

ABERRANT ROOT CANAL ANATOMY: A REVIEW

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Successful endodontic treatment involves accurate diagnosis, good understanding of the biological principles and excellent execution of the treatment. To be able to execute an excellent treatment, it's imperative that the clinician has comprehensive knowledge of the root canal anatomy and the know-how to locate and treat this anatomy.

Many outcome studies conducted over the past few decades showed incomplete debridement and disinfection of root canal space as the most important factor in endodontic treatment failure (1,2,3). Missed canal in the initial treatment as a significant cause of root canal failure was shown by Hoen et al (4). They also showed a significant relation between an asymmetrical obturation in a root space and the incidence of a missed canal in an initial treatment.

Methodology:

Root canal anatomy is studied by both in vitro and in vivo methods. In vivo methods include clinical treatment of a tooth followed by radiographic evaluation of the root canal anatomy. In vitro methods include

1. Direct observation
2. Microscopic observation
3. Macroscopic sectioning
4. Microscopic sectioning
5. Dyes
6. Filling and decalcification
7. Filling and clearing
8. Radiography
9. Contrasting media (Hypaque)
10. Cone beam Tomography.

Classification:

Weine classified root canal anatomy into 3 types.

Type I: One canal with one orifice and one apical foramen (1-1)



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Type II: Two canals that merge into one and exit as one canal (2-1)

Type III: One canal that divides into two and exit as two canals. (2-2)

Vertucci's classification was more elaborate and it covered 8 types.

Type I	1-1
Type II	2-1
Type III	1-2 -1
Type IV	2-2
Type V	1-2
Type VI	2-1-2
Type VII	1-2-1-2
Type VIII	3-3

Studies with Percentages:

The methodology employed and the criteria used to describe root canal anatomy will decide the percentages of canals found in any tooth. For example Neaverth et al (5) have used "two separate canals could be visualized on radiographic examination (two files or two GP points to no less than a mm short of the length)" as the criteria for two canals in a mesiobuccal root of a maxillary first molar. On the other hand Sempira et al (6) have used the presence of "two canals to at least 4 mm from the apex" in the mesiobuccal root of maxillary first molar to determine the percentage of Mb2 canal. These differences in criteria dictate the great variation seen in the percentages of root canals seen in different studies. However, if one reviews the published evidence certain features of aberrant anatomy stand out in a tooth/ root.

Ethnicity has a significant influence on aberrant anatomy,(26). Radix Entomolaris, an extra distal root in a mandibular molar, is often seen in Oriental and Eskimo populations (23). Similarly 2 and 3 canal premolars are seen frequently in black populations (12,15,27). 'C' shaped anatomy is seen more commonly in Chinese, Korean and Indian populations (22,25).

Bilateral symmetry is a feature of aberrant anatomy. Rarer the aberration, the more common is the bilateral symmetry (28).

Clinical Management of Aberrant Anatomy:

Radiography: Angled views of teeth reveal aberrant anatomy. Angled views allow us to visualize the root anatomy in 3 dimensions so that better assessment of the root canal anatomy is made. It is imperative that at least 2 angled views shall be taken before attempting endodontic treatment.

Tooth	Feature
Maxillary Central Incisor	Over 60% lateral canals (7)
Maxillary Lateral Incisor	Lingual curvature Large mid root canal diameter
Maxillary Canine	Single canal (9) Lateral canals
Maxillary First Premolar	Three canals with two canals in the buccal root (mesiobuccal, distobuccal and palatal canals) (11,12)
Maxillary Second Premolar	Three canals with two canals in the buccal root(mesiobuccal and distobuccal and palatal canals) (12)
Maxillary First Molar	Two mesiobuccal canals in majority of cases. Occasionally three mesiobuccal canals, two distobuccal and two palatal canals (16,17,18,19)
Maxillary Second Molar	Two mesiobuccal canals in majority of the cases. 'C' shaped canals (30)
Mandibular Incisors	Two canals that join apically. Occasionally 2 separate canals (8)
Mandibular Canine	Two canals. Buccal and lingual (9)
Mandibular First Premolar	Two to three canals. Mesiobuccal, distobuccal and lingual. 'C' shaped anatomy occasionally (10,13,15)
Mandibular Second Premolar	Two to three canals. Mesiobuccal, distobuccal and lingual. 'C' shaped anatomy occasionally (14,15)
Mandibular First Molar	Four to six canals. Three mesial canals and three distal canals. Radix entomolaris with a separate distolingual root (20,21,23,24)
Mandibular Second Molar	Four to five canals. Three mesial canals. 'C' shaped anatomy(22,25)

Once a canal disappears mid-root, one shall always suspect a bifurcation. Twin periodontal ligament outlines of the root also indicate a broad root and therefore extra anatomy. Guide files are placed in root canals and radiographs are taken to reveal the symmetry of the guide file to the external contours of the root. If there is an asymmetry, it often means hidden anatomy. Also guide files reveal any hidden curvatures that are in multiple planes. (Fig 1-3)

Clinical Anatomy: Contour of the gingiva often indicates aberrant anatomy. For example, broad buccal gingiva in a maxillary or mandibular premolar may suggest a broad buccal root. This in turn may suggest

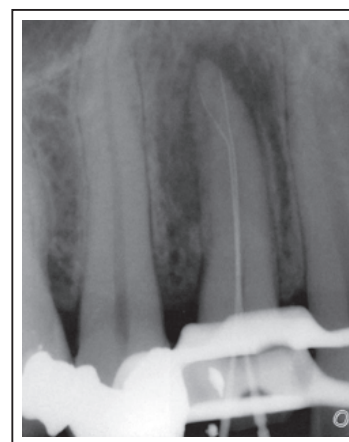


Figure 2: Distobuccal canal located.

