (B) type II, and (C) type III

CLINICAL DIAGNOSIS

Clinically C-shaped canal can be recognized based on definite observable criteria (i.e., the anatomy of the floor of the pulp chamber and the persistence of hemorrhage or pain when separate canal orifices were found).²⁷ The pulp chamber may be large occluso-apically with a low bifurcation. In a true C-shaped canal, an instrument can pass from mesial to distal aspect without obstruction. In other configurations, such passage is impeded by discontinuous dentine bridges.² If a file could not be passed through the isthmus of the pulpal floor, it might be considered that the root canal is being separated or merge just below the isthmus area.¹⁵ The first diagnostic indication of such anatomic variance may be the localized periodontal disease due to narrow root grooves present with fused roots and C-shaped roots. When a deep groove is present on lingual or buccal surfaces of the root, a C-shaped canal is to be expected.²⁰ Clinically, the others noted that all teeth that qualified as having a C-shaped canal system had to exhibit all the following three features: fused roots, a longitudinal groove on the lingual or buccal surfaces of the root, and at least one cross-section of the canal belongs to the C1, C2, or C3 configuration.²⁰

RADIOGRAPHIC DIAGNOSIS

In a study by Haddad et al.¹¹, most radiographs revealed radicular fusion or proximity, a large distal canal, a narrow mesial canal, and a blurred image of a third canal in between. Radiographs taken while negotiating the canals may show two characteristics for category I (continuous) canal configuration: instruments tending to converge at the apex and/or may exit at the furcation.¹⁷ The latter sometimes may resemble a perforation of the furcation.^{2, 9,10, 15} The root configuration of molars may be appear as a single fused root or as two distinct roots with a communication, the latter of which may not be very obvious at first glance.¹² Radiographic interpretation is overall more effective when combination of radiographs (“preoperative and working length radiographs” or “preoperative and final radiographs” or “all three radiographs”) are taken. However, working length radiographs are more helpful whereas preoperative radiographs are the least effective.²⁷

LOCATION AND NEGOTIATION OF CANALS

Initial canal-system recognition occurs by routine endodontic access and removal of pulp tissue.¹⁷ However, modifications in the access cavity designs may be required to facilitate location and negotiation of the complete canal system.²⁸ If a C-shaped root is present, two of Melton's three categories (category I and II) should be evident (in category III, two or three separate canals may appear initially as a typical three-canal orifice mandibular molar).² For continuous Cshape orifice, 3 initial files are inserted, one at either end and one in the middle. When the orifice is oval, two files are inserted, that is, one file at each end of the orifice and when the orifice is round, one initial file is inserted.²⁹ In calcification cases, several orifices may be probed that link up on further instrumentation.¹⁴ Because of bifurcation, dentin fusion, and curvatures; there are chances of missed canals.²⁹ To ensure that these irregularities are not missed, exploration should be carried out with small size endodontic Kfile with a small, abrupt apically placed curve.³⁰ Fiberoptic transillumination can enhance variant canal anatomy identification. Fiberoptic tip placed under the rubber dam on the buccal surface illuminates the pulp chamber. The canal system appears as a dark line or area in an illuminated field.¹⁷ Also the surgical operating microscope has made treatment more successful.^{31,32} In order to access all the irregularities in the Cshaped canal system, the orifice portion of the slit can be widened with Gates Glidden drills.³³ In all categories, the mesiobuccal and distal canal spaces usually can be prepared normally. However, the isthmus should not be prepared with larger than no. 25 files; otherwise, strip perforation is likely. Also, Gates-Glidden burs should not be used to prepare the mesiobuccal and buccal isthmus areas especially in C1 (continuous C type) and C2 (semicolon type) configurations.²¹ The AbouRass *et al.*'s anticurvature filing technique has been recommended to avoid danger zones that are frequently present at mesiolingual walls.⁴ However, extreme caution must be taken to prevent strip perforation during cleaning and shaping of Cshaped mandibular premolars, which have thin dentinal walls in the radicular groove area.³³ Ni-Ti rotary instruments seem to be safe, further enlargement to an apical dimension greater than size 30 (0.06 taper) is not recommended.³⁴ Kfiles or Hfiles could be passively introduced into the canal, and filling could be specifically directed towards the isthmus areas to obtain better debridement after instrumentation by Ni-Ti rotary instrumentation.³⁵ The self adjusting file (SAF) system has been reported to be more efficacious than the protaper system in this case.³⁶ Extravagant use of small files and 5.25% NaOCl is a key to thorough debridement of narrow canal isthmuses.¹⁷ Alternative canal cleaning techniques, like use ultrasonics, would be more effective. An increased volume of irrigant and deeper penetration with small instruments using sonics or ultrasonics help in more cleansibility in fan-shaped areas of the C-shaped canal.²

