IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 21, Issue 7 Ser.2 (July. 2022), PP 18-27
www.iosrjournals.org

Management of Various C Shaped Canal Systems in Mandibular Permanent Second Molars Using Dental Operating Microscope & CBCT: A Case Series

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Abstract:
Background: *C-shaped root canal systems, common anatomic variation of mandibular permanent second molar is threat to endodontic treatment.*
Aims: *The aim is to discuss the etiology, incidence, anatomic features, classification of the C-shaped canal configuration. C-shaped canal configuration 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. Knowledge of the C-shaped canal configuration is essential to achieve success in endodontic therapy.*
Methods & materials:
Radiographic and clinical diagnosis aid in identification and negotiation of the fan-shaped areas and intricacies of the C-shaped anatomy. Effective management of this anomalous canal configuration can be achieved with rotary and hand instrumentation assisted with sonics and ultrasonics. Modifications in the obturation techniques will ensure a 3-dimensional fill of the canal system and chamber retained restorations like amalgam or composites, serve as satisfactory post endodontic restorations.
Results: *Majority Radiographic type I cases had a common feature of continuous C shape canal coronally, maintained their shape in middle and coalesced apically. Root canals with different shaped openings, common with Radiographic type II and III may intercommunicate and tend to remain separated all throughout.*
Conclusions: *X-rays and pulpal floor morphology provide clues for complex root canal anatomy. Also the Prevalence rate & female predilection in WB population are to be considered in clinical practice.*
Keywords: *C-shaped canal, CBCT, DOM, Mandibular second molar, West Bengal populations.*

Date of Submission: 01-07-2022 Date of Acceptance: 11-07-2022

I. INTRODUCTION:

Mandibular second molars usually have two roots and three root canals but variation in the number of roots as well as canal morphology are not uncommon. It has most important anatomic variations of "C" configuration of canal system, which was first documented in endodontic literature by Cooke and Cox in 1979[1] but its presence was discovered quite earlier.[2,3,4,5]

Varied prevalence rate is seen in East Asian population groups like Chinese -0.6%-41.27%[6] , Koreans-31.3%-45.5%[7] , Burmese- 22.4%[8] which was much higher than the Indian- 7.5% - 12.5%[9,10], Thai- 10%[11] or Sri Lankan population -6%-8%.[12]

Manning (1990)[14] speculated that the failure of the Hertwig‟s epithelial root sheath to fuse on the lingual or buccal root surface was the main cause of a C-shaped root, which always contains a C-shaped canal. The roots display an occluso-apical groove on the buccal or lingual surface or both. The main feature of this variation is the presence of a fin or web connecting the individual root canals to form a letter „C‟ shape at the root canal orifice. The floor of the pulp chamber is at deeper level than CEJ.[15] Below the orifice level, the root structure can harbour a wide range of anatomic variations.

The complex anatomy poses great difficulty in cleaning shaping and subsequent obturation. Though number is less, but IOPA x-rays & varied pulpal floor anatomy provide informations regarding its presence and different types of its inner root canal anatomy.

1. ETIOLOGY

The failure of fusion of Hertwig‟s epithelial sheath is the most lucid explanation for the formation of the C-shaped canal configuration. Failure of the Hertwig‟s epithelial sheath to fuse on the buccal side will result in the formation of a lingual groove, and failure to fuse on the lingual would result in a buccal groove. Hence, this fusion is not uniform and a thin interradicular ribbon connects the two rootstogether. Failure of the sheath to fuse on both the buccal and lingual sides will result in the formation of a conical or prism-shaped root. Fusion is most likely to occur if the distance between the root canals is small.

Earlier, the irregular fusion of the Hertwig‟s epithelial sheath was attributed to trauma, such as radiation or chemical interference, but following the documentation of racial predilection, it is more likely to be of genetic origin.

2. CLASSIFICATION:

Fan's anatomic classification using µCT (Fan et al 2004): Fused roots with one groove or two groove(non divided fused), CEJ-pulpal floor distance & cross-sectional anatomy confirm diagnosis (Fig.1)

- ***Category I (C1)*:** The shape was an interrupted „C‟ withno separation or division.
- ***Category II (C2)*:** The canal shape resembled a semicolonresulting from a discontinuation of the „C‟ outline, buteither angle or should be no less than 60°.
- ***Category III (C3)*:** Two or three separate canals and both angles, and were less than 60°.
- ***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).

