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Review Article

Aberrations in Root Canal Morphology

Mohamed Hany Ahmad Abd Elghany[1]*, Esrraa Atiah A Alzahrani[2], Nouran Hassan A. Alhazmi[2], Hadeel Ibrahim M Abughaniah[2], Afnan hashim M Niaz[3], Sarah F Alhazmi[4], Bahyah Zake O Helmy[5], Sara Faiz A Jambi[5], Lama Mohammed Adwan[5], Waad Omar S Aldabyani[5], Mada Adil Raqban[6]

[1]*Cairo University, Egypt*

[2]*Ministry of Health, Saudi Arabia*

[3]*Al Hada Armed Forces Hospital, Saudi Arabia*

[4]*National Guard Hospital, Saudi Arabia*

[5]*Ibn Sina National College, Saudi Arabia*

[6]*Alfarabi Medical College, Saudi Arabia*

***Corresponding Author:** Mohamed Hany Ahmad Abd Elghany, Cairo University, Egypt.

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Abstract

Introduction: To have a successful root canal therapy, the most crucial part is to have complete knowledge about the root canal morphology and the aberrations that are associated with it. A thorough understanding of the canal helps the clinician to effectively disinfect and shape the canal, reducing the chances of failure of the endodontic procedure due to residual bacterial infection. Due to the advent of the current armamentarium used in dentistry, we can perform a successful endodontic treatment in the most complicated cases.

Aim of Work: This study aims at describing the root canal anatomy of all the teeth and all the aberrations associated with it to help the clinician have a thorough knowledge of the Canal system.

Methodology: The review is a comprehensive research of Google Scholar and PubMed from the year 1985 to 2019.

Conclusion: A complete knowledge of the root canal system and all the variations present in it is of utmost importance in the success of an endodontic procedure. For thorough cleaning and shaping, all the canals must be located and isolated. To achieve a 3D seal after obturation, it is vital that all the canals are filled, avoiding any leakage through any canal, leading to failure of the endodontic procedure. Every tooth has different anatomy and knowing all the teeth anatomy is not possible, but to avoid missing of any canal, good preoperative X-rays should be taken in case any canal aberration is detected.

Keywords: *Canal Aberrations; Supernumerary Root; Radix Entomolaris; Extra Root Phenomena; Radix Paramolaris; C Shaped Canals*

Introduction

For a successful root canal therapy, the essential part is to have complete knowledge about the root canal morphology and the aberrations that are associated with it. A thorough understanding of the canal helps the clinician to effectively disinfect and shape the canal, reducing the chances of failure of the endodontic procedure due to residual bacterial infection. Radiographic evaluation helps the clinician to visualize the number of root canals. Still, the exact angulation of the canal cannot be figured out precisely with just a single angulation

X-ray. Two to three radiographs from different angles help us to find the exact curvature and number variation of the canal. In a study conducted by Nattress., *et al*. it was concluded that radiograph taken from a single angulation does not necessarily show the canal morphology, they radiographed 790 mandibular incisors and used the fast break guideline (that indicates if the canal is disappearing in between it means it can be bifurcating) to show that 1/3rd of the radiographs did not show the furcation hence leading to failure and emphasizing the fact that multiple radiographs should be used in such complicated cases (Figure 1) [1].

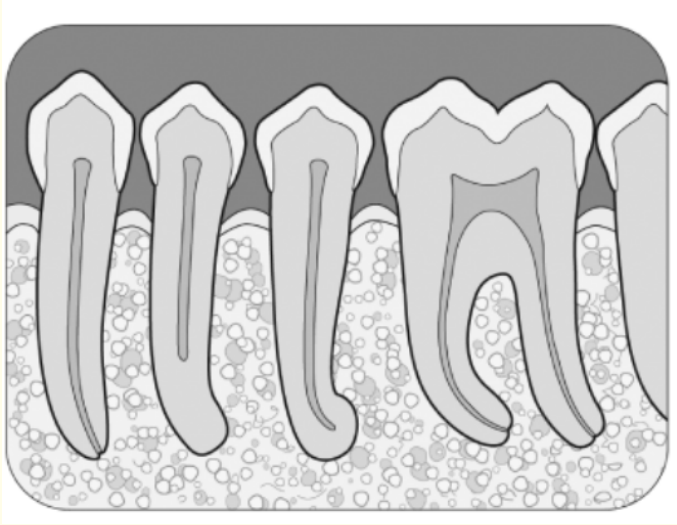

Figure 1: *Schematic representation of mandibular premolar, which shows the disappearance of the canal in the middle of the root depicting bifurcation of the canal that cannot be visualized by a single radiograph [2].*

