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C-Shaped Root Canal Configuration in Mandibular Second Molars: A Review and Its Prevalence in Indian Population

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ABSTRACT

The success of endodontic treatment mainly depends on adequate knowledge of root canal morphology and its variations. One of the most important anatomic variations is the 'C' configuration of canal system. The main feature of C-shape is the presence of a fin or web connecting the individual root canals. Root containing a C-shaped canal often has a conical or square configuration. Recognition of these unusual variations in canal configuration facilitates thorough cleaning, shaping, and obturation of root canal system. Due to the great challenges in diagnosis, classification and management of 'C' configuration, the present article aims to give a comprehensive review on aetiology, classification, diagnosis, management of C-shaped canals and also to determine its frequency in Indian population.

Key Words: Anatomy, C-shape, Canal configuration, CBCT, Hertwig's epithelial sheath, Mandibular second molar

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INTRODUCTION

One of the most important anatomic variations in root canal morphology is 'C' configuration of canal system, which was first documented in endodontic literature by Cooke and Cox[1] in 1979. C-shaped canal is so named for the cross sectional morphology of the root and root canal.

Instead of having several discrete orifices, the pulp chamber of the C-shaped canal is a single ribbon shaped orifice with 1800 arc, which starts at the mesiolingual line angle and sweeps around the buccal to the end at the distal aspect of pulp chamber.[2] Below the orifice level, the root structure had wide range of anatomic variations like a single, ribbon like, C-shaped canal from orifice to apex[3] with three or more distinct canals below the C-shaped orifice.[4]

Typically, this canal configuration is found in the teeth with fusion of the roots either on its buccal or lingual aspect. C-shaped canals are most often found in mandibular second molars, though they can be found in mandibular first molars, maxillary molars, mandibular premolars, and maxillary laterals.

Once recognized, the C-shaped canal provides a challenge with respect to debridement and obturation, especially 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 root.[1,5] Because of the great challenges in the diagnosis and critical need for proper management of 'C' configuration, this article will address its aetiology, classification, diagnosis, treatment and its frequency in Indian population.

Aetiology

The shape and number of roots are determined by Hertwig's epithelial sheath, which bends in a horizontal plane below the cementoenamel junction and fuses in the center leaving openings for roots.[6] Failure of the Hertwig's epithelial root

sheath to fuse on the lingual or buccal root surface is the main cause of the C-shaped roots, which always contain a C- shaped canal.

The C- shaped roots may also be formed by coalescence because of deposition of the cementum with time.[7] C- shaped canals appear when fusion of either the buccal or lingual aspect of the mesial and distal roots occurs. This fusion remains irregular and the roots stay connected by an interradicular ribbon. The floor of the pulp chamber is deep and has as unusual anatomic appearance. Two or three canals may be found in the C-shaped groove or the C- shaped may be continuous throughout the root length.[5,8]

Classification of morphology of C-shaped pulp chamber floor and canal systems

Yin Min et al.[9] (2006) investigated morphology of pulp chamber floor in the mandibular second molars with C-shaped canal systems. The reconstructed images were classified into four types based on the shape of pulp chamber floor and the location of the dentin fusion between the peninsular like floor and pulp chamber wall (Figure 1).

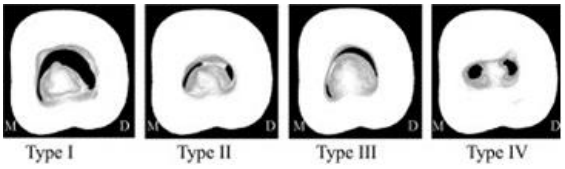

Figure 1. Types of pulpal floor: M-mesial side: D-distal side

Type I; continuous C- shaped orifice (peninsula- like floor)

Type II; dentin fusion between peninsula- like floor and buccal pulp chamber wall, forming one/two mesial orifice(s) and distal orifice

Type III; dentin fusion between peninsula- like floor and mesial pulp chamber wall, forming a large mesio-buccal-distal (MB-D) orifice and a small mesiolingual orifice

Most teeth with C-shaped roots also have a C-shaped pulpal floor and this new classification of pulpal floor anatomy would be helpful in locating the C-shaped canals.

Melton's classification[10]

Melton et al.1991 proposed the following classification based on their cross-sectional shape (Figure 2).