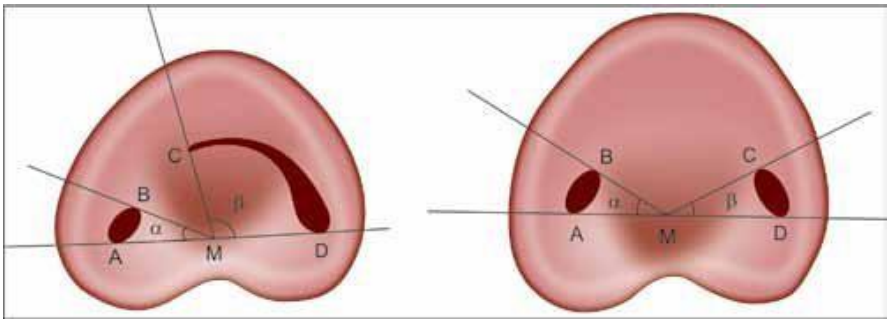
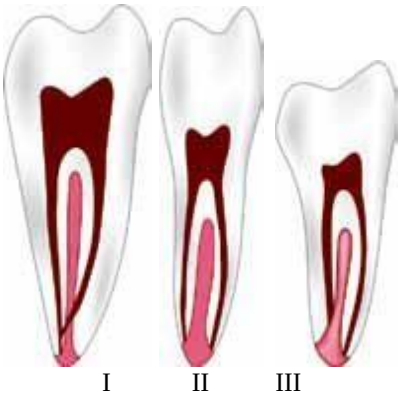


Fig. 1: Classification of C-root canal configuration according to fan

Fan's Classification (Radiographic Classification):

Fan et al classified C-shaped roots according to their radiographic appearance into three types (Fig.2):

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).
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.
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.



I II III

Fig.2: Fan's radiographic classification

MIN'S CLASSIFICATION OF PULP CHAMBER FLOOR:(Fig.3)

Type I: A peninsula-like floor with a continuous C-shaped orifice.
Type II: A buccal, strip-like dentin connection exists between the peninsula-like floor and the buccal wall of the pulp chamber that separates the C-shaped groove into mesial (M) and distal (D) orifices. Sometimes the mesial orifice separates into a mesiobuccal (MB) and a mesiolingual (ML) orifice by another strip-like dentin between the peninsula-like floor and the mesial wall of the pulp chamber.
Type III: Only one mesial, strip-like dentin connection exists between the peninsula-like floor and the M wall, which separates the C-shaped groove into a small ML orifice and a large MB-D orifice. The MB-D orifice was formed by the merging of the MB orifice andthe D orifice.
Type IV: Non-C-shaped floor. One distal canal orifice and one oval or two round mesial canal orifices are present.

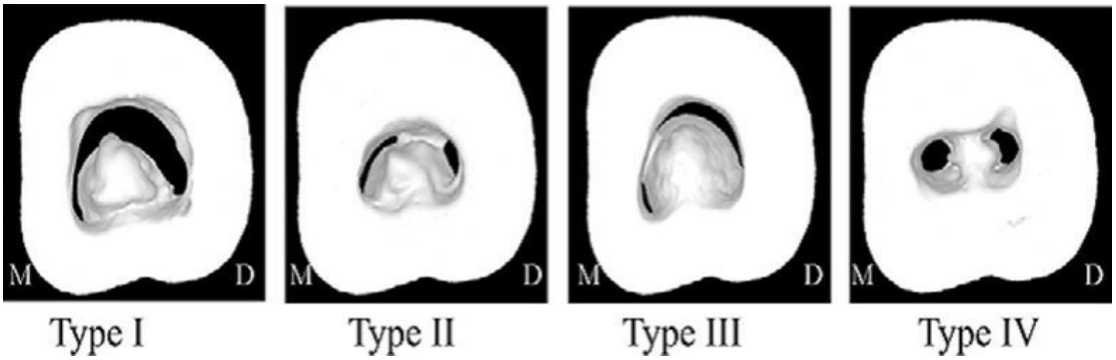


Fig.3: Min'sclassification of pulp chamber floor

3. INCIDENCE:

Prevalence is estimated to be between **2.7 and 9.0% in nonAsian**population. The C-shaped canal configuration has frequentlybeen reported in **Asian countries** with a high prevalence of **2.7%–45.5%** in mandibular second molars.[1,4]**(**Table I&II)