Due to the advent of the current armamentarium used in dentistry, we are able to perform a successful endodontic treatment in the most complicated cases. Various modalities like Multiple radiographs, ultrasonic tips used for troughing of the canal, use of dyeing agents for the canal like 1% methylene blue, champagne bubble test using 1% sodium hypochlorite. One of the most useful tools for locating canals and variations of the canal are Dental operating microscopes (DOM), it not only enhances the magnification but also provides additional light and visibility. Various studies have shown a significant increase in locating canals with the use of microscopes [3]. Wu., *et al*. [4] concluded in their research that using DOM increased the rate of success in the case of various complicated root canal anatomy. Cone Beam Computed Tomography (CBCT) is also very useful in the detection of any canal anomaly. Lin., *et al*. conducted a study on a total of 1412 incisors. They concluded that multiple canals were found in the incisors and were easily visualized using CBCT, which also showed the exact position of the furcation [5].

The success or failure of the root canal procedure is directly proportional to the complexity of the canal and frequency of the missed anatomy, and hence a complete knowledge of the root canal system of the tooth is of utmost importance to perform a good cleaning and shaping followed by a 3D obturation of the canal to seal the apex. This review reports the aberrations seen in the canal, thereby providing complete knowledge of the canal anatomy in order to reduce the chances of failure of the procedure [5].

Maxillary teeth

Maxillary central and lateral incisors

Maxillary central and lateral incisors generally present with a single canal running along the length of the root located in the center of the tooth. the incidence of any variation in the root canal anatomy of central and lateral incisors is 2 and 10%, respectively [6]. In cases where more than one canal is present, the canal follows various configurations like Vertucci class II, Class IV (Figure 2), or developmental anomalies like Dens invaginatus (Figure 3) fusion, gemination [7]. More than two canals have also been reported in central incisor by Walvekar and Mangani, who reported 3 and 4 canals, respectively [8,9].

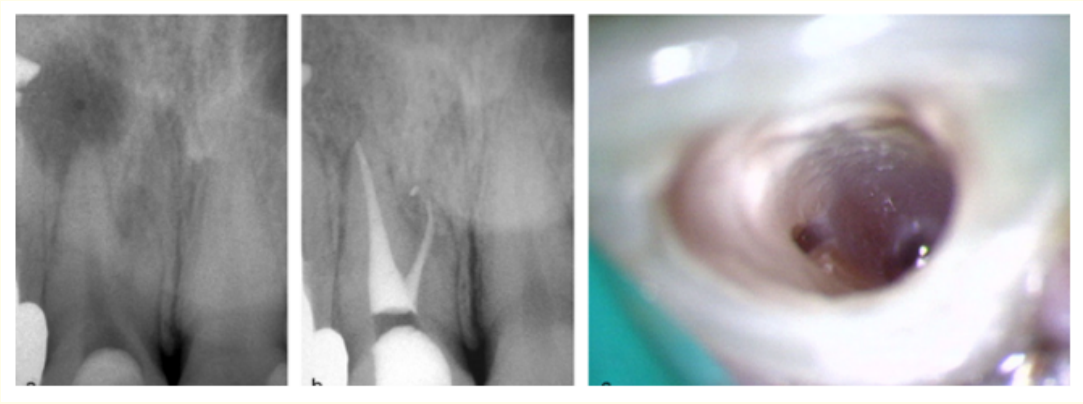

Figure 2: *Central incisor with two canals. The clinical picture shows the location of the two orifices [10].*

