How to Manage FAN’S C Shape Canals along with S Shape Morphology in Indian Population: A Case Series and Narrative Review

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CASE REPORT

How to Manage FAN’S C Shape Canals along with S Shape Morphology in Indian Population: A Case Series and Narrative Review

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ABSTRACT

The C-shaped root canals offer greater negotiation, debridement, and obturation difficulty as they present with intercommunications, lateral canals, and reduced dentin thickness. **Objective:** This case series elaborates on the recognition that these varying configurations is important to enhance adequate cleaning, shaping, and sealing of the root canal. **Case Reports:** On clinical examination, all the teeth showed caries were nonresponsive to sensibility tests and other diagnostic tests, suggestive of pulp necrosis with apical periodontitis. Conventional root canal treatment with different techniques and obturation systems have been used. This case series presents the successful management of various C-shaped configurations classified by Fan et al. and emphasizes the different treatment approaches for effective therapy. The cleaning and shaping process should always follow the canal anatomy to maintain the canal shape at the same point the primary and secondary curvatures and thin interconnections are negotiated, prepared, and sealed. **Conclusion:** The morphological variation existence and their different types and management should be known for improved healing and enhanced success of root canal treatment.

Key words: C shape root canal, fused root, second molars

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INTRODUCTION

The anatomical anomaly of the root canal connecting them through fin or web-like structure is called a C-shaped root canal. Cooke and Cox termed the C-shaped canal architecture after seeing their morphology in cross-section, which resembled the letter “C,” and they first identified it in mandibular molars in 1979. Below the cemento-enamel junction, Hertwig's epithelial root sheath curves in a horizontal plane and fuses in the middle, leaving spaces for roots. If they fail to fuse, C-shaped root morphology with a C-shaped canal forms on the root surface of the buccal or lingual side. Other causes can be root coalescence due to cementum deposition over time. Mandibular second molars are the most prevalent location for this variant, while it can also be seen in mandibular first premolars, maxillary molars, and even maxillary lateral incisors. 70% of people may have a C-shaped canal on both sides of their teeth. There is a racial preference towards c-shaped canals. More cases have been recorded in Asian nations including China (31.5%) and Korea (44.5%). Studies on the Indian population reported with prevalence of 7.5%, and of those, 54.84% had two apical foramina. Melton et al. suggested categorising C-shaped canals in 1991 based on the geometry of their cross-sections. Fan et al. provided the anatomic and radiographic categorization in 2004, which are as follows: C1: The shape is an uninterrupted “C” with no separation or division. C2: The canal shape resembles a semicolon resulting from a discontinuation of the “C” outline, but either angle α or β should be no less than 60 degrees. C3: Two or three separate canals and angles, α and β, are less than 60 degrees. C4: Only one round or oval canal is in the cross-section. C5: No canal lumen can be observed usually seen near the apex only. Radiographic classification by Fan et al.; Type I: Canals merge to one main canal before exiting...
Table 1. Results of the diagnostic tests and classification.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>Age</th>
<th>Gender</th>
<th>Tooth number</th>
<th>Percussion</th>
<th>Palpation</th>
<th>Cold test</th>
<th>Electric pulp test</th>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>Female</td>
<td>#47</td>
<td>tender</td>
<td>sensitive</td>
<td>no response</td>
<td>no response</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>Male</td>
<td>#37</td>
<td>tender</td>
<td>normal</td>
<td>no response</td>
<td>no response</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>Male</td>
<td>#37</td>
<td>tender</td>
<td>sensitive</td>
<td>no response</td>
<td>no response</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>Female</td>
<td>#47</td>
<td>normal</td>
<td>normal</td>
<td>no response</td>
<td>no response</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>5</td>
<td>55</td>
<td>Female</td>
<td>#37</td>
<td>tender</td>
<td>sensitive</td>
<td>no response</td>
<td>no response</td>
<td>Within normal limits</td>
</tr>
</tbody>
</table>

Table 2. Classification according to Fan et al. (Clinical & Radiographic).