AREA POPULATION		PREVALENCE (%) FOR C SHAPED CANAL IN MANDIBULAR 2ND MOLAR
NON ASIAN		2.7- 9%
ASIAN		2.7- 45.5%
SOUTH ASIA	BURMESE	22.40%
	INDIA	7.50%
	SRILANKA	3%
EAST ASIA	CHINA	93.10%
	HONGKONG	52%
	KOREA	45.50%

Table I:

TOOTH	INCIDENCE OF C SHAPED CANAL
MANDIBULAR PREMOLAR IN CHINESE	29.7%
MAXILLARY FIRST MOLARS	0.12%
MAXILLARY THIRD MOLARS	4.7%
MANDIBULAR THIRD MOLARS	3.5 – 4%
MANDIBULAR SECOND PREMOLARS	1 %

Table II:

II. MATERIAL AND METHODS:

1. DIAGNOSIS:

It is very crucial to diagnose the C-shaped canal prior to initiating endodontic treatment considering the difficulties that can be encountered in canal shaping and obturation.

Clinical Diagnosis

The pulp chamber of teeth with C-shaped canals is usually large apico-occlusally with a corresponding apically located bifurcation. Several orifices may be probed that link up on further instrumentation.

- An instrument can be passed from mesial to distal aspect without obstruction in a true C-shaped canal. Dentin bridges impede such passage in other configurations.
- In cases with a separate canal and a buccal or lingual C-shaped canal, an instrument inserted into any side of the C ends in the distal foramen of the tooth. This instrument can probe the complete extension of the C. The canal is separate if the

instrument cannot be passed through the isthmus of the pulpal floor.

- The first diagnostic indication of C-shaped roots may be localized periodontal disease predisposed by narrow root grooves on the buccal or lingual surface. A separate root canal exiting at the apical level should be suspected when the orifice looks connected at the subpulpal level.

Radiographic Diagnosis

- The simplest, noninvasive clinical method to provide a clue about the canal morphology is a preoperative periapical radiograph and an angulated radiograph from 20° mesial or distal projection.
- Fan *et al*. stated that for a mandibular second molar to qualify as having a C-shaped canal system, it has to exhibit all the following three features:

a. Fused roots
b. A longitudinal groove on lingual or buccal surface of the root.
c. At least one cross-section of the canal should belong to the C1, C2 or C3 configuration, as per Fan˝s anatomic classification.

- Cooke & Cox, opined that it is impossible to diagnose C-shaped canals from preoperative periapical radiographs.
- **Haddad *et al.*** in their review suggested that preoperative radiographs revealed many similar characteristics such as **radicular fusion**, **radicular proximity**, a **large distal canal** or a **blurred image of a third canal in between**, which allowed the prediction of C-shaped canal.
- **Working length radiographs** of C-shaped canals may show two characteristics: instruments converging at the apex and/or may exit at the furcation resembling a furcal perforation. This appearance occurred more in category I(continuous).(Fig. 4)

Fig.4:**WL IOPA of Type I C shaped canal showing files converging at the apex**

- Interpretation of more than one radiograph or use of an apex locator gives a differential diagnosis of C-shaped molars from furcation perforation.
- Film combinations - “preoperative and working length radiographs” or “preoperative and final radiographs” or “all three radiographs” make radiographic interpretation more effective than single radiographs in diagnosing the C-shape.(Fig. 5)