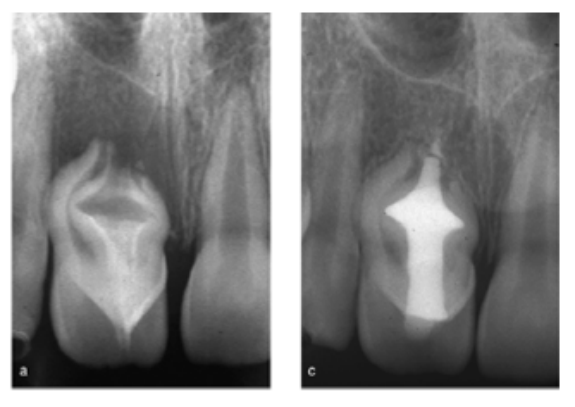

Figure 3: *Developmental anomaly like dens in dente seen in central incisor [10].*

Maxillary canine and premolars

Maxillary canine generally shows a simple one canal configuration. Rare variations have been seen like the case report presented by Bolla., *et al*. in 2011, where they treated two rooted maxillary canines [11].

Maxillary Premolars have generally shown to have single roots with two canals that have separate routes and openings in the root. The different variations seen in Maxillary premolar are shown in table 1 [2,10].

Tooth	Variation	Occurrence
Maxillary First Premolar	Vertucci type IV	60 - 65%
	Vertucci Type V	6 - 7%
	Three Canals: Mesibuccal, DistoBuccal, Palatal called Radiculous	5 - 25%
Maxillary Second Premolar	A single Canal centrally in one root	38 - 48%
	Two canals that join present in one root	20 - 22%
	Vertucci Type III	5 - 10%
	Vertucci type V	6 - 9%
	Two canals that are seen in two separate roots	10 - 20%
	Vertucci Type VI	2 - 5%
	Vertucci Type VII	1 - 2%

Table 1: *Variations in the canal anatomy in case of maxillary premolar [2,10].*

The incidence of the missed canal is very high in cases of maxillary molars; hence extra caution should be taken while treating such cases. A minimum of two radiographs in mesial and distal angulation should be taken. A study by Sieracki., *et al*. concluded that the radiographic image of the premolar must be studied well, and if the MD width of the mod root region is equal to that of the crown of the premolar, it increases the chances of occurrence of three canals in such cases [12].

Maxillary molars

The anatomy of molars be it Maxillary, Mandibular, First, or Second is always highly complicated. Various reasons that affect the anatomy of molars are ethnicity, developmental variations, etc. In a study conducted by Cleghorn., *et al*. [13], he examined around 400 Maxillary molars, out of which 96% had three canals, which is the MB, DB, and Palatal. 3.8% of teeth showed only two canals, and around 5% of the teeth showed fusion of the roots. Cleghorn also studied the mesiobuccal root of the maxillary first molars separately to study the incidence of MB2 canal (Second Mb canal in Mb root) and found that around 57% of the teeth had an MB2 canal. The DB root showed a single canal in most of the cases with 2% cases showing two canals. Palatal roots also showed a single canal in almost 99% of the cases (Figure 4). Second, Molars have almost the same pattern of the canal and root distribution as first molars with a slightly decreased occurrence of MB2 canals and higher C shaped canal anatomy compared to First Molars [10,14].

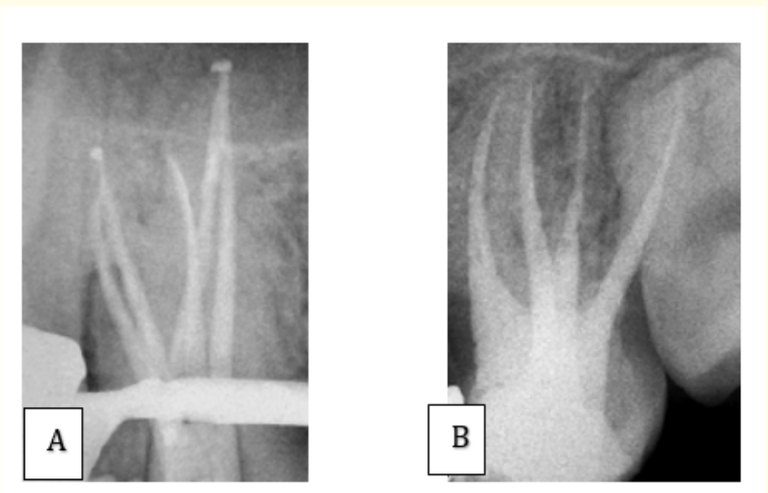

Figure 4: *A: Maxillary first premolar with 2 DB and 2 palatal canals. B: Second molar with 2 palatal canals. [10].*