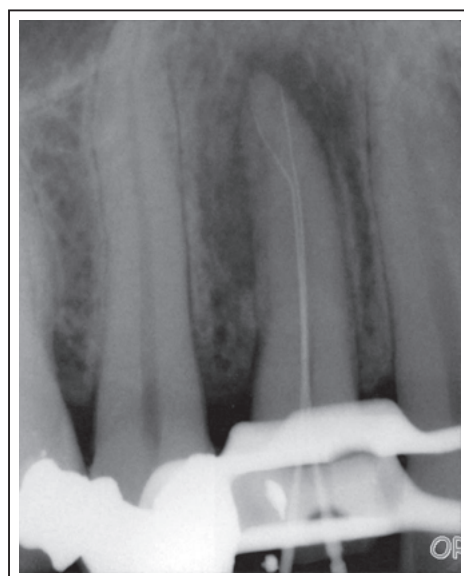


Figure 1: Off-centre appearance of guide file in the buccal and palatal roots of maxillary premolar.



Figure 3: All three canals obturated.

the presence of two canals in the buccal root. Gingival recession some times may reveal a bifurcation of the buccal root indicating two canals in maxillary and mandibular premolar teeth (fig 4). Teeth that have an extra cusp or an aberrant clinical crown may indicate aberrant pulp chamber and root canal anatomy (fig 5-8).

Magnification: A surgical operating microscope (S.O.M) (www.globalsurgical.com) is highly recommended to perform all endodontic therapy (fig 9). An S.O.M not only magnifies the chamber anatomy in great detail but also allows great amount of light to illuminate the pulp chamber. This allows the operator to understand the subtleties of pulp chamber anatomy, visualize the pulpal floor and locate root canal orifices. This becomes even more useful when there are pulpal floor calcifications blocking canal orifices (31). Significant amount of preparation of the pulpal floor is required to identify and carve calcifications away to locate root canal orifices. The use of an SOM greatly facilitates this process and makes endodontic therapy more predictable and less stressful to the operator.

Size and extension of access plays an important role in the predictable location of all root canals. Modified access extensions are required to identify canals like

Mb2 in a maxillary molar, Middle mesial canal in the mesial root of a mandibular molar, second buccal canal in a maxillary premolar and the radix entomolaris in a mandibular molar. Initial access shape is determined by the shape of the pulpal floor (32). Then, appropriate extensions are made to facilitate the location and straight line access into all canals. Complete unroofing of the chamber roof is a basic step in access design and yet many clinicians err by not removing the roof of the chamber (fig10a,10b).



Figure 4: Gingival recession allows to see the bifurcation of the buccal root in a mandibular premolar.

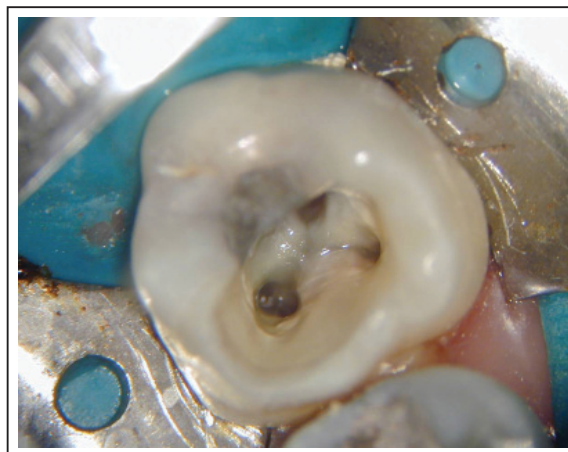


Figure 6: Access reveals two palatal canals and one mb canal that bifurcated.



Figure 7: Preoperative radiograph of the molar.

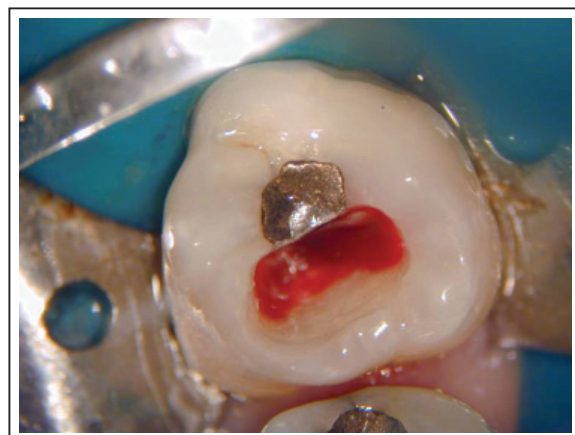


Figure 5: Extra cusp on the distal in a maxillary second molar.

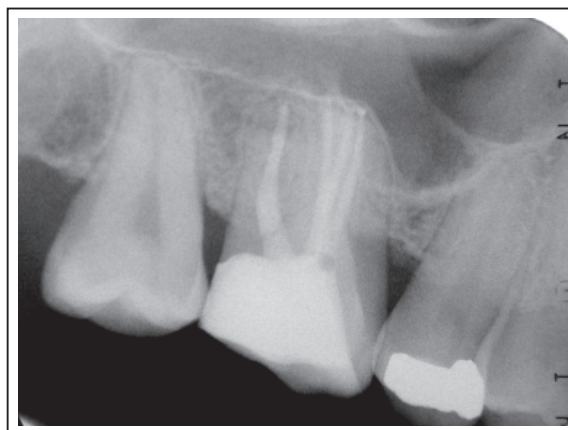


Figure 8: Post-operative radiograph of the molar.

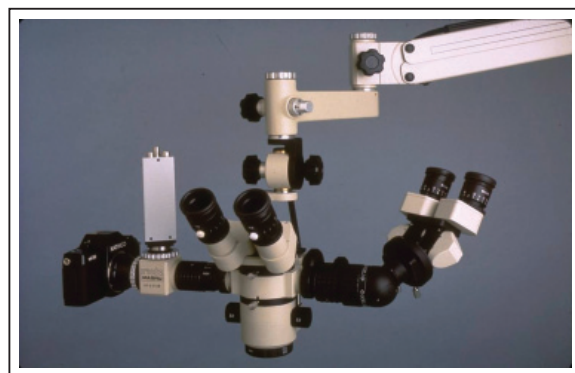


Figure 9: Surgical operating microscope.

Subtle color changes are observed between the coronal dentin and the pulpal floor dentin under the SOM. This is useful in the location of the pulp chamber and canal orifices. Pulpal floor is usually is dark gray in color and contrasts from the light colored axial dentin. When access preparations are made this color difference allows the operator to be very precise in removing the axial dentin to expose the pulpal floor. There is also a very subtle difference in color between tertiary dentin and axial dentin. This difference allows the operator to be once again very precise in carving away this irritational dentin to expose the pulpal floor and subsequently canal orifices.