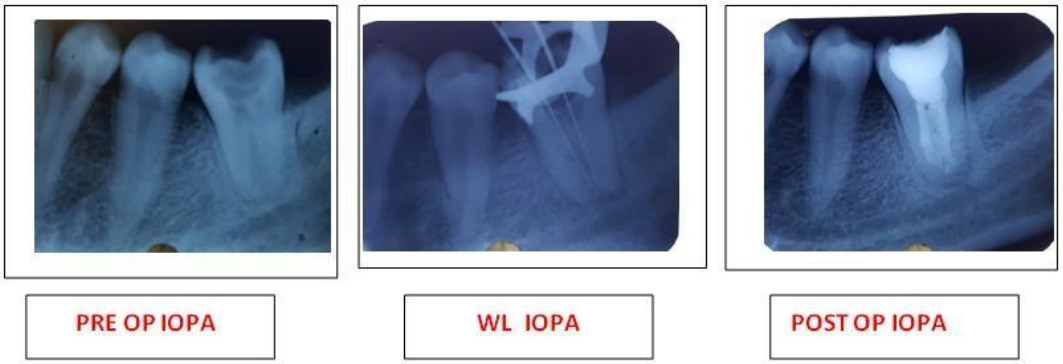


Fig.5: **Preop IOPA, WL IOPA, Postop IOPA**

- **Working length radiographs are more helpful** while preoperative radiographs are least effective.
- Newer imaging modalities like spiral CT and micro CT aid in the diagnosis of C-shaped canals. Both are time consuming and have limited application in in-vivo studies
- However limited - volume **CBCT** with low radiation dose and high resolution, on the other hand, is a **precise and nondestructive technique which allows for both qualitative and quantitative evaluation of root canal morphology in three dimensions**. Further, it gives greater diagnostic data with reduction of subjectivity in interpretation, as the problem of overlap, common in two dimensional views is eliminated. (Fig.6)

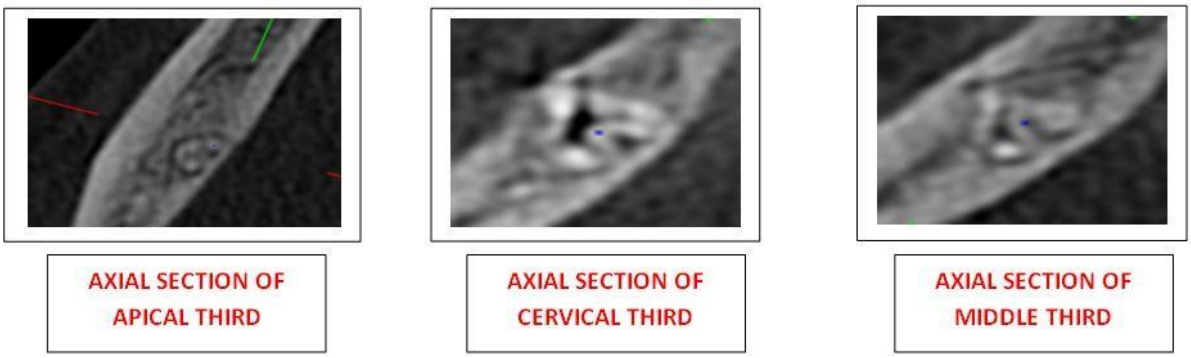


Fig.6: CBCT Axial Sections of apical, cervical & middle third

2. MANAGEMENT:

The C-shaped configuration presents a complex canal anatomy. This makes it difficult to clean and seal the irregular areas which contain infected debris or soft-tissue remnants. Many modified techniques have been proposed to accomplish meticulous cleaning and shaping for a successful root canal treatment. The associated challenges can arise during diagnosis to instrumentation, obturation, and post space preparation.

Location and negotiation of canals :

- Modifications in the access design facilitates location and negotiation of the complete canal system after complete caries excavation.
- For **continuous C-shaped orifice**, **three files** are inserted, one in the middle and one at either end.
- With **oval orifices**, **two files** are inserted, one at each end of the orifice.
- **One file** is inserted when the **orifice is round**.
- Calcifications in the pulp chamber can conceal the C-shape. The orifices have to be probed which link up on further instrumentation.
- Canals may be missed because of bifurcation, dentin fusion, and curvatures.
- These irregularities should be explored with small size endodontic files - #8, #10 or #15 K-files.
- The root canal system in C- shaped canals appear as a dark line or area under fiber optic transillumination.
- Surgical operating microscope (SOM) is an important adjunct in successfully treating such canals. (Fig.7)