<table>
<thead>
<tr>
<th>Category</th>
<th>Fan’s Clinical classification</th>
<th>Fan’s Radiographic classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>The canal shape resembles a semicolon resulting from a discontinuation of the “C” outline, but either angle $\alpha$ or $\beta$ should be no less than 60 degrees.</td>
<td>Category II</td>
<td>Type III - asymmetric type</td>
</tr>
<tr>
<td>The shape is an uninterrupted “C” with no separation or division.</td>
<td>Category I</td>
<td>Type I - merging type</td>
</tr>
<tr>
<td>Only one round or oval canal is in the cross-section</td>
<td>Category IV</td>
<td>Type I - merging type</td>
</tr>
<tr>
<td>Two or three separate canals and both angles, $\alpha$ and $\beta$, are less than 60 degrees.</td>
<td>Category III</td>
<td>Type II - symmetric type</td>
</tr>
<tr>
<td>No canal lumen can be observed is usually seen near the apex only</td>
<td>Category V</td>
<td>Type I - merging type</td>
</tr>
</tbody>
</table>
at the apical foramen, Type II: Separated mesial and distal canals in each root exit as separate canals, Type III: Separated mesial and distal canals, with the distal canal having a long isthmus across the furcation area. Considering the lower prevalence of this morphology in the Indian population yet understanding this anatomic complexity is crucial, and this case series focuses on the clinical handling of all categories of Fan’s radiographic and clinical classification (Table 1).

CASE REPORT

Case 1
A 28-year-old female patient visited Dept of Endodontics suffering from pain in the right-side lower tooth. The patient gave non-contributory medical history. History of presenting illness revealed prolonged sensitivity to hot and cold for the past six months and the not relieved after taking analgesics. Clinical examination showed a deep mesio proximal carious lesion approaching pulp in #47. The tooth was nonresponding to cold and electric pulp tests and was tender on percussion testing. Radiographs showed radiolucency on the coronal aspect of the tooth in approximation to pulp with an associated periapical radiolucency. The tooth had a single fused root with three canals, joined at the apical area to form a wide isthmus between roots, suggesting a type III C-shaped canal (Figure 1a). With the findings, the diagnosis was symptomatic irreversible pulpitis with symptomatic apical periodontitis, and nonsurgical root canal treatment was planned.

Case management 1
After administration of local anaesthesia, under rubber dam isolation, access cavity preparation three orifices were recognized which was in accordance with Fan anatomic classification “category II” (C2), negotiated using smaller size K files (Figure 1b). The ultrasonic tips (Dentsply Start -X tips) used for refining the access. Cleaning and shaping of the canal done with circumferential filing with hand K files (Dentsply Maillifer, Switzerland) till 30 size. The pulp chamber was irrigated with 3% NaOCl (Parcan, Septodont Healthcare, India) activated using endo-activator. Intracanal medicament calcium hydroxide was placed and patient was asked to report after 2 weeks. After two weeks, Radiograph taken with master GP was placed upto the working length (Figure 1d). Obturation was done with thermoplasticised GP (Calamus, Dentsply Maillifer, Switzerland). Core restoration with adhesive resin (Figure 1e-f). The patient was recalled after 6 months and 1 year. The radiograph taken after 1 year showed complete resolution of periapical lesion (Figure 1g).

Case 2
A 25-year-old male patient visited the Department of Endodontics suffering from pain in the left-side lower tooth. The patient gave non-contributory medical history. The patient gave a history of dull, persistent pain for several months back that subsided after a few weeks. Clinical examination showed deep occlusal caries approaching pulp in #37. The tooth was nonresponding to cold and electric pulp tests and was tender on percussion testing. Radiographs showed radiolucency on the coronal aspect of the tooth in approximation to pulp with widened periodontal space. The tooth had a single fused root with two canals joined at the apical area, suggesting a type I C-shaped canal (Figure 2a). With the findings, the diagnosis was necrotic pulp with symptomatic apical periodontitis, and nonsurgical root canal treatment was planned.

Case management 2
After administration of local anaesthesia, under rubber dam isolation, access cavity preparation recognized two canal orifices with continuous communication between them in the form of the letter “C” which depicts Fan anatomic classification “category I” (C1) (Figure 2b). The canals were then negotiated till apex with the #10K stainless steel file (Dentsply Maillefer, Switzerland). Cleaning and shaping of the canal was done by circumferential filing with hand K files (Dentsply Maillifer, Switzerland) to 30 sizes in the mesial canal and 40 sizes in the distal canal. The pulp chamber was irrigated with 3% NaOCl (Parcan, Septodont Healthcare, India) activated using endo-activator. Intracanal medicament calcium hydroxide was placed and patient was asked to report after 2 weeks. After two weeks, Radiograph taken with master GP was placed upto the working length (Figure 2d). Obturation was done with cold lateral compaction and accessory cones with GuttaFlow 2 (ROEKO GuttaFlow®-COLTENE) (Figure 2e). Core restoration with adhesive resin (Figure 2e-f).
Case 3
A 45-year-old male patient visited Dept of Endodontics suffering from pain in the left-side lower tooth. The patient gave non-contributory medical history. History of presenting illness revealed sensitivity to hot and cold and spontaneous pain not relieved by taking analgesics. Clinical examination showed disto occlusal caries involving pulp in #37, and it was severely tender on percussion testing. Radiographs showed radiolucency on the coronal aspect of the tooth in approximation to pulp. The tooth had a single fused root with a wide canal, suggesting a type I C-shaped canal (Figure 3a). With the findings, the diagnosis was symptomatic irreversible pulpitis with apical periodontitis, and nonsurgical root canal treatment was planned.