Isthmus: It is the space that connects two or more canals that exist in the same root (29). Isthmus is the frequent location of an aberrant canal (fig 11a-b). Isthmus houses pulp tissue (12a-c). If the isthmus exists only in the coronal third, it should be eliminated to remove the pulp tissue. If the isthmus extends from the coronal to the middle/apical third, it should be

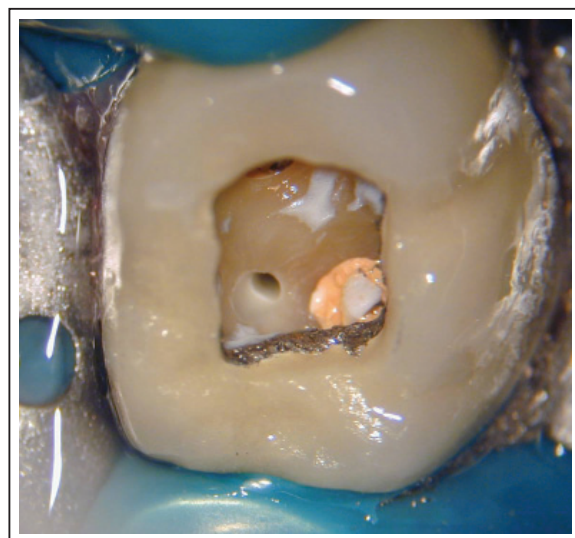


Figure 10a: Roof of the chamber not unroofed in the original treatment.



Figure 11a: Isthmus explored between Mb and ML canals in a mandibular molar.

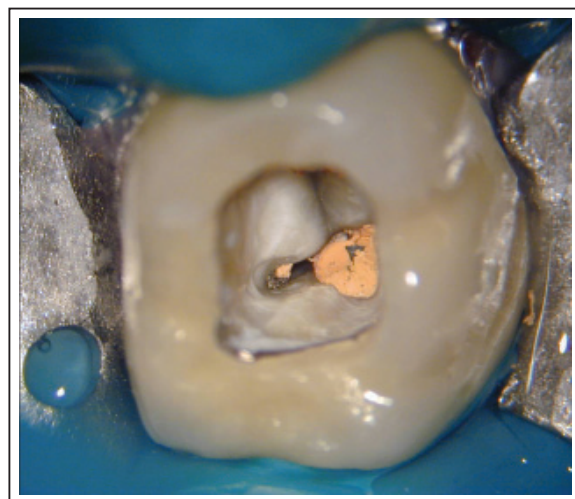


Figure 10b: Complete removal of the roof reveals a second distal canal in a mandibular molar.



Figure 11b: Three mesial canals and two distal canals.

Pulpal Floor: When access preparations are made, coronal dentin is removed to make entry into the pulp chamber space. Often times the pulp chamber space is reduced in size or completely filled with either secondary dentin or tertiary dentin.



Figure 12a: Isthmus between the DB and DL canals in a mandibular molar housing tissue.

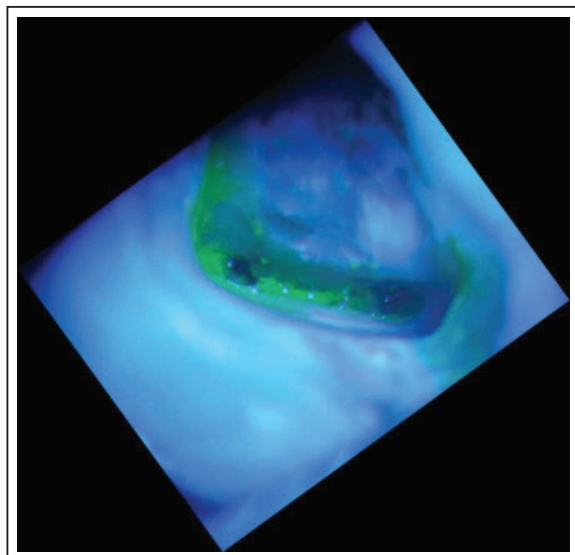


Figure 12b: Ophthalmic dye stains the tissue.



Figure 12c: Tissue removed.

considered as a separate canal and cleaned, shaped and obturated like any other canal.

Some of the instruments used for the purpose of carving the pulpal floor calcifications and troughing an isthmus are the following.

Burs

- ¼, 1/2, #1, #2 Round burs
- LN Burs
- Composite finishing burs
- Munce discovery burs
- (www.cjmengineering.com) (fig 13)

Ultrasonics (www.eie2.com) (fig 14-16)

- CKT D1
- CKT D2
- Ball tip

The idea is to use a flat/round ended bur/ ultrasonic tip to trough the surface to remove the calcifications. Munce discovery burs are used in a low speed hand piece. They offer a significant advantage over the other burs being long, stiff and a thin shank. This allows better

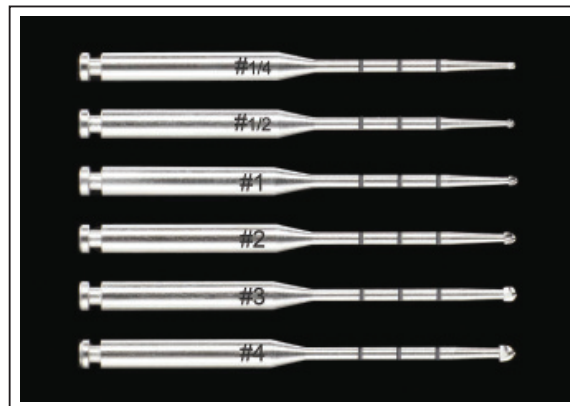


Figure 13: Munce discovery burs.