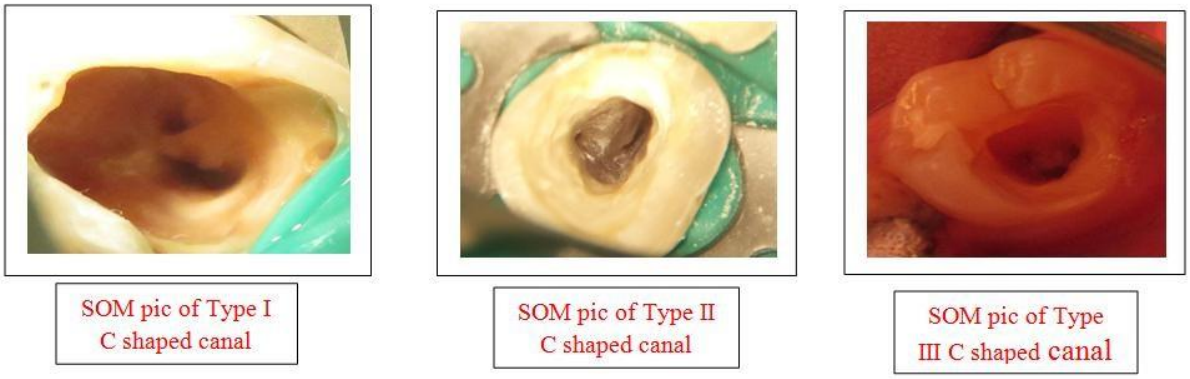


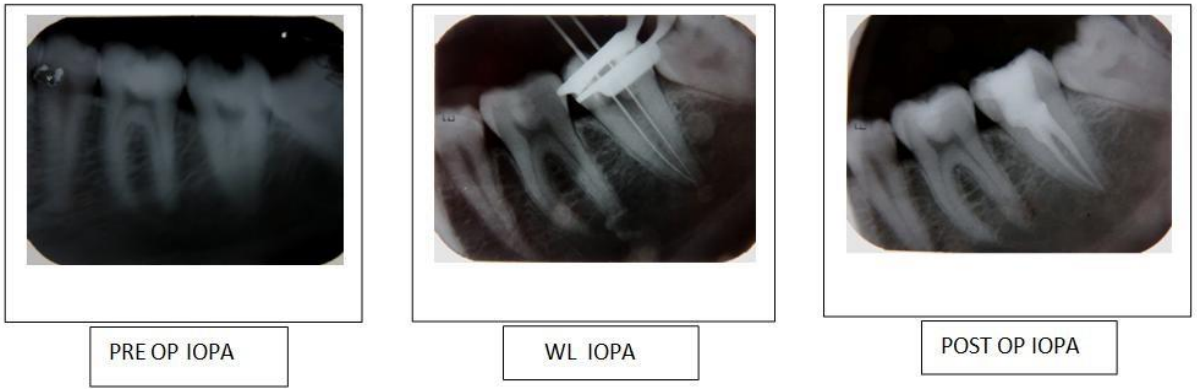
Fig.7: SOM pics of C shaped canal

Cleaning and shaping :

- In most situations, the mesiobuccal and distal canal spaces can be prepared utilizing a conventional approach.
- Instrumentation of the isthmus above #25 size files should be avoided to minimize the potential for strip perforation.
- The orifice portion of the slit can be widened with Gates Glidden drills to access all the irregularities.
- For narrow, interconnecting isthmus areas as in C1 (continuous C type) and C2 (semicolon type) configurations, Gates Glidden drills should not be used and cleaning should be carried out using #25 or smaller instruments, with copious irrigation using 5.25% sodium hypochlorite.
- Abou-Rass *et al*., recommended anti-curvature filing technique to avoid danger zones.
- Perforation of the thinner lingual walls can be minimized by instrumentation directed buccally.
- Apical instrumentation should be limited to #30(0.06 taper).
- Following rotary instrumentation, filing using K-files or H-files may be specifically directed towards the isthmus areas to obtain better debridement.
- The recently developed **self-adjusting file (SAF) system is more efficacious than the protaper system** for shaping C-shaped canals.
- Intracanal instruments are unable to access and debride the entire portion of the large canal space, making the role of irrigation more relevant. Canal irrigation techniques incorporating ultrasonics is more effective in achieving adequate debridement.
- Deeper penetration with small instruments and increased volume of irrigant allows more cleansability in fan-shaped areas of the C-shaped canal.However, injudicious ultrasonic instrumentation carries the risk of perforation.