Case management 3
After administration of local anesthesia, under rubber dam isolation, the endodontic build-up was done using flowable (PREVEST FUSION PRO) & packable (IVOCLAR TE ECONOM PLUS) composite. The access cavity was preparation showed one oval canal orifice in the form of the letter “C” belonging to Fan anatomic classification “category IV” (C4) (Figure 3b). The canal was then negotiated till apex with the #20K stainless steel file (Dentsply Maillefer, Switzerland). Cleaning and shaping the canal done with hand K files (Dentsply Maillifier, Switzerland) to 45 sizes. The pulp chamber was irrigated with 3% NaOCl (Parcan, Septodont Healthcare, India) activated using endo-activator. Intracanal medicament calcium hydroxide was placed and patient was asked to report after two weeks. After two weeks, Radiograph was taken with master GP placed up to the working length (Figure 3d). Obturation was performed with a hybrid technique of cold lateral compaction in the apical area and thermoplasticised GP (Beefill Pack, Germany) in the coronal area with AH plus sealer (Dentsply Maillefer) (Figure 3e)—core restoration with adhesive resin (Figure 3e-f).

Case 4
A 35-year-old female patient visited Dept of Endodontics suffering from pain in the right-side lower tooth. The patient gave non-contributory medical history. History of presenting illness revealed prolonged sensitivity to hot and cold for the past six months and the not relieved after taking analgesics. On Clinical examination, the tooth showed disto occlusal caries in #47. The tooth was nonresponding to cold and electric pulp tests and was non-tender on percussion testing. Radiographs showed radiolucency on the coronal aspect of the tooth in approximation to pulp with an associated periapical radiolucency. The tooth had a single fused root with two canals, suggested type II C-shaped canal and “S”-shape (Figure 4a). The curvature analysis was done preoperatively. With the findings, the diagnosis was pulp necrosis, and nonsurgical root canal treatment was planned.

Case management 4
Under rubber dam application, an access cavity preparation revealed three orifices which were in accordance with Fan anatomic classification “category III” (C3), negotiatied using small size K files (Figure 4b). The ultrasonic tips (Dentsply Start -X tips) were
used for refining the access. Cleaning and shaping of the canal were done with crown-down technique using hand K files (Dentsply Mailfllfer, Switzerland) followed by preparation using pre-curved hyflex CM file 4% taper (HyFlex CM, Coltene, Whaledent). The pulp chamber was irrigated with 3% NaOCl (Parcan, Septodont Healthcare, India) activated using endo-activator. Intracanal medicament calcium hydroxide was placed, and the patient was asked to report after two weeks. After two weeks, Radiograph was taken with master GP placed up to the working length (Figure 4d) and obturated with GuttaFlow 2 (ROEKO GuttaFlow®-COLTENE) (Figure 4e).

Case 5
A 55-year-old female patient visited Dept of Endodontics suffering from pain in the left-side lower tooth. The patient gave non-contributory medical history. Clinical examination showed occlusal caries involving pulp in #37, and it was severely tender on percussion testing. Radiographs showed radiolucency on the coronal aspect of the tooth with blunting of the root apex. The tooth had a single fused root with a wide canal, suggesting a type I C-shaped canal (Figure 5a). With the findings, the diagnosis was symptomatic irreversible pulpitis with apical periodontitis, and nonsurgical root canal treatment was planned.

Case management 5
Under rubber dam application, an access cavity preparation revealed an oval canal which was in accordance with Fan anatomic classification “category V” (C5) (Figure 5b). The root canal width in the coronal part lacked the usual taper, so the canal was shaped with circumferential filing using hand K and H files and apical tug-back achieved with master cone 60 size 4 % taper (Figure 5c). The lateral condensation technique was chosen as the teeth were expected to have resorption (Figure 5d). Core restoration with adhesive resin followed by crown placement. After one year follow-up period, a significant reduction in the size of periapical radiolucency was noted (Figure 5e).