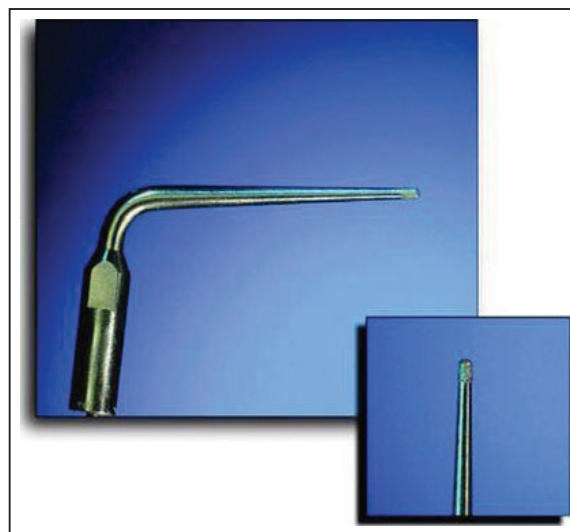


Figure 14: CKT1D ultrasonic tip.

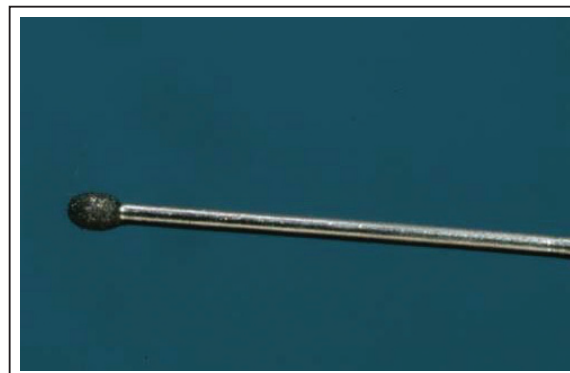


Figure 15: Ball shaped tip.



Figure 16: CKT 2D ultrasonic tip.

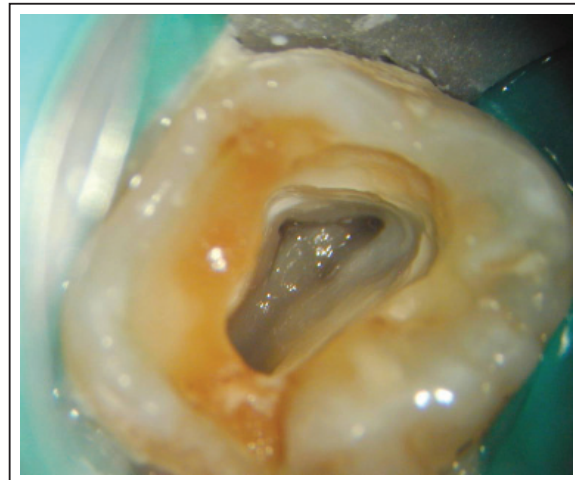


Figure 17a: Initial access in a maxillary molar revealing four canals.

visualization when working deep in the chamber or root. Some of the limitations of this series of burs are in posterior teeth in patients with limited mouth opening. CKT series ultrasonic tips from Eie2 are excellent for both chamber and deep root troughing. They are especially useful in posterior teeth and in patients with limited mouth opening.

Canal Relocation:

All canals in multirooted teeth, exit the pulp chamber at an angle. Once a canal is located, this exit curvature shall be minimized or eliminated. This will create a straight line access to the mid root (fig 17a-b). This in turn facilitates negotiation of the canal to the apex. The following instruments can be used for this purpose.

Burs

- ¼, 1/2, #1, #2 Round burs
- LN Burs
- Composite finishing burs
- Munce discovery burs
(www.cjmengineering.com)

Ultrasonics (www.eie2.com)

- CKT D1
- CKT D2
- Ball tip

Gates Glidden drills

- 4, 3, 2 (sizes 90,70,50)

Niti files

- Access shapers

Dyes can help locating pulp tissue in pulp chamber. Sable seek (www.ultradent.com), methylene blue (www.vista-dental.com) or fluorescein sodium (www.haag-streit.com) are the appropriate choices (33). Dyes stain any vital or dystrophic pulp tissue in the chamber or root canal space. Under magnification this staining guides the operator to the pathway to the pulp canals.

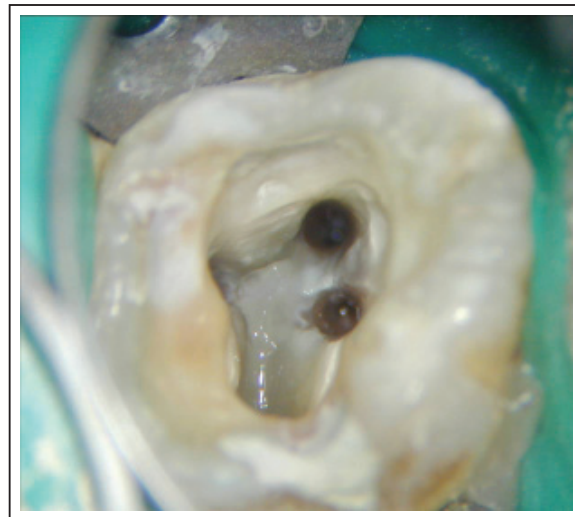


Figure 17b: Final access after the canals are relocated.

Similarly, **transillumination** the pulp chamber with an external fiber-optic light source allows differentiation of sclerotic dentin from normal dentin. This in turn allows precise removal of the sclerotic dentin to locate root canal orifices (fig 18).

Sub chamber bifurcations. In mesial roots of mandibular second molars, buccal roots of maxillary second molars and buccal roots of maxillary premolars, only one canal is seen on making the access. Upon careful troughing of the canal orifice, this single canal is found dividing into two canals apical to the chamber level (fig 19a-b).

Apical bifurcations on the other hand can be seen in any root of any tooth. Adequate coronal flaring and using pre-bent hand files in an exploratory fashion to scout the walls of the root canal often help in the location of the apical bifurcations. Subsequently a straight line access (with in the limits of safety) to the apical bifurcation will help clean, shape and obturate the splitting canals (20a-b).