III. ASE SERIES :

CASE I: TYPE I C SHAPED CANAL



Cleaning and shaping of the canal was done with hand K files and ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to F3. The anti- curvature filing method was performed to avoid the strip perforation. Copious amount of 5% sodium hypochlorite was used for irrigation .

CASE II: TYPE II C SHAPED CANAL

The cleaning and shaping was performed with hand K files and Hero Shaper rotary files (Micro‑ Mega, Besançon, France). The anti‑ curvature filing method was used. Five percentage sodium hypochlorite was used for irrigation.

CASE III: TYPE III C SHAPED CANAL

Cleaning and shaping was done using hand K file and ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to F3. Copious amount of 5% sodium hypochlorite was used as an irrigant.

Obturation Techniques

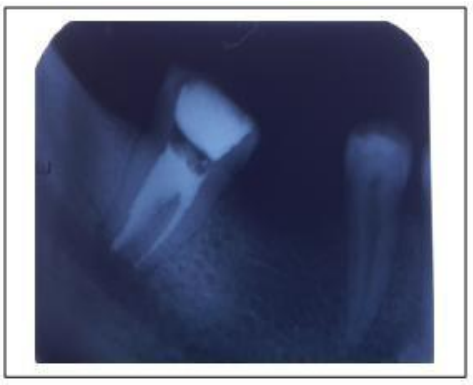
- For placement of the master cones in C-shaped canals, **Barnett** recommended a large diameter file to be seated in the distal canal before placing the master cone in the mesial canal. The file is then withdrawn, master cone seated in distal canal, followed by placement of accessory cones in the middle portion of the C-shaped canal.
- Sealing the buccal isthmus is difficult using lateral condensation alone, as the isthmus cannot be prepared with a flare to permit deeper placement of the spreader. This makes application of gutta-percha, thermoplasticized with electric spreaders or spreaders heated in an open flame or delivered by injectable systems more appropriate.
- The technique developed by **Walid** tries to overcome these problems by the simultaneous use of two pluggers to down pack the main canals in a C-shaped canal. Two fine-medium cones were seated in the mesiolingual and distal canals. No accessory cones should be placed in the fin between them and a medium point was fitted in the mesiobuccal canal. Three pluggers are used for obturation. Using Touch˝N Heat (Sybron Endo/Analytic, Irvine, CA) gutta-percha at the mesiolingual orifice level was seared off where the largest plugger was placed, while down packing the distal canal with the smallest plugger. While packing the mesiolingual canal, the smallest plugger used in the distal canal was held in place. The resistance toward the passage of obturating material from one canal to another was increased by placing two master points and blocking the canal entrance with a plugger.
- **Ordinola- Zapata *et al.*,** in their study **using Maggiore's modified MicroSeal technique** found that the apical third was less accurately filled and concluded that C2 canals with a 120° or 150° is more difficult to fill than a 60° angle C2 canal.
- **Martin** developed the EndoTec II (Medidenta, Inc., Woodside, NY) that combined the qualities of both the ease and speed of lateral compaction as well as the superior density gained by vertical compaction of warm

gutta-percha. Using the **"zap and tap"** maneuver, improved compaction could be achieved while obturating a C-shaped canal by using the device. This involves **heating the EndoTec plugger for 4 to 5 seconds (zap)** followed by **moving the hot instrument in and out in short continuous strokes (tap)** 10 to 15 times.

CASE I: TYPE I C SHAPED CANAL

The obturation was performed using The Obtura III Max system (Obtura Spartan, Fenton, MO, USA) and Endoflas FS (Sanlor, Colombia).

CASE II: TYPE II C SHAPED CANAL



The obturation was done using 6% resilon cone and RealSeal sealer (SybronEndo, Orange, CA, USA) a resin based obturation system.

