Journal of Dentistry and Dental Practices
ISSN: 2689-5994

Academic Strive
Researcher's perception is our reality

Review Article *Volume 6 Issue 1*

Sailing through the 'Cs' of Root Canal

Yagnik K*
Gujarat University, India

***Corresponding author:** Dr. Krushnangi Yagnik, Gujarat University, India, Tel: +91-9714442345; Email: krushnangiyagnik@gmail.com

Received Date: February 23, 2024; **Published Date:** March 08, 2024

Abstract

Anatomical variations in root canal system have always been a subject of enigma and inquisitiveness. The curved, calcified and the c-shaped canals of a tooth are the major 'Cs' to sail through which we need enormous knowledge and skills. There are various causes for each such condition and these causes may be as preliminary as that during the tooth development stage. Existence of such variations remains unknown until we resort to appropriate diagnostic methods. After accurate diagnosis, next requirement would be to detect the extent, type and position of such condition. Having done so altered and specialized endodontic principles and methods need to be followed while treating such teeth. Thus, in the present article we have tried to summarize the cause, development, and management principles of these major 'Cs' of Root Canal.

Keywords: Root Canal; Anatomy; Teeth

Abbreviations: HERS: Hertwig's Epithelial Root Sheath; PCO: Pulp Canal Obliteration; EDTA: Ethylenediaminetetraacetic Acid; SAF: Self-Adjusting File.

Introduction

- For successful endodontic, thorough knowledge about the normal as well as variations in the internal and external anatomy is must [1].
- Extensive research work has been done for the same, with a voluminous contribution by Hess. Also, Wheeler, Rankine-Wilson, Weine, Perth are some of the other contributors who have contributed to the studies of pulp anatomy [2].
- A three-dimensional image should be visualized before commencing the endodontic treatment, along with it considering the possible variations in the canal system [2].

Methodology

For the present review article, a vast data has been collected using various sources. For all the three types of canal variations, the relevant endodontic text books were meticulously referred and used as references. The text books manly helped for obtaining the basic gold-standard conventional methods for the management of these types of cases. Furthermore, for addition of gradual update and step by step management of the respective anatomical forms, internet and mainly google search engine was used to accumulate and combine the data. These, included, lot many review articles, in vitro studies, in vivo studies and case reports as well. The collection and compilation of the data has been produced here in the best possible manner, for the management of curved, calcified and c-shaped canals.

Discussion

Curved Canals

- Studies have shown that, the root canal anatomy is seldom a straight course, though may seem so in the two-dimensional radiographs. It tends to have curvatures in one or more planes [3-5].
- The sudden change in the axial inclination of the crown or root of the tooth, is termed as dilaceration. Mechanical trauma seems to be the most accepted cause, however

the exact cause and pathogenesis remain questionable and controversial [6-8].

Variations in Curvatures

- ✓ Curves of the Apical Third
- ✓ Curves of the Middle Third
- ✓ Curves of the Coronal Third [4]

Measurement of Canal Curvature: The commonly known and studied methods are as follows [9,10]:

- ✓ Schneider's Method [11]
- ✓ Weine's Method [11]

A Newer Method Has Been Proposed for the Measurement of the Canal Curvature

Method Estrela C, et al. [10]**:** This method uses two 6-mm semi-straight lines superimposed to the root canal, the primary line (light gray) being the one that represents the longer continuity of the apical region and the secondary line (dark gray) is being the one that represents the middle and cervical thirds. Of the secondary line, only the 6 mm closest to the primary line is used for measurement. From the midpoint of each semi-straight line, two perpendicular lines are drawn until they meet at a central point, which is the circumcenter.10The distance between the circumcentre and the midpoint of each semi-straight line is the radius of the circumference and that is the magnitude of the curvature. The semi-straight lines can be shorter, if necessary [10].

The values of root curvature are classified as follows [10]:

- ➢ Small radius (r≤4 mm): severe curvature;
- ➢ Intermediary radius (r>4 and r≤8 mm): moderate curvature; and
- ➢ Large radius (r>8 mm): mild curvature

Dobo-Nagy, et al. [12] classified root canal curvatures, using a standard description of root canal shapes with the help of differentiated geometrical pattern analysis and computer graphics [12]. Lopes, et al. [13] reported for curved canal with the same radius, it is possible that arcs (curved segments) with different lengths (angles with different degrees) may exist. These may affect the intensity of the tensile and compressive stresses induced in the helical shaft of an endodontic instrument, thus altering its resistance to cyclic fatigue [13-15].