C-shaped canals in Maxillary molars are very rare, but not an impossible phenomenon, Martins., *et al*. [14] studied a total of 2227 teeth and concluded that 1.1% of the first molars and 3.8% of second molars had shown a C-shaped morphology. They further said that even though the evidence of C shaped canals is less, the complexity is high and classified the c shaped canals in 5 groups [14]. The morphology of the maxillary molar canal should be studied thoroughly during an endodontic procedure, various adjuncts like CBCT, Dental Loupes, Dental Operating microscopes when used during the clinical procedure enhance the quality of root canal that has been done [15].

Mandibular teeth

Central and lateral incisors

The root canal anatomy of central and lateral incisors is more complicated than what it appears on the radiographs. The periapical radiograph more often shows a single canal in the center of the tooth, whereas, in reality, many variations are seen in the root canal morphology. In a study conducted by Vertucci on 300 incisors, he concluded that two canals were found in 30% of central and 25% lateral incisors. When the canal configuration was studied, it was found that out of 1025 teeth, 12% of cases have to join canals, and 3% cases showed two independent canals. Two new canal configuration was seen by Kartal [16] namely; a 2-3-1 and a 1-2-3-1 where two separate canals are seen till the mid root, at this point the lingual canal divides and all the three canals exit by a single apical foramen and where a single canal runs till the mid root divides into two which again join into one canal and divide into three exits at the apical foramen (Figure 5) [16]. A good access cavity with enough extension in the incisor gingival region using magnification helps the clinician to find all the canals. Diagnostic tests like CBCT also increase the chances of finding new canals [17].

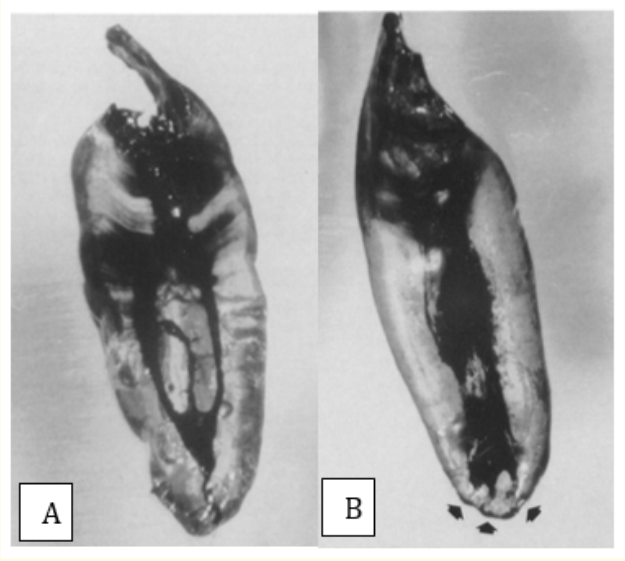

Figure 5: *Two new configuration seen A: 2-3-1 B: 1-2-3-1 [17].*

Mandibular canines

A single canal in a single root is the most common configuration seen in Mandibular canine. Variations like 2 canals exiting by a single foramen are seen 4.9%, 1.2% teeth showed 2 canals with 2 foramens. Mandibular canine with two roots and having three canals is also

seen. In a study conducted on the Iranian population using CBCT, it was seen that the most common pattern was Vertucci Type I (89.7%), Type III (5.7%) Type II (3.7%) followed by Type V (1%) [18].

Mandibular premolars

First premolars

Cleghorn in 2007 studied the anatomy of 6700 teeth and concluded that 98% had a single root, two roots were seen 1.8%, three in 0.2%, and four in 0.4% [19]. The number of canals varied in the tooth, single canal was seen in 75.8%, 2 or more canals in 24.2%. Comparing the results of various studies, it was seen that Ethnicity played a major role in the variation of canal morphology. In a Chinese study conducted using CBCT, it was seen that 98% first premolars had single root 2% had two roots, 87.1% presented with the single canal, 11.2% -2 canals, 0.6% -3canals. C shaped canals were also seen in premolars with an incidence of 11.2% [20]. Other canal aberrations seen in Premolars were 2 canals present in two roots, 3 canals that are seen in three separate roots, 3 canals in one root, and one canal that separates mid root into three separate canals [10] (Figure 6).