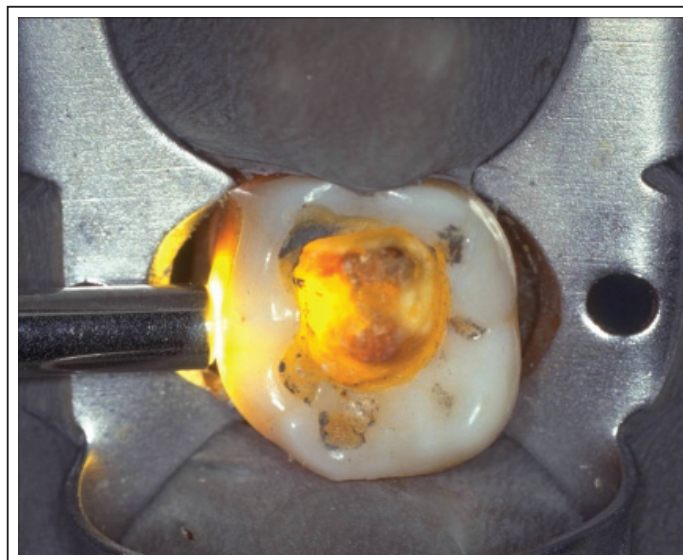


Figure 18: Transillumination reveals dystrophic calcifications in the pulp chamber.

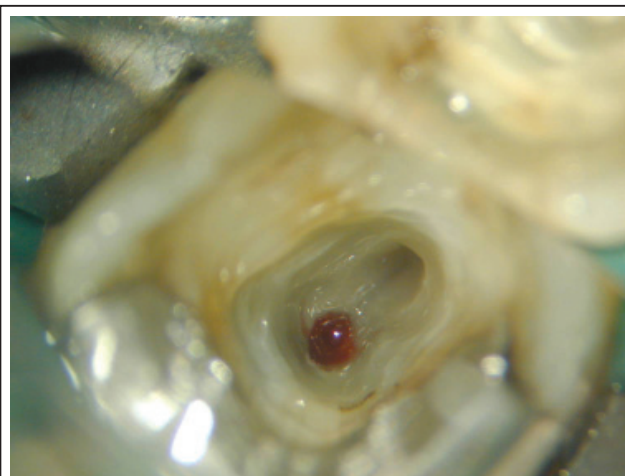


Figure 19a: Initial access in a mandibular molar reveals only one canal in the mesial root.

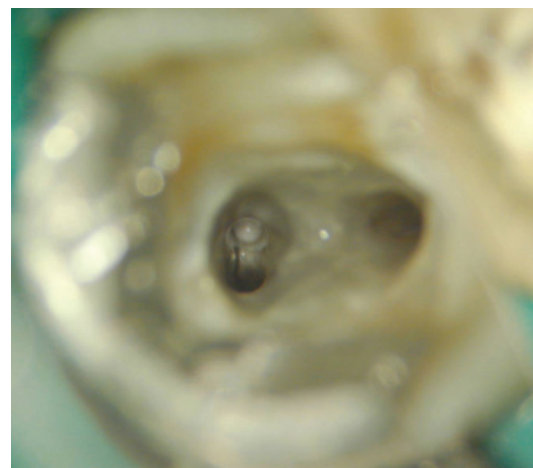


Figure 19b: Final access reveals two canals in the mesial root.

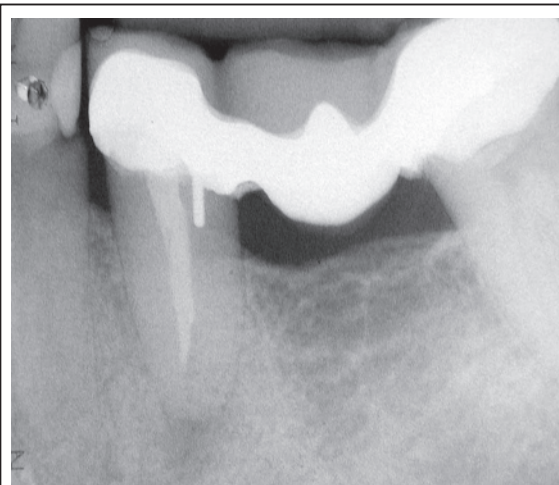


Figure 20a: Mandibular premolar with failing root canal treatment.

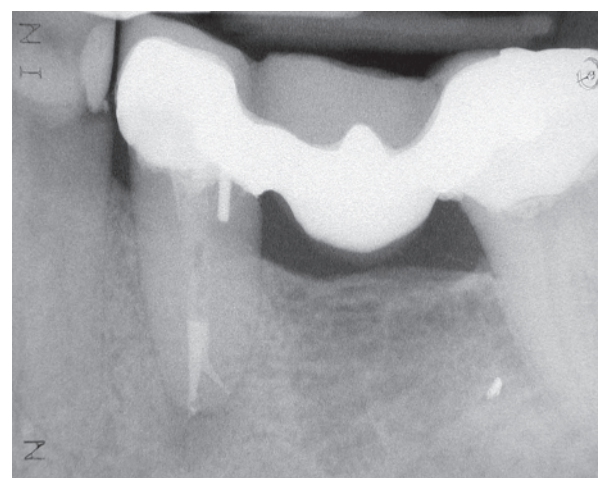


Figure 20b: Apical split located and treated.

'C' shaped canals are frequently seen in mandibular second molars and less frequently in maxillary second molars and mandibular premolars (fig 21a-c). The canal shape resembles the letter 'C'. There are three different variations to this entity.

1. All canals are joined in the 'C'
2. Two canals are joined in the 'C' and one canal stays separate.
3. All canals stay separate with in the 'C'

One of the most difficult aspects of treating this anatomy is the predictable removal of pulp tissue in the isthmus that connects all canals. Ultrasonic debridement, special irrigation techniques and intra-canal medicaments have a better chance in debriding and disinfecting these canals (fig 22a-b).

Radix Entomolaris is separate root that exists usually to the distolingual in a mandibular molar. A mandibular

molar with the radix shall have three roots with 4 canals, not be confused with a mandibular molar with two roots and four canals (fig. 23a-d).