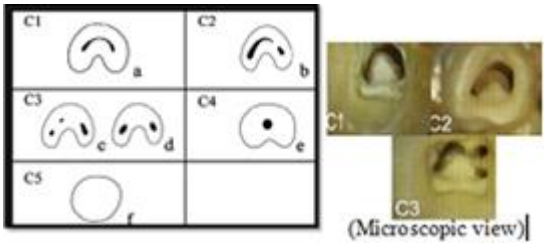

Figure 2. Classification of C-shaped canal configuration

Category I: continuous C-shaped canal running from pulp chamber to the apex (C1)

Category II: semicolon shape (;) orifice in which dentine separates main C- shape canal from one mesial distinct canal (C2)

Category III: refers to those with two or more discrete and separate canals: subdivision 1: 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 canals in mid root to apex, subdivision III; C- shaped orifice that divides into two or more discrete and separate canals in the coronal third to the apex (C3).

Fan's classification[11] (Anatomic classification) (Figure 2, 3A & B)

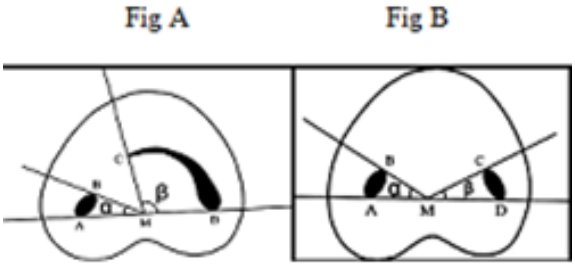

Figure 3. (A) measurement of angles for C2 canal. Angle β >600 (B) measurement of angles for C3 canal. Both α & β <600

Fan et al. in 2004 modified Melton's method into the following categories;

Category 1(C1): shape was interrupted C with no separation or division.

Category II(C2): semicolon shape resulting from discontinuation of C outline, but either angle α or β should be no less than 600.
Category III(C3): 2or 3 separate canals and both angles, α or β, were less than 600.
Category IV(C4): only one round or oval canal in that cross section.
Category V(C5): no canal lumen could be observed (which is usually seen near the apex only).

Fan's classification[12] (Radiographic classification) (Figure 4)

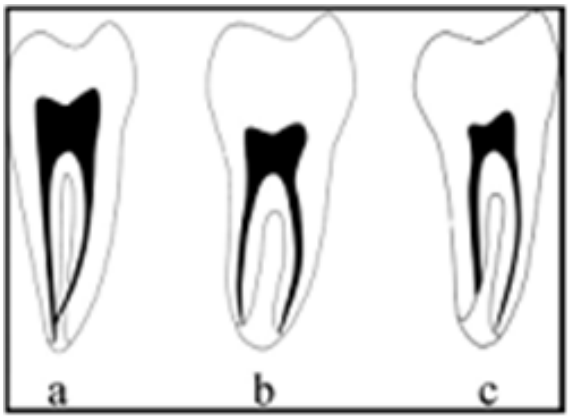

Figure 4. Showing Fan's radiographic classification

Type I: conical or square root with a vague, radiolucent longitudinal line separating the root into distal and mesial parts. There was mesial and distal canal that merged into one before exiting at apical foramen (Fig a).
Type II: conical or square root with a vague radiolucent line separating the root into distal and mesial parts. Mesial and distal canals appeared to continue on their own pathway to the apex (Fig b).
Type III: conical or square root with a vague radiolucent longitudinal line separating the roots into distal and mesial parts with mesial and distal canals, 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 c).

Prevalence of C-shaped canals in Indian population
Many studies shown that C-shaped canal is not uncommon and its frequency ranges from 2.7% to 8% with highest incidence (10%-31.5%) in Japanese[13], Chinese[14], Hong Kong Chinese[15], Lebanese[16], and Thai[17] population. The prevalence of C-shaped canals varies greatly among different ethnicities and in Asian population has been reported to be as high as 30% as in whites. This variation may occur in mandibular first molars, maxillary molars, mandibular first premolars, maxillary lateral incisors but most commonly found in mandibular second molars. When present on one side, C-shaped canal may be found in the contra lateral tooth in 70% of individuals.[18]

MATERIALS AND METHODS

One hundred and thirty four second molars scheduled for root canal treatment were examined over a period of 1-2yrs in a private practice in India. A random sampling method is used. Selected patients were explained about proposed treatment.