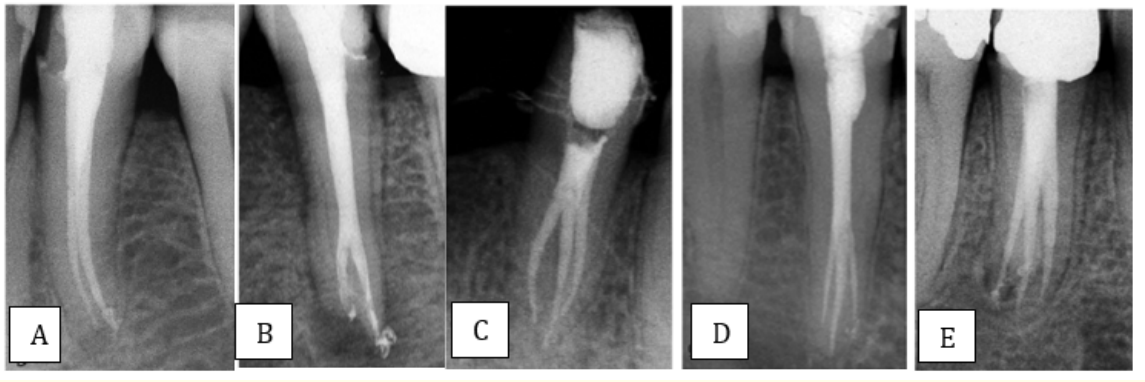

Figure 6: *Mandibular premolars A: 2 canals in a single root, B: 2 canals in two roots, C: 3canals in two roots D: 3 canals in one root, E: 3canals in three roots [10].*

Second premolar

One root with a single canal is seen 97.2% of the teeth and 2 canals seen in 2.2% of the cases [20]. C-shaped canals were seen in 0.6% cases in second premolars. Rarely even three canals have been in second premolars in 0.4% cases. In a systematic review of Iranian population, it was seen that 82% premolars followed Vertucci class I configuration followed by Type III in 6.25%, Type II in 5.32% and Type IV in 4% [21]. Mandibular premolars often are very difficult to perform a root canal on as the complexity of canals is very high in these teeth. Preoperative Radiographs and CBCT is of utmost importance in these cases in case there is a doubt about the canal anatomy [21].

Mandibular molars

Mandibular molars are the first teeth that erupt in the permanent jaw and hence are more prone to caries for a longer duration of their existence. The most occurrence of a canal in mandibular molars is two separate roots. The mesial root which contains two canals and one distal root that has a single canal which is mostly large elliptical or oval in structure, these canals are mostly straight in angulation and have a small distal curve in the end. The mesial canals, on the other hand, are curved throughout their course and are narrower compared

to distal canals. 90% of the canals remain separate throughout their course, but exit through the same foramen, remaining 10% have different foramen. Various classifications have been given for Mandibular molars by Vertucci, Weine and Gulabiwala [22] (Figure 7).