Management of Curvatures

In curved canals, uneven cutting is a commonly encountered difficulty. This may cause procedural errors. However these can be reduced by Garg N, et al. [2].

- **Decrease in the Filing Force** [2]
- ✓ Precurving the file
- ✓ Extravagant use of smaller number files
- ✓ Use of intermediate size files
- ✓ Use of flexible files
- ✓ Use of Glide Path Files
- **Decrease in the Length 0f Aggressively Cutting File** [2]
- ✓ Anticurvature filing
- ✓ Modifying the cutting edges
- ✓ Changing the canal preparation techniques

Since, quite a time managing the curves of root canal has been a matter of quest and in this struggle the concept of Glide path and the use of Glide path files have been an important milestone (Table 1).

Manual	Mechanical
• K- Files	• PathFiles
• C + files	• G –files
• C- Pilot files	• Safesiders
• C files	• V-files
• Hi-5 Files	• PreShaper
• Pathfinders TM CS	• EndoWave
• PathfindersTM	
• Senseus Profinders	
• K-Finders	
• S-Finders	
• D-Finders	

Table 1: Instruments in Preparation of Glide Path.

Glide path helps in retaining the original canal anatomy, and reduces the chances for the loss of curvature. With the establishment of a successful and appropriate Glide path, the clinician can win over complex and challenging endodontic cases [16].

Evolution in the Methods of Managing Curvatures

The principles of Endodontics have set a prototype, which suggests, that any curved root canal must be prepared up to #25 apically and that suffices for efficient biomechanical preparation. Also, it is suggested that, filing beyond this (#25), may cause failures like deviations, perforations, zipp, etc [17].

This prototype, however, has begun to be modified in the 21th century by the following approaches [17]:

- ✓ The flexible Nickel-Titanium (NiTi) manual as well as rotary instruments have been efficient and safe. Clinician's skill and expertise can allow use of even #40, #45 or #50 files (.02 taper) safely in apical portion of curved canals, and thus reducing chances of canal

aberrations [17].

- ✓ Determining the apical anatomic diameter or the initial apical file. For this, the middle and cervical thirds of the canal needs to be enlarged using newer instruments (Orifice Shaper, Flare, Endo- Flare, Coronal Shaper, LA Axxess) [17].
- ✓ Effective cleaning and shaping achieved by microsurgery of the root canals using three or four instruments larger than the determined the real anatomic diameter. Thus, the dentin removed in this region will be, approximately 150 to 200 microns [17]. This change in prototype, has developed new hypotheses to create other theories and a new prototype on the instrumentation of curved root canals. This will gradually modify the approach of clinicians, however further investigations for new theories will be needed [17]. While managing the curved canals, four aspects are considered. First, minimal filing is at the tip, Second, enlargement of the coronal portion, Third, the apex is completed, and Fourth, apical flaring [5]. The crown-down method, that is preparing the coronal part of the canal, prior to the apical one, works well in the coronal portion where the canal is comparatively straight [5].

New Instruments for Early Flaring

With gaining popularity for early flaring of the canal, within a short time many new instruments, with some deviations from the standardized ISO taper (slightly increased taper), were developed. These were known as the instruments with the non-ISO standard tapers [5].

New File Systems for Preparation of Curved Canals

There have been three major areas of development for these systems [5]:

- ✓ Increased flexibility by changing file designs,
- ✓ Increased flexibility by changing file metals and
- ✓ Files that do not zip due to modified tips or flute removal.

The Zone Technique

The zone technique, given by John McSpadden, et al. [18] has two objectives for minimising file stress for any type of NiTi rotary file during the shaping process. First, coronally the canal diameter should be large enough the instrument to reach the curvature passively, and prevent any engagement in that portion of the canal, while using the file apical to the curvature. Secondly, for safe rotation in the curvature of the root canal. The file diameter should not be too large. The zone technique does not set a thumb rule for shaping of canals; the canal anatomy determines the most suitable sequence, especially the position of the first curvature. The first step is to determine the presence of any significant curvature, and the distance of the curvature from the apex, with the help of ISO size 20 manual NiTi file. The area beyond the curvature is termed as the 'apical zone' and that above the curvature as the 'coronal zone' [18].

Locating the curvature and measuring the working length are equally important, since the efficient enlargement and shaping of the canal is determined by the anatomy of the tooth. The principles of the zone technique are Mcspadden JT, et al. [18].