DISCUSSION
The C-shaped canal has a distinctive canal configuration. The intra-oral radiographs are frequently used to evaluate the architecture of the root canals. Most intraoral radiographs show C-shape canals as (a) fusion or the close vicinity of two roots, (b) a large distal root canal, (c) a small mesial root canal, and (d) a bizarre image of a third canal in the middle area.9 Preoperative radiographs from multiple angles and supplementary images, such as bitewings, panoramic or contra-lateral dental radiographs, and CBCT, are essential to identify them. Clinical identification of C-shape canals involves clear, observable criteria, including the structure of the pulp chamber’s floor.2 Before days used, Krasner laws for finding pulp chamber and canal orifice: „principle of color change“ and „principle of orifice location“.9,10 Nowadays with magnifying devices, we can observe the pulp chamber floor clearly. In order to prevent perforations, the aperture of the orifice, enlarged during the initial stages of treatment, should not be too deep towards the apex. At the same point, GG drills are not to be utilized to prepare the mesio buccal and isthmus areas on the buccal aspect after the orifice position because they may result in over-preparation and perforation.11 At thinner lingual walls of mandibular molar C-shape canals, there is a greater risk of root perforations.12,13 Debris and pulp tissue typically remain inside continually C-shaped canals, as demonstrated by Melton et al.9 Therefore, for adequate disinfection, use of Hedstrom files, irrigating with large amounts of 5.25% NaOCl, and circumferential filing along the sides of the canal are particularly beneficial. Although many cases have been encountered in previous literature, none reported with management of all categories of C shape morphology. Case 1 showed mesial canals separated by an imperceptible isthmus. Since a file could not pass through the isthmus on the pulpal floor, the preop radiograph showed a small dentin fin was present and that canals merged below the isthmus. Hence ultrasonic tips were used to enlarge, followed by copious irrigation with sodium hypochlorite. The canals were prepared as mesial and distal canals. In cases 1 and 2, anti-curvature filing with hand k files was preferably done away from the furcation in order to protect the thin dentin isthmus from perforation.14 Better tactile sensitivity was achieved by circumferential filing, and sodium hypochlorite agitated using an Endo Activator improved irrigant penetration. In a C-shape canal, more cleansibility may be possible with higher irrigant volume and deeper penetration using small instruments activated by sonic or ultrasonic waves.15 The mesio lingual and distal canal spaces were prepared and obturated separately in case
Table 3. Review of Different methods and techniques used for the management of C-shaped canals.