CANAL-SYSTEM OBTURATION

Technique modifications may require for the obturation of C-

shaped canals. The mesiolingual and distal canal spaces can be prepared and obturated as standard canals. To ensure proper placement of the master cones, Barnett²⁴ recommended placing a large diameter file in the most distal portion of the canal, before seating the master cone in the mesial canal. The file is then withdrawn and the master cone of the distal canal is seated, followed by placement of accessory cones in the middle portion of the Cshaped canal. However, in lateral compaction root fracture and perforation of the root can occur.^{37,38} Also sealing the buccal isthmus is difficult if lateral condensation is the only method used. Gutta-percha can be thermoplasticized with spreaders heated in an open flame or electric spreaders or delivered by injectable systems. Single-insertion thermoplasticized gutta-percha condensation devices may not condense gutta-percha adequately into the long narrow isthmuses. Martin³⁷ has developed a device Called EndoTec that appears to achieve the best qualities of both lateral and warm condensation techniques. An Army group, in 1993,³⁹ found a "zap and tap" maneuver: preheating the EndoTec plugger for 4 to 5 seconds before insertion (zap) and then moving the hot instrument in and out in short continuous strokes (taps) 10 to 15 times. The plugger was removed while still hot, followed by a "cold spreader with insertion of additional accessory points." However, difficulty increases due to two reasons: (1) divergent areas that are frequently unshaped and may offer resistance to obturating material flow and (2) communications between the main canals of the C-shape, through which the entrapped filling materials that should be captured between the apical tug-back area and the level of condensation may pass from one canal to another. For this, Walid³⁸ in 2000, described the use of two pluggers simultaneously to down pack the main canals in a C-shaped canal. Two fine-medium cones were selected for distal and mesiolingual canals and no accessory cones were placed in the fin between them, whereas a medium point was fitted in the mesiobuccal canal. Three pluggers were selected for obturation. A Touch'N Heat was used to sear off gutta-percha at the mesiolingual orifice level where the largest plugger selected was placed while down packing the distal canal with the smallest plugger. Then, the smallest plugger used in the distal canal was held in place while packing the mesiolingual canal. Placing two master points and blocking the canal entrance with a plugger increases the resistance toward the passage of obturating material from one canal to another.

POST ENDODONTIC RESTORATION AND PROGNOSIS

Proper post-canal adaptation and stress distribution is more likely to result in the tubular distal canal so if post placement is desired, use of only the distal canal should be considered. Placement of posts or antirotational pins in the mesiolingual and mesiobuccal areas of C-shaped root invites perforation. Also, post width should be minimized.¹⁷ Since the floor of the pulp chamber is deep it can provide enough retention from the available undercuts.^{17,24} Chamber retained, bonded amalgam or composite is a better choice as the core or as the final

restoration in these teeth.^{34,38} Restorations with failure in the furca have a poor prognosis. If the failure result from an apical etiology and apical surgery is not possible, viable options include extraction, extraoral retrofilling, and replantation. Because C-shaped roots generally are conical, they are easy to extract without fracture.¹⁷

CONCLUSION

The Cshaped root canal configuration has an ethnic predilection and a high prevalence rate in mandibular second molars. By Understanding the anatomical presentations of this variation and following the sound principles of biomechanical preparation, obturation, and restoration, the long-term prognosis for the C-shaped root retention equals that of other teeth.

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