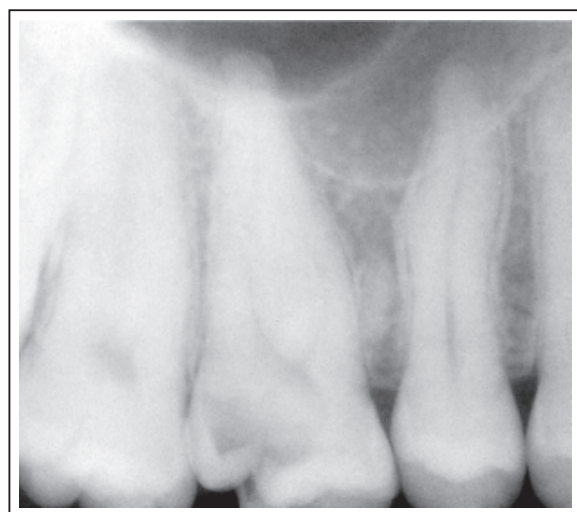


Figure 21a: Maxillary molar with a 'c' shaped anatomy.



Figure 21b: DB and palatal canals are in 'C' shape. Notice the two Mb canals.

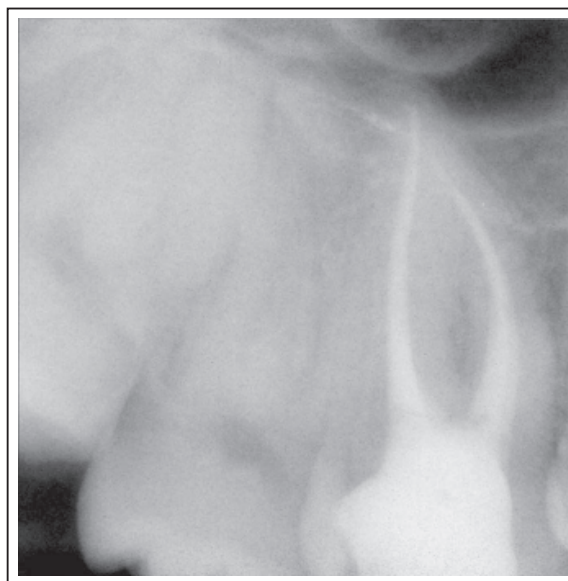


Figure 21c: Post op radiograph of the 'C' shaped maxillary molar.

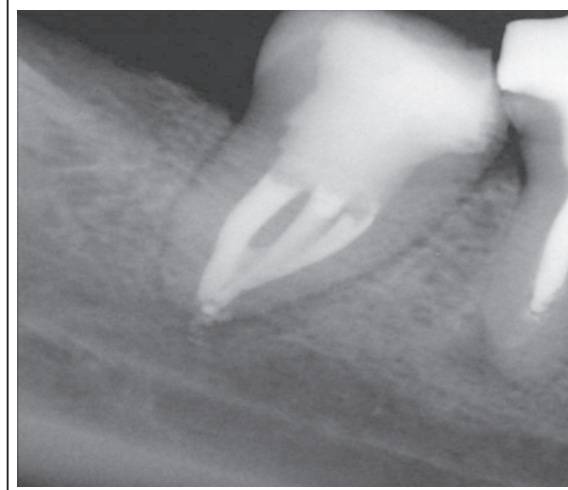


Figure 22a,b: Pre and Post op radiographs of retreatment of 'C' shaped mandibular second molar.



Figure 23a: Radix entomolaris successfully treated in the mandibular first molar.

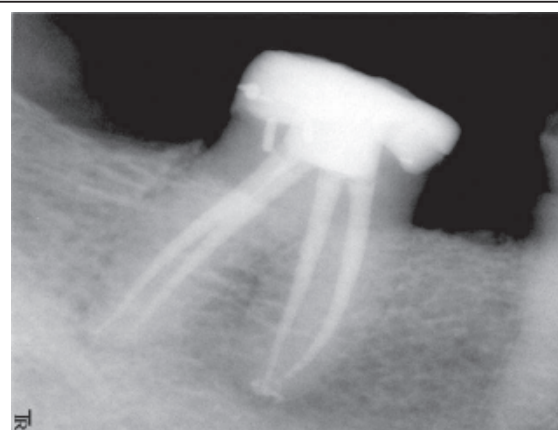


Figure 23b: Mandibular molar with two roots and four canals.

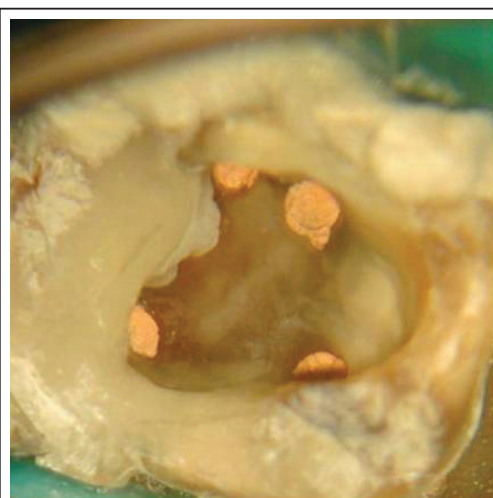


Figure 24a: Access of radix entomolaris showing the off centre DL canal.



Figure 24b: Access of mandibular molar with two roots and four canals.

Access preparation in a radix shall be different as the orifice to the distolingual root is far more lingual than the distolingual canal orifice in a two rooted mandibular molar (fig 24a-b). Another very important feature of this root is the sharp coronal curvature to the lingual and equally abrupt apical curvature to the buccal.

Middle mesial canals in the mesial root of mandibular molars are far more common than reported in the literature. When they exist they are located in the isthmus connecting the mesiobuccal and mesiolingual canals. More often than not they join either the mesiobuccal or mesiolingual canals. However, it is not uncommon to see them exit the root as a separate canal (fig 25a-b).

Three mesiobuccal canals in a maxillary molar (Mb1, Mb2, Mb3) is a less frequent phenomenon. Nonetheless the clinician shall be on the look out for this anatomy. When an Mb3 exists it usually is palatal to the Mb2 (fig 26a-d).

Two Distobuccal canals in maxillary molars is a frequent phenomenon. Db2 exists palatal to Db1 orifice

in the developmental line connecting the DB1 and palatal canals. Most times the two canals merge to exit apically as one canal. Occasionally two separate canals may be seen (27a-c).