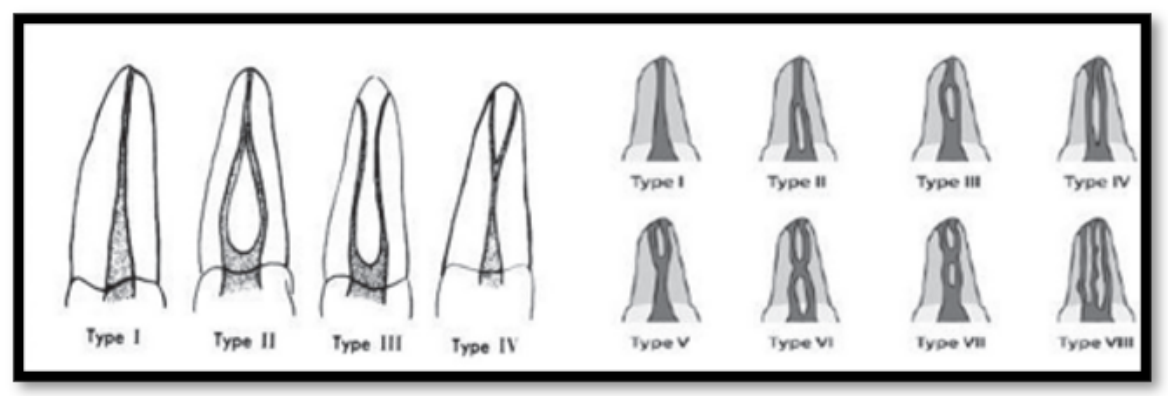

Figure 7: *Canal configuration classified by Wein and Vertucci [22].*

The incidence of two roots with three canals has been seen as the highest with two mesial canals seen in 56% of the cases, two canals with a single exit seen in 28% cases. Single canal in 12% and three canals in 1% of the cases [23].

Extra canal phenomena

This phenomenon explains that due to the deposition of dentin during maturation of the teeth, there are high chances that a third canal will be formed inside the root since the distal root has a larger dimension, chances of dentin deposition reduces in these canals and is higher in mesial canals leading to the formation of Middle Mesial Canals [24]. In a study conducted by Nosrat., *et al*. they studied 75 mandibular first and second molars and concluded that 20% of teeth had a negotiable middle mesial canal. The middle mesial canal, when present, is seen in the middle of the two existing mesial canals, the orifice is more often than not covered the projections from dentin. The distal root of mandibular first molar has a single canal in 70% of the cases, two canals that are separate are seen in 5%, two canals that join into one exit is seen in 15% and a 1-2-1 configuration in 2% of the cases. The second canal in the distal root may be suspected in cases where the canal opening is not present in the center of the pulpal floor, the use of Magnification, preoperative X-rays in different angulations, and CBCT are very helpful in the diagnosis of extra canals [24].

Supernumerary roots

A.E Taylor first described three rooted mandibular molars. Turner., *et al*. conducted a worldwide survey to check the incidence of supernumerary roots and concluded that out of 11,318 individuals who were included in the survey, 3 roots were most commonly seen in Asian populations (25%). Radix Entomolaris (RE) is the most common presentation of supernumerary teeth. The extra root present is seen distolingually, making it an entomolaris. It is fixed to the distal root, and the canal can vary from being a full-blown mature canal to an underdeveloped small canal that looks like an extension of the distal canal. The incidence of radix entomolaris can vary from 3 - 5%. Carlsen and Alexandersen have described 4 different types of RE (Figure 8) [25].

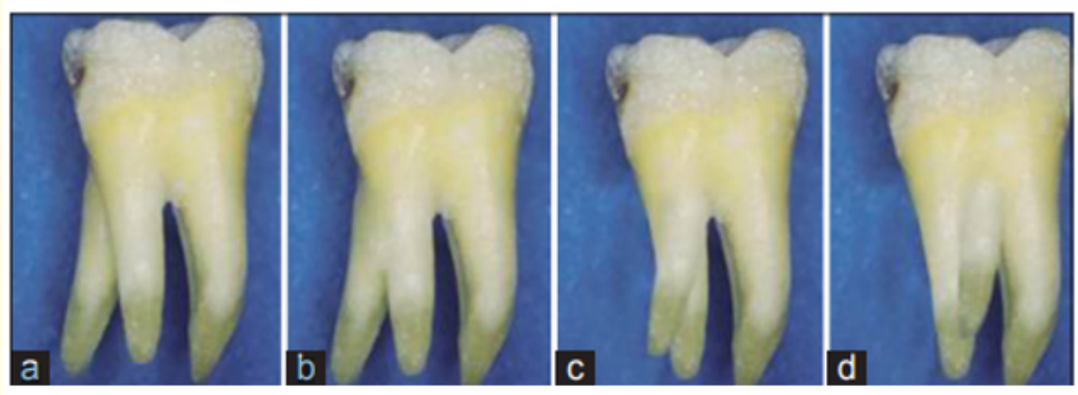

Figure 8: *Classification of RE. Type A: RE is located in the distal area and has two normal root component. Type B: RE is located in the distal area with One normal root component. Type C: cervical part of RE located in the mesial area. Type AC: RE is located in the center between mesial and distal roots [25].*

Radix paramolaris: When the extra root is located buccally, it is termed as Paramolaris. The occurrence of RP is very rare in mandibular first molars (less than 0.5%), and it has been mostly seen in the second and third molars. In case the outline of the distal root is not clear in the radiograph, an extra root can be suspected, and an angulated x-ray at 30degrees should be taken to confirm. In case an extra cusp is seen or the distolingual lobe is large, that indicates an extra root [22].