- ✓ Simple (easy to learn and carry out);
- ✓ Reduced working time (number of steps reduced);
- ✓ Reduced chances of NiTi rotary file separation in root canal [18].

The Zone Technique is Applied in Four Steps, Described Below

- ✓ **Step I:** Determination of the terminus of the coronal zone
- ✓ **Step II:** Determination of the diameter for final enlargement at the terminus of the coronal zone
- ✓ **Step III:** Enlargement of the apical zone
- ✓ **Step IV:** Enlargement of the apical zone to the desired dimensions

Using the Zone Technique, Following Points Should be Considered [18]

- ✓ The tip of the NiTi rotary instrument should neither burnish the wall of the canal nor transport the canal.
- ✓ The file should be advanced into the canal at1 mm increments with in/out motions.
- ✓ A minimal specific pressure needs to be applied to advance the file, after the first 1 mm into becomes engaged in canal. If additional pressure is required or if a screwing-in force is encountered, use a different tapered file or circumferentially file the canal walls coronal to this position.
- ✓ In the canal, file advancement should be at the rate of at least 0.5mm per second without increasing the insertion pressure.
- ✓ A file with more than 0.02 taper is used, then do not advance more than 2 mm beyond the preparation of the previous file if any part of the file is engaged in a curvature.
- ✓ The 0.02 tapered files with a diameter size of 0.20 mm and smaller, may engage more than 6 mm of the file's working surface if the file is engaged in a curvature, with exceptions for other dimensions' files.
- ✓ No pressure should be applied on any file while advancing into the canal.
- ✓ In the apical zone, beyond the curvature, the file diameter should be less than 0.60 mm for a 0.02 taper, 0.55 mm for .04 taper, 0.50 mm for 0.6 taper, and 0.35 mm for a .08 taper. This consideration is the result of testing for 45º curvatures with 8 mm radii, and applicable to

these dimensions for NiTi rotary files. File diameters can be larger for lesser curvature and lesser for sever curvatures of canal [18].

Newer design files can help reduce excessive stress on files. To achieve this, the reason for stress should be understood along with the specification of where and how to use the files. Using too large sized files for severe curvatures and a large part of file's working surface engaged in canal are the prime reasons for file breakage. To minimize this organized sequence for shaping the canal should be adopted. The aim of the zone technique was to avoid fracture of larger NiTi rotary instruments in curved canals and to shape these curves without the risk of any aberration of canal [18].

Need for Management of the Curves

Efficient Management of curved canals helps prevent these Procedural Errors:

- Ledging
- Canal blockage
- Perforation
- Stripping or lateral wall perforation
- Canal transportation
- Zipping [2,19]

Calcified Canals

Pulp canal obliteration (PCO), is the hard tissue deposited within the root canal space [20]. The calcified pulp chamber results in a darker hue, the loss of translucency and the crown of appears yellowish [20].

- **Calcification of the Pulp can Occur Due to** [21]:
  - ✓ Mineralization as a result of irritants
  - ✓ Senility
- **Retrogressive Pulp Changes:** These altered pulp conditions are [21]
  - ✓ Atrophy and fibrosis
  - ✓ Dystrophic calcification (calcific metamorphosis)
- **P.E. Lovdahl, et al. have Concised Pulpal Responses to Irritation as** [21]:
  - ✓ Rapid death with canal patency.
  - ✓ Irritational response with pulpal death
  - ✓ Extensive irritational response and exposure of pulp system.

Development

Conventionally, calcified bodies in the dental pulp have been classified on the basis of their structural characteristics [21]. **Orthodentin, Tubular Dentin, may be Found both in Denticles and in Pulp Stones**: The common classification used is given by Kronfield [21,22].

- "True" denticles (consists of tubular (ortho) dentin),
- "False" denticles (consists of concentric layers of calcified material not resembling dentin),
- "Diffuse calcifications" (small calcified deposits scattered throughout the pulp tissue).

Regular Calcified Material may be Found Peripherally [21]

Treatment Planning

Proper diagnosis is mandatory for efficient treatment planning [23]. The tooth involved is monitored radiographically and treated in case, any area of rarefaction or clinical symptoms develop [24].

- Radiographs -Reduced kVp and increased milliamperage helps increase the contrast and interpretation easier [24,25].
- A number of preoperative views assists the clinician to locate root canals or any additional root/canals [24,25].
- The buccal object rule and radiographic markers like stabilized burs/ gutta percha can help determine the bucco-lingual orientation in posterior teeth [24,26].
- However in case of non-surgical treatment for anterior teeth with calcified canals, visual aspect is more reliable for labio-lingual position [24].
- With the advent in magnification, very minute details of tooth become visible, making it more accurate and conservative to penetrate through the dentin [24].