Three canal maxillary and mandibular premolars are far more common than reported in the literature (fig 28a-b). When three canals exist in premolars they are usually two in the buccal root and one in the lingual root (29a-b). Occasionally the three canals in a mandibular premolar can exist in a 'C' shaped anatomy.

Conclusions:

Aberrant anatomy is far more common in today's endodontic specialist practice. Clinicians shall be constantly on the look out for 'occult' anatomy as successful outcome of any case depends on the complete debridement and disinfection of all canals. Thorough knowledge of the root canal anatomy and the consistent use of Surgical Operating Microscope facilitate the location and treatment of aberrant anatomy.

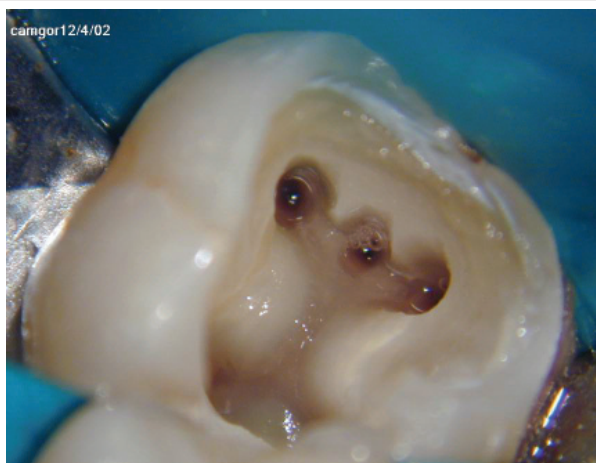


Figure 25a: Mandibular molar with three mesial canals.

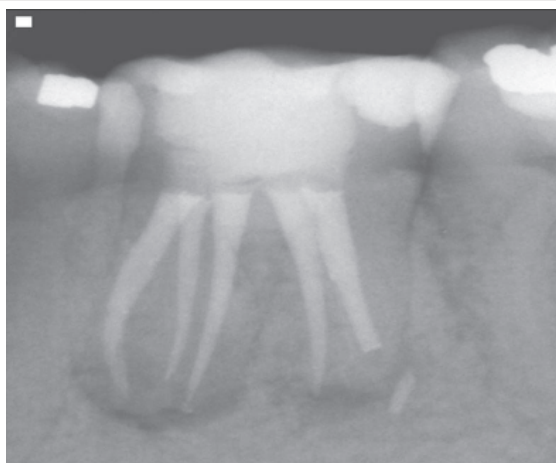


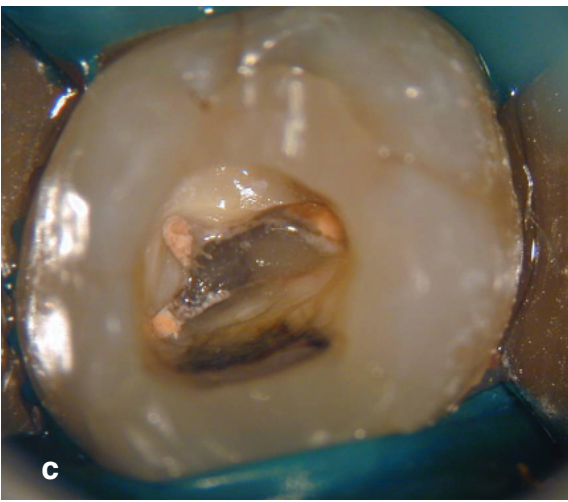
Figure 25b: Middle mesial canal with a separate portal of exit.



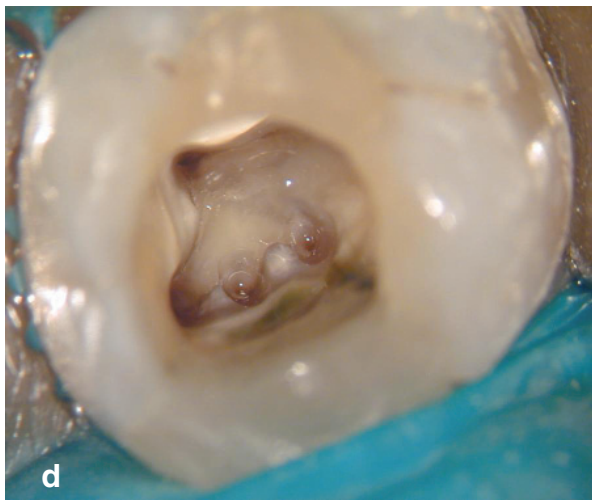
a



b



c



d

Figure 26a-d: Maxillary molar retreatment reveals three Mb canals. All three canals merged apically.