CASE III: TYPE III C SHAPED CANAL

The obturation was did using lateral condensation method with ProTaper F3 Gutta- perchamaster cone andEndoflas FS (Sanlor, Colombia).

IV. DISCUSSION:

C-shapedcanalsystemisa complexanatomicalvariationreported in various human teeth such asmandibular first premolar[18], mandibular firstmolar[19],maxillaryfirstmolar[20]and maxillary secondmolar[21],butoccursmostfrequentlyinmandibular second molars[22].Thisconfigurationshows anethnicpredilectionwithhigh incidenceinAsianpopulation[16].East Asianpopulationgroupslike China(0.6%-41.27%)andKorea(31.3%-45.5%)have shownahigh prevalence ofthisanatomicvariation.Ithasalsobeenreportedtobe prevalentatmuchhigherrateinBurmesepopulation(22.4%)thanthe Indian,ThaiorSriLankanpopulationamongstSouthAsiancountries. Similarly,ahigherincidenceofC-shapedanatomywasdocumented inLebanesepopulation(19.1%)ascomparedtotheotherWestAsian populationgroups(Iranian,Jordanian,SaudiArabian)[23].
Conventionalintraoralradiographictechniquesusingsilverhalide filmisacommonlyusedmethodfordeterminingthecanalanatomy[24].Thisprocedureismorebeneficialinevaluatingrootcanalanatomy and itsvariationslikeC-shapedcanalsystemwhenfilmsareused with combinationtechnique(Preoperative,WorkinglengthandFinal radiographs)[17].Hencethesimilartechniquewasusedfordiagnosisin presentcases.Radiographically,suchteethmaypresentassinglefused rootorastwodistinctrootswithacommunication.Thelattermaynot beclearlyvisibleontheradiographgivingappearanceoftwodistinct roots.Alargeanddeeppulpchamberisalsousuallyobservedinthese teeth[23].

Diagnosisofsuchteethcanbemadebasedonspecific clinical findingslikepeculiaranatomyof pulpfloor,persistenthemorrhageor painwhenseparatecanalorificesareobservedandnarrowrootgrooves causinglocalizedperiodontal disease[17].C-shapedorificeanatomy mightreflectsignificantvariations indifferentteeth. Meltonet al proposed threecategoriesofC-shapedcanalsystembasedonthecross-sectionshapenamelycontinuous Cshape(Category-I),semicolon shape(Category-II)andtwoorthreediscreteorifices(Category-III). Also,theyreportedthatsecondtypeofanatomyis themostcommon[17].
ManagementofC-shapedcanalsystem includesidentificationof canalanatomyusing deeporificepreparationandcarefulprobingwith smallfiles.Useofsophisticatedequipmentssuchas surgicaloperating microscopeisalsorecommendedforthispurposeasitcanfacilitate thelocalization andhandlingofadditionalcanalsduetolighterand considerablyhighermagnificationofthefieldofview[25-27].Itis suggestedthattheorificeportionsoftheslitbesignificantlywidened butnotdeeplytowardstheapexsoastoavoidperforation[17].
Mandibular molars with C-shaped root canals have been reported to be associated with higher percentage of uninstrumented canal areas (59.6%) using NiTi rotary instruments than manual K-file group (41.6%)[28] . NiTi rotary instrument seem to be safe in such canals and recommended to an apical dimension not greater than size 30 (0.06 taper). It could be followed by use of K-files or H-files specifically directed towards the isthmus areas assisted by ultrasonic irrigation to obtain better debridement [23]. Use of thermoplasticizedgutta percha technique is considered to be better for obturation in canal irregularities.However lateral condensation technique& resin based obturation was employed in present cases because of its wide usage in clinical practice. We found excellent results in such complex root canal variations.

V. CONCLUSION:

C-shaped canal system is a complex anatomical variation showing high prevalence rate in mandibular second molars.Prognosis of such difficult cases can be improved by acquiring better understanding amongst clinicians pertaining to characteristic features, diagnosis and effective management techniques.

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Ranjita Poddar, et. al. "Management of Variousc Shaped Canal Systemsin Mandibular Permanent Second Molars Using Dental Operating Microscope & CBCT: A Case Series." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 21(07), 2022, pp. 18-27.