C shaped canals

Cooke and Cox first documented C shaped canals in 1979. The cross-sectional view if such canals look like a C and is a single continuous orifice with a 180-degree arc. It is generally seen in roots that have undergone fusion in the buccal and lingual aspects. C shaped canals prove to be a huge challenge during cleaning and shaping owing to their large size and numerous fins. C shaped canals are not very easy to discover on radiographs, and clinical recognition after access opening followed by a CBCT gives a full proof idea of its existence. Ultrasonic irrigation followed Lateral Condensation and thermoplasticised obturation techniques are used for the cleaning shaping and obturation of such canals (Figure 9). In a study conducted by Shemesh., *et al*. where they examined 1465 Mandibular 2nd molars and 1229 first molars and concluded that prevalence of 0.16%in first molars and 4.6% in second molars [26]. The incidence of C shaped canals differ according to ethnicity. A study conducted on the Chinese population showed that out of 542 teeth tested, 39.8% showed C shaped canals in second molars. C shaped configuration can be divided into five groups, as explained by Fan., *et al*. in 2004. He used microcomputed tomography to assess 58 mandibular second molars and studied the cross-section at 0.5 mm interval (Table 2) [27].

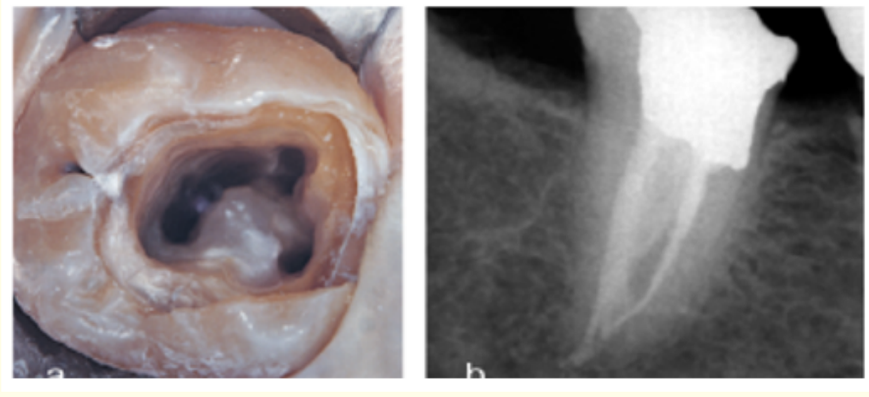

Figure 9: *Access cavity of a C shaped molar followed by obturation [10].*

Type	Description
C1	A single C which is not interrupted or divided.
C2	A semicolon shaped C
C3	2 - 3 separate canals which have an isthmus present between them
C4	A single oval canal
C5	The lumen of the canal not visible

Table 2: *Fans classification of C shaped canals [27].*

How to prevent missing of canal aberrations

Radiographs: Multiple radiographs can be taken at different angulations whenever a canal aberration is suspected [10].

Good access opening: A good access opening following the laws of access opening should be done, and all the dentinal projections from the pulp chamber should be removed using ultrasonic tips [10].

Magnification: Magnification in the form of Dental Loupes and dental operating Microscopes acts as a very useful adjunct to prevent missing of canal aberrations [10].

CBCT: A preoperative CBCT gives a 3D image of the tooth, and all the canals are visible in the cross-section, thus reducing the chances of missing any canal [10].

Conclusion

Complete knowledge of the root canal system and all the variations present in it is of utmost importance in the success of an endodontic procedure. For thorough cleaning and shaping, all the canals must be located and isolated. To achieve a 3D seal after obturation, it is important that all the canals are filled, avoiding any leakage through any canal, leading to failure of the endodontic procedure. Every tooth has different anatomy, and knowing all the teeth anatomy is not possible, but to avoid missing any canal, good preoperative X-rays should be taken in case any canal aberration is detected.

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