Location of Canal Orifices: Krasner, et al. have laws which are useful in locating calcified canal orifices. These are [21]:

- **Law of symmetry 1:** Except for maxillary molars, the orifices of the canal are equidistant from a line drawn in a mesiodistal direction through the pulp-chamber floor [21].
- **Law of symmetry 2:** Except for maxillary molars, the orifices of the canals lie on a line perpendicular to a line drawn in a mesiodistal direction across the center of the floor of the pulp chamber [21].
- **Law of color change:** The color of the pulp chamber is always darker than the walls [21].
- **Law of orifices location 1:** The orifices of the root canals are always located at the junction of the walls and the floor [21].
- **Law of orifices location 2:** The orifices of the root canals are always located at the angles in the floor-wall junction [21].
- **Law of orifices location 3:** The orifices of the root canals are located at the terminus of the root development fusion lines [21].

Even though there appears severe calcification, one must assume the presence of canal existence and thus make efforts to locate, clean shape and fill it. It has been suggested

that lesser calcification is seen in the canals near the root apex.27The LN bur (Caulk/ Denstply, Tulsa, OK, USA), the Mueller bur (Brasseler, Savannah, GA, USA) and thin ultrasonic tips help to locate calcified canals. DG-16 explorer also plays a vital role for the same [21]. Now initially a fine instrument, usually a No. 8 10 K –file is inserted into the orifice, and attempted to negotiate the canal. As an alternative, instruments with reduced flute, such as a Canal Pathfinder (JS Dental, Ridgefield. Conn.) or those with greater shaft strength like the Pathfinder CS (Kerr Manufacturing Co.), which tend to penetrate even highly calcified canals, can also be used. Cervical ledge or bulge should be removed [21]. Even if the fine instrument cannot negotiate the canal orifice, then use No. 2 round bur at slow speed and drill 1-2mm in the centre of the orifice and re-establish the orifice with the explorer. The pulp chamber should be dry while troughing in the area OD orifice location. Whitish chips accumulate at the orifice, produced by the slow speed rotating bur. The excess chips are blown off, while those retained, appear as white spots on the dark floor of the chamber and guide for exploration. This is useful for MB2 in maxillary molars or separation of mesio-buccal and mesio-lingual canals expected in mandibular second molar [21]. A newer combination of access refinement ultrasonic tips and magnification has been introduced that has revolutionized the basic concept of access cavity preparation [21]. The uncovering of the floor of the pulp chamber can be facilitated by using the CPR 2D or BUC 1 tips [21]. The CPR 2D or BUC 1 tips help at times to vibrate out the pulp stones; at other times, they can be planned using a BUC 2 tip- just like planning the root surface [21]. The floor is ground till the dark-colored dentin is visible, as it helps to guide the extension of access cavity. The fine instruments like the Micro- Orifice Opener (DenstplyMaillefer, Ballaigues, Switzerland.) aid to locate the canals and initial penetration under the microscope [21].

Other Methods for Orifice Loaction [27]:

- Dye Test
- Champagne Bubble Test
- Magnification And Illumination
- CBCT
- Nd: YAG Laser [28]

Biomechanical Preparation: Preferable method is crown down one, initiated with coronal flaring. The use of chelating agents is advised as; these substances combine chemically with the Ca+2 ions and expected to soften the dentin. The most commonly used material is ethylenediaminetetraacetic acid (EDTA), which, on combining with Ca+2 ions transforms hydroxyapatite crystals into the calcium salt of ethylenediaminetetraacetate [4].

- The Chelating Agents cause [4]:
  - Lubrication
  - Emulsification
  - Flotation

Thus, for successful endodontic management of calcified teeth, it is necessary to properly locate and diagnose the tooth pre-operatively, precise canal orifice locations, judicious biomechanical preparation of the canal and ultimately three dimensional obturation of the canal space providing optimum seal [29,30].