The patients who accepted treatment and observation were included in the study after obtaining consents. Two pre-operative radiographs were taken at a constant target film distance and two different angulations. One with a 900 angulations to the tooth in a buccolingual direction and the other at a mesial and distal angulations of approximately 200 using shift cone technique to allow better visualization of the bucco-lingual anatomy.

The radiographs were examined on a viewer using 6x magnifying lens. The number and position of canals were noted. The characteristic features noted on radiographs are typical image that allowed prediction of the existence of this anatomic situation, radicular fusion, blurred image of third canal in between, a large distal canal and narrow mesial canal were noted.

Clinical examination was carried out after adequate anaesthesia with rubber dam isolation. Access cavity was prepared and root canals were explored with size 10k files: radiographs were taken with the file within the canal to confirm canal morphology. Teeth were identified as having C-shaped canal morphology based on Melton et al. classification

RESULTS

Out of 134 molars, 22(16.5%) exhibited C-shaped canals. 11 molars presented a continuous C-shaped canal, 6 molars had a semi colon shape (category II) with mesial canal located on buccal or lingual side.

Remaining teeth were considered in category III. The frequency obtained in this investigation lies between 2.7% reported by Weine et al. (1988) and 31.5% reported by Yang et al. (1988). However further studies with large sample size would be necessary to confirm this phenomenon.

Methods and techniques in Diagnosis

Pre operative awareness of C-shaped canal configuration before treatment can facilitate effective management. An array of techniques has been developed which include use of radiographs, placing files in the canal, CBCT, µCT, spiral CT which gives accurate diagnosis and avoid difficulties during treatment.

Radiographic diagnosis (non-invasive method)

A preoperative radiograph and an additional radiograph from 200 mesial or distal projections may be the only non invasive means clinically to provide clues about canal morphology.[19] Radiographs reveal radicular fusion or proximity, a large distal canal, a narrow mesial canal, and a blurred image of third canal in between. Radiographs taken while negotiating the canals reveal two characteristics for such canal configuration; instruments tending to converge at the apex and/or may exit at furcation which resemble a perforation at furcation. Also, using third generation apex locator with the ability of reading canal lengths in the presence of electrolytes, should help to distinguish between the two.[10] Radiographic interpretation is overall more effective when based on film combinations (preoperative, working length, final radiographs) than single radiographs. Working length is most helpful than preoperative and final radiograph in diagnosing with C- shape.[20] Barril et al.5(1989) emphasized C- shaped canals are difficult to interpret on radiographs because of thickness of bony trabeculae. C-shaped canals must be suspected when roots are fused or very close to each other. Kala M[21] (2011) suggest to take two preoperative radiographs using shift cone technique to allow better visualization of the bucco-lingual anatomy even though the proportion of C-shaped teeth detected by radiographic method was significantly lower than the proportion of clinically diagnosed cases.

Radiographic diagnosis (invasive methods)

Al–Fouzan[22] (2002) stated that radiographic techniques have certain disadvantage in which it presented in only 2D image with possibility of missing some of the roots and root canals. Cimilli H et al.[23] (2005) demonstrated that high resolution visualization of the root canal shape can be achieved by spiral computed tomographic imaging. Lorena Karanxha et al.[24] (2012) highlights the usefulness of CBCT imaging for accurate diagnosis and management of unusual canal morphology. Bing Fan et al.[11] (2004) used micro-computed tomography (µCT) to assess cross-sections of teeth and for three dimensional reconstruction of canals at high resolution. This sophisticated tool allows geometrical measurements to be made on root canals, non destructively, before and after cleaning and shaping.

In vitro diagnosis of C-shaped canal

A. Clearing & injection of dye[25]

   Clearing technique is advantageous for studying root canal anatomy as it provides 3D view of the pulp cavity and instruments are not needed to enter the pulp system. After locating the canal orifices the teeth were placed in 5.2% sodium hypochlorite solution to dissolve debris and pulp remnants. All the specimens were then thoroughly rinsed in running water for 4h to clean the root canals of any debris. Once washed, Indian ink was injected into root canals and teeth were demineralised for 3 days in 5% nitric acid at room temperature(200)C. The dehydration process consisted of a series of rinses with 80% ethyl alcohol over night, followed by 90% for 1hour and then 100%ethyl alcohol rinses for 1hour. The dehydrated teeth were placed in methyl salicylate for 2hour to make them clear and transparent. The cleared teeth were examined under a magnifying glass at 5x magnification.