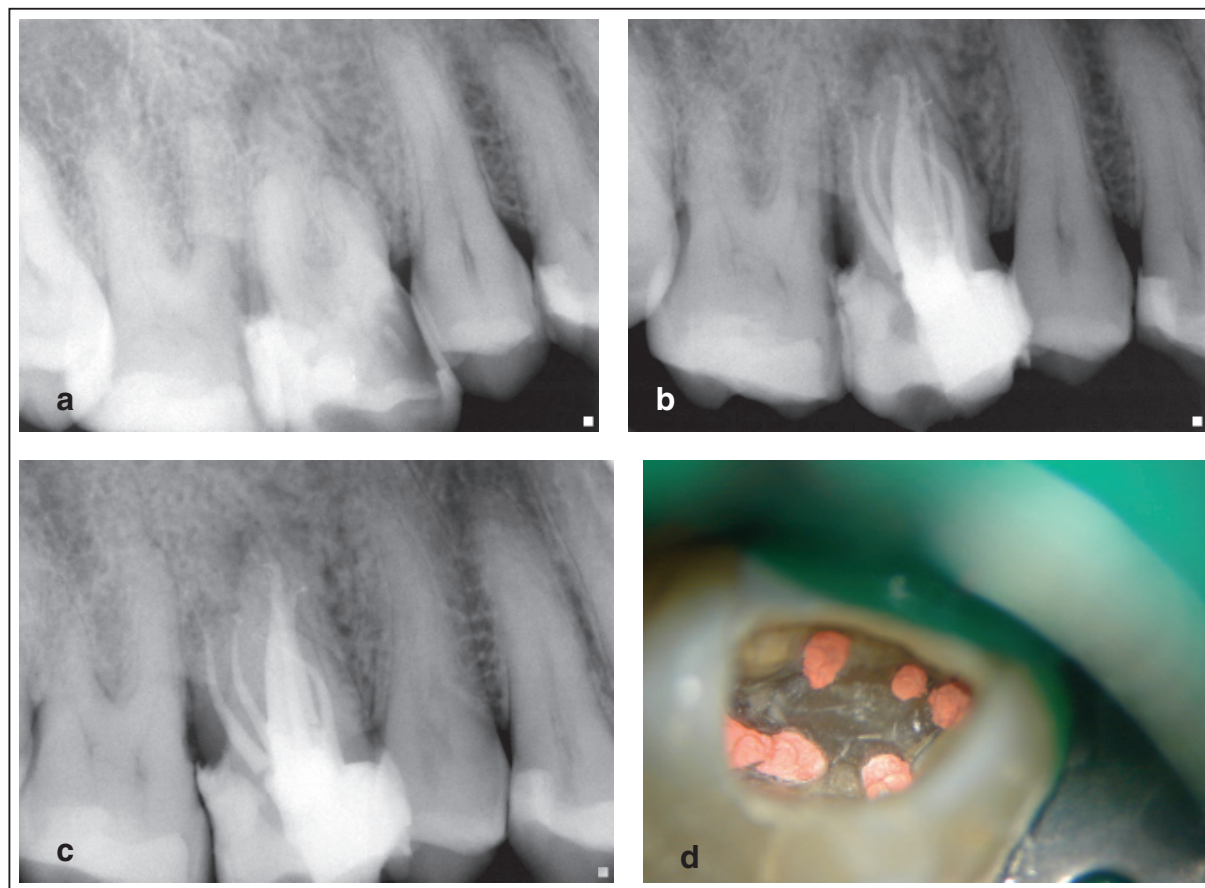


Figure 27a-d: A rare occurrence of two separate Db canals in a maxillary molar. Also notice three Mb canals.

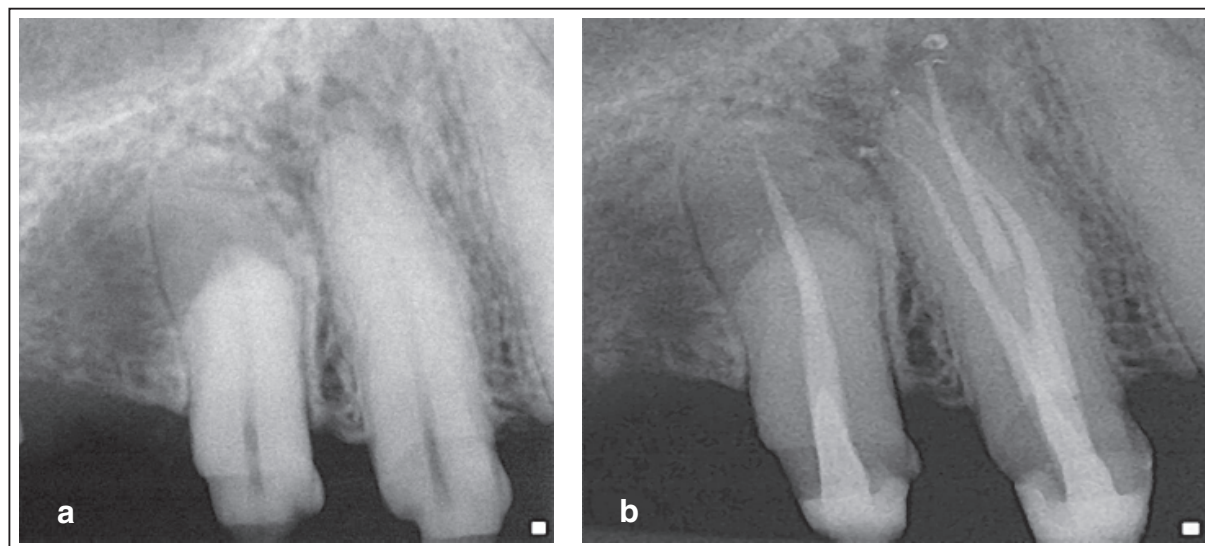


Figure 28a,b: Maxillary first premolar with three canals.

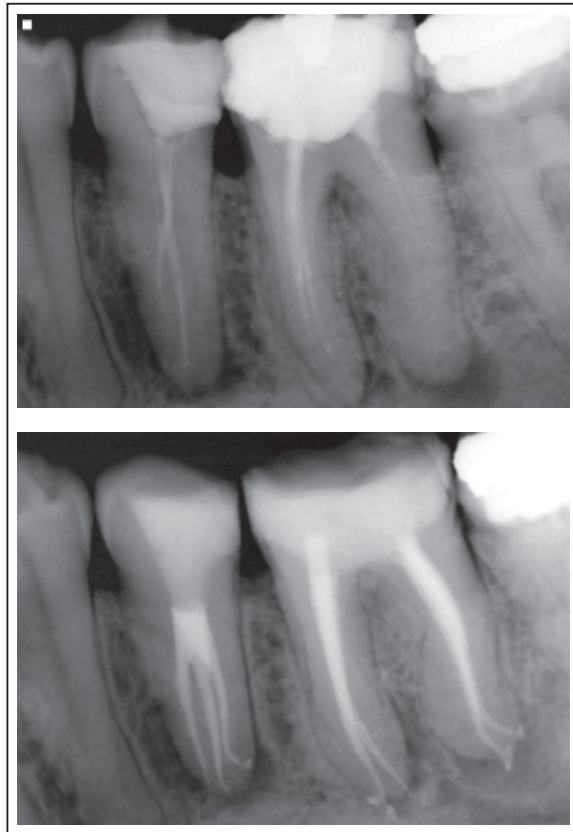


Figure 29a,b: Mandibular premolar with three separate canals.

Keep in mind, no aspect of clinical endodontics is more important in locating aberrant anatomy than the **attitude and desire** of the clinician.

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