C-Shaped Canals: In 1908 (Keith 1913) and 1911 (Keith & Knowles 1911), C-shaped roots and root canals were first documented. In the endodontic literature first documented by Cooke, et al. [31] in three case reports [29-31]. Various epidemiological survey and studies have demonstrated the incidence and prevalence of C-shaped canals in various teeth [32]. With Mandibular 2nd Molar with highest incidence, Mandibular 1st Molar [32,33], Mandibular 3rd Molar [34], and Maxillary Molars [35-37] have also been reported to have C-shaped canals. Extensive studies [38,39] on C-shaped canals of Mandibular 2nd Molar have been done including various populations like, Japanese [40], Chinese [35], Hong Kong Chinese [41], Lebanese [42] and Thai [43]. Studies have also explained about the variations in the C-shaped canals, their connections and their anatomical complexities [39,44,45].

Cause: The Hertwig's Epithelial Root Sheath (HERS) that bends horizontally, below the Cementoenamel Junction, fuses in the centre leaving opening for the roots and thereby determining the shape and number of the roots. Failure of HERS to fuse in the furcation area or coalescence by cementum deposition with time, may be the cause for fused roots. A lingual groove is formed due to failure of fusion on buccal side and vice a versa and a conical root is formed sue to fusion failure on both, buccal and lingual aspects. Study in mouse molars, showed that roots are formed by union of dentin leaflets. This union may be irregular, forming accessory canals and at times, especially in the third molars, the leaflets failed to form. Such a failure of dentin leaflet formation resulted in a C-shaped root and canal [29,32,33,46].

Classification

- Melton's Classification [47]
- Fan's Classification (Anatomic Classification) [47]
- Fan's Classification (Radiographic Classification) [47]

3-D Classification of C-Shaped Canal System: Yuan Gao, et al. investigated three-dimensional (3-D) morphology of C-shaped root canal system using micro-computed tomography (CT) and 3-D reconstruction and in 2006 suggested this classification [48].

- **Type I (Merging type):** Canals merged into one major

canal before exiting at the apical foramen; partial dentin fusion area may appear in the coronal and (or) middle portion of the canal system [48].

- **Type II (Symmetrical type):** separated mesial canal and distal canal located at the mesial part and distal part of the root, respectively. From the buccal-lingual view, symmetry of the mesial canal and distal canal was present along the longitudinal axis of the root [48].
- **Type III (Asymmetrical type):** Separate mesial and distal canals were evident. From a buccal-lingual view, the distal canal may have a large isthmus across the furcation area, which commonly made the mesial and distal canal asymmetrical [48].

Apical Anatomy of C-Shaped Root Canals Systems

- In 2007 G. S. P. Cheung, et al. [49] found that, extreme complexities and variations exist in the apical anatomy of C-shaped root canal systems (in mandibular second molars) [50].
- Most of the C-shaped canals' apical portion had two (i.e.type II, IV, V or VI) or three (i.e. type VIII) main root canals. One-fifth of the specimens exhibited four or more main canals.
- 3D-reconstructed models showed accessory and lateral canals, inter-canal communication and apical delta. The prevalence of these ranged from 11% to 41% [50].

Diagnosis

- **Radiographic Diagnosis**
- The only non-invasive means to guide about the canal morphology is a preoperative radiograph along with a radiograph from 20° mesial or distal projection [47].
- Differential diagnosis from furcation perforation is made on the basis of interpretation of more than one radiograph [47].
- **Clinical Diagnosis**
- Specific observable criteria, like the anatomy of the floor of the pulp chamber and the persistence of haemorrhage or pain when separate canal orifices were found, help in clinical diagnosis. The occluso-apically the pulp chamber of a C-shaped canal tooth may be larger with a low bifurcation. Alternatively, C-shaped canal may be disguised due to calcification. Also, several orifices may be probed which aids to link up on further instrumentation [47]. Unobstructed passage of instrument from mesial to distal side suggests a true C-shaped canal. Whereas this is impeded in other type of canal configurations [47]. Inability to pass the file through the isthmus of the pulpal floor during clinical inspection, may suggest the root canal as being separated [47].
- New methods should be developed to diagnose the existence and the configuration of the entire C-shaped canal system. The canal may be connected in the coronal portion yet separated in the apical region and such a pattern may be missed.