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Diagnostic and Special techniques used</th>
<th>Findings, differences, and variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinanoglu A (2014)</td>
<td>CBCT</td>
<td>OPT usage can assist in recognizing and diagnosing C-shaped root canal systems. Radicular fusion or proximity is a characteristic feature of C-shaped canal systems. Nonfused root appearances should also be considered suspicious.</td>
</tr>
<tr>
<td>Sanjay Chhabra (2014)</td>
<td>Dental operating microscope</td>
<td>Clinically, when a C-shaped canal system is observed, one cannot assume that such a shape continues throughout its length. The prognosis of such complex canal anatomies can be improved by the simultaneous use of sophisticated techniques such as surgical operating microscope and CBCT.</td>
</tr>
<tr>
<td>Summayah Khawaja (2021)</td>
<td>CBCT</td>
<td>Wide variations of canal configuration are observed in the mesial root of mandibular second molars. Moreover, specific types of morphological change in the root canal system of C-shaped molars were observed and described for the first time. The results of this study emphasize the significance of knowledge of root canal morphology besides using advanced technology in developing modified clinical approaches to treat these cases successfully.</td>
</tr>
<tr>
<td>Flávia A. Plazza (2022)</td>
<td>Passive ultrasonic irrigation and negative pressure</td>
<td>PUI in three cycles of 20 s (NaOCl-EDTA-NaOCl), two cycles of 60 s (EDTA-NaOCl), or one cycle of 60 s (NaOCl) was more effective at removing debris and increasing the exposure of the dentinal tubules.</td>
</tr>
<tr>
<td>Ramya Ragu (2017)</td>
<td>Calcium hydroxide as an intracanal medicament</td>
<td>Combination of 0.2% Chitosan and ultrasonic agitation results in a lower amount of Ca(OH)$_2$, remnants than 17% EDTA, and 20% Citric acid, irrespective of the type of vehicle present in the mix.</td>
</tr>
<tr>
<td>Pawar AM (2017)</td>
<td>CBCT</td>
<td>Fused roots with C-shaped canals were rare and demonstrated significant variations from the coronal to the apical third.</td>
</tr>
<tr>
<td>Avi Shemesh (2017)</td>
<td>CBCT</td>
<td>CBCT is an efficient three-dimensional radiographic examination for C-shape root canal configuration evaluation. CBCT may help the clinicians during clinical work in considering appropriate cleaning, shaping, and obturation technique according to the characteristic of C-shape root canal configuration.</td>
</tr>
<tr>
<td>Won-Jun Shon (2011)</td>
<td>A retrospective study- to assess preoperative periapical lesion's impact on the success of intentional replantation.</td>
<td>Root canal treatment failure on the C-shaped mandibular second molar can be predictably treated by intentional replantation regardless of the presence of the periapical lesion.</td>
</tr>
<tr>
<td>Katia R. Vaz de Azevedo (2019)</td>
<td>CBCT</td>
<td>Reinforce the need for advanced technologies, including the operating microscope and instruments specially designed for the preparation of oval or flattened canals for the treatment of C-shaped canals.</td>
</tr>
<tr>
<td>Mrinalini M (2023)</td>
<td>C-shaped root canal using thermoplastised obturation with a modified gutta-percha cartridge design- Case report</td>
<td>An operating microscope is recommended, and CBCT helps determine the canal course throughout the root length. The side-vented design of the cartridge is beneficial.</td>
</tr>
<tr>
<td>Gunjan Gautam (2017)</td>
<td>Endoactivator And Diode Laser-Assisted Disinfection for Treating C-Shaped Canal-Case Report</td>
<td>C-shaped canals were successfully treated using technology like endoactivator and diode laser for irrigation and disinfection of the root canal system.</td>
</tr>
</tbody>
</table>

4. Although they can occasionally be merged to form a single circular or oval-shaped canal, as seen in our third case, these canals are always distinct and independent from the apex, which should be confirmed with working length radiographs taken at different angles. When the buccal and lingual canal walls are so thin at mesial sites especially presented with curvatures as in our case 4, the biomechanical preparation of a C-shaped root canal should be performed with caution as it can result in lateral perforation. Intracanal medicament was placed in all these cases which also rendered significant healing of periapical lesions. For canal imperfections,
the conventional cold lateral condensation with thermoplasticized GP approach is advised. Both methods were applied in these cases to produce greater outcomes and three-dimensional sealing into this intricate anatomy. The thermoplasticised GP flows into the intricate anatomy, thereby sealing the fins, isthmus, and interconnections. Case 4 presented with high difficulty index S-shape morphology analyzed using Cunningham’s and Senia’s method. After initial negotiation, Hyflex files were pre-curved according to the curvature as they tend to maintain the original canal curvature. Case 5 was managed with difficulty as the canal was exceptionally wide with an ongoing resorption process. Special consideration to cold lateral compaction was given in case 3 and case 5 as there was continuing resorption process. Despite the poor prognosis, the periapical lesion resolved in case 1 and 5. The chamber retention restorations and adhesive core restorations will be advocated in these circumstances as this morphology is accompanied by multiple interconnections. During surgical intervention, the intercanal connections or abnormalities along the root length can present challenges for retro preparation and retro filling. All of these cases were managed non-surgically using dental loupes (Zumax Loupes-3X) and it was very helpful in managing this varying anatomy as they aided especially in visualizing unusual pulpal floor. Henceforth, for endodontic therapy to be successful, it is crucial to understand the various potential changes in the internal architecture of teeth and future considerations should be given for managing these areas by analyzing the different techniques and choosing the appropriate among them.

CONCLUSION

This case series showed managing different C shape canal anatomies successfully using different instrumentation and obturation techniques. The cleaning and shaping process should always follow the canal anatomy so that the canal shape is maintained at the same point the primary and secondary curvatures, and thin interconnections are negotiated, prepared, and sealed. It also facilitates the understanding of this complex anatomic morphology and the improved treatment procedures with the help of magnifying aids; illumination is required for the success of endodontic therapy.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this case report.

INFORMED CONSENT

All the patients were informed about the diagnosis, treatment plan, and procedures, and a valid consent was received for submitting the clinical photographs and information to the respective journal.

PATIENT PERSPECTIVE

The patients were relieved of their discomfort and were satisfied with the treatment.

REFERENCES


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