B. Intra radicular contrast medium[26]

   Wei Fan et al. in their study investigated radiographic features of the C-shaped canal system in mandibular second molars and their relationship to the canal anatomy by using intra radicular contrast medium and micro–computed tomography (µCT) scanning.. The contrast medium was introduced into the canal by using a specialized device, and the buccal-

lingual radiograph was taken for each tooth. The radiographic images were classified into 3 types: Types I (merging type), II (symmetrical type), and III (asymmetrical type). The relationship between the radiographic and anatomic features was analyzed by collating the μCT scanned canal images with the radiographic types.

CLINICAL DIAGNOSIS

Clinical recognition is based on definite observational criteria like large pulp chamber in the occluso- apical dimension with a low bifurcation, anatomy of floor of pulp chamber and the persistence of haemorrhage or pain when canal orifices are present. At the outset, several orifices may be probed and it was also possible to pass instrument from mesial to distal canal without obstruction.

Fiber optic transillumination[4] enhances canal anatomy identification. Placing the fiber optic tip under the rubber dam on the buccal surfaces illuminates pulp chamber. Canal system appears as a dark line or area in an illuminated field. Yilmaz Z et al.[27,28] stated use of surgical operating microscopes had made treatment more successful.

MANAGEMENT

The possibility of C-shaped canals has to be considered during the clinical and radiographic examination. Early recognition facilitates thorough cleaning, shaping and obturation of the root canal systems. Visualization of canals can be achieved by any of the above mentioned methods.

Canal preparation and working length determination:

Chai WL et al.[29] (2004) visualizes canal widths of C-shaped roots of mandibular molars and suggests a higher risk of root perforation at thinner lingual walls of C-shaped canals during shaping and post canal preparation procedure.

Initial canal system recognition occurs after achievement of routine endodontic access and removal of tissue from pulp chamber. Deep orifice preparation and careful probing with small files characterize C- shape more accurately. In all categories, the mesio-buccal and distal canal spaces can be prepared normally however the isthmus should not be prepared larger than[25] files due to chance of strip perforation. Gates-glidden burs also should not be used to prepare mesio--buccal and distal isthmus areas.

Extravagant use of small files, anti-curvature filing method in coronal third of canal is needed to prevent perforation and use of 5.25% NaOCl is important to ensure thorough debridement of narrow canals. The orifice portions of the slit must be widened considerably and the ribbon canal space is frequently eccentric to the lingual side of C-shaped radicular dentin.[30] Alternative canal cleaning techniques like use of sonic and ultrasonic effectively remove tissues from C- shaped ramifications.

Canal system obturation:

Obturation of C- shaped canals may require technical modifications. Mesiolingual and distal canal spaces are prepared and obturated as standard canals. However sealing the buccal isthmus is difficult if lateral condensation is only used. Gutta-percha can be thermo plasticized with spreaders heated in an open flame and delivered by injection systems. Single insertion may not condense gutta-percha adequately into long narrow isthmus.

In addition proper placement of sealer with ultrasonic endodontic files is critical. Walid N[31] (2000) described the use of two pluggers simultaneously to down pack the main canals in a C-shaped canal. Martin[32] (2002) devised EndoTec II considering the ease and speed of lateral compaction as well as the superior density gained by vertical compaction of warm gutta-percha to achieve best qualities. Liewehr et al.[33] (1993) found a better results while obturating C- shaped canal by using EndoTec with zap and tap manever: “preheating the EndoTec plugger for 4-5 seconds before insertion (Zap) and then moving the hot instrument in and out in short continuous strokes(taps) 10-15 times. The plugger is removed while still hot, followed by a “cold spreader with insertion of additional accessory points’’.

Although the prevalence varies, when sound principals of biomechanical preparation and obturation are followed, the long term prognosis for the C-shaped root retention equals that of other molars.

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