Management

Canal-System Identification and Preparation: The access cavity for such teeth varies considerably and depends on the morphology of pulp of the specific tooth. Fibreoptic trans illumination can be of much assistance. Also, the surgical operating microscopes have provided increased visibility and thus more successful treatment. The deep-orifice preparation and careful probing with small files are the characteristic feature while managing C-shaped canals. Amongst all variation, the mesiobuccal and distal canal spaces usually can be prepared normally. Advisably, the isthmus should not be prepared with larger than no. 25 files; due to the risk of strip perforation. Gates-Glidden drills are also contraindicated to prepare the mesiobuccal and buccal isthmus areas. Extravagant use of small files and 5.25% NaOCl helps thorough debridement of narrow canal isthmuses [47]. Alternatively, use of ultrasonics, would be more effective. An increased volume of irrigant and deeper penetration with small instruments using sonics or ultrasonics may render more cleansibility in fan-shaped areas of the C-shaped canal [47]. The ribbon canal space is usually eccentric to the lingual side of the C-shaped root dentin. To avoid perforation, anti-curvature filing method in the coronal third of the canal is resorted to. Buccally directed filing helps avoiding the chances of perforation. In C-shaped mandibular molars, the mesiolingual canal is separate and distinct from the apex, although it may be considerably lesser in length than the mesiobuccal and distal canals [47]. These canals are easily over-instrumented in C-shaped molars with a single apex. In these molars, the mesiobuccal canal swings back and merges with the distal canal, and these exit onto the root surface through a single foramen. A few of these molars with C-shaped orifices have mesiobuccal and distal canals that do not merge but have separate portals of exit [37]. A newer development of self-adjusting file (SAF) system has shown more efficacy than the conventional rotary system for shaping of C-shaped canals [49].

Canal-System Obturation

- Obturation of C-shaped canals is technique sensitive due to the isthmus area that may have insufficient flare and thus making deep placement of the spreader difficult and so application of thermoplasticized gutta-percha seems more appropriate. Moreover, proper placement of sealer with ultrasonic endodontic files is challenging, irrespective of the obturation technique. A device Called EndoTec II (Medidenta, Inc., Woodside, NY) was developed which fulfils the best qualities of both the techniques that is ease and speed of lateral compaction and the superior density of vertical compaction [37]. It

uses a "zap and tap" manoeuvre: preheating the EndoTec plugger for 4 to 5 seconds before insertion (zap) and then moving the hot instrument in and out in short continuous strokes (taps) 10 to 15 times. The plugger was removed while still hot, followed by a "cold spreader with insertion of additional accessory points" [47].

- Following points make the C-shaped canal management different: divergent areas which may remain unshaped and cause difficulty in obturating material to flow and communications between the main canals of the C-shape, through which the entrapped filling materials that should be captured between the apical tug-back area and the level of condensation may pass from one canal to another [47]. Touch'N Heat (Sybron Endo/ Analytic, Irvine, CA) has also demonstrated successful outcome in obturating the C-shaped canal systems [47]. Janet Kirilova, et al. [51] has suggested that one single method would not suffice the filling of root canal system. Using the combination of cold lateral condensation along with continuous wave of condensation using System B and Obtura II and Thermall obturators and sealer will help serve the purpose of complete three-dimensional obturation of the canal space [52]. According to Thomas, et al. [53] due to the merit of use, adabtability, insolubility and sealing ability, GuttaFlow can be used clinically, especially in very wide root canals with irregular canal walls [51].

Summary and Recent Advances

Few points, need to be considered while managing C-shaped canals: Well recorded pre-operative radiograph with additional 20° mesial or distal angulation, minimal preparation of isthmus area and perform anti-curvature filing, avoid using GG drills, meticulous irrigation for such cases, proper apical stop with relevant sized master cone and then using thermoplasticized gutta percha obturation technique for effective 3D filling of the C-shaped root canal space [53].

For, Curved and Calcified canals, machine-assisted irrigation, such as PIPS (Fotona LLC) and the multisonic GentleWave (GW) system (Sonendo Inc, Laguna Hills, Ca, USA), have seen to improve the cleaning of minimally instrumented canals or even uninstrumented canals. A non-instrumentation method helps to save the tooth structure, avoiding all the instrumentation risks of curved and constricted or calcified root canal management. Recently, according to a study by Wang, et al. the un instrumented root canal areas of intact premolars, using the non-instrumentation technique, showed a lot of surface irregularities in different parts of the root canals with completely absence of tissue remnants and dentine debris. The results of this study indicate that it is possible to completely clean the root canal space without instrumentation in intact single-rooted premolars extracted for orthodontic reasons. Whether the same is possible in curved and calcified canals remains to be explored in the future [54].

Recently, a new method has been introduced for treatment of calcified teeth called 'Guided Endodontics'. Software is used to align CBCT data to virtually plan a customized root canal access cavity. Subsequently, a template can be prepared using a 3D printer. This 'static guide' gives a predetermined pathway that aids in a minimally invasive access to a calcified root canal [54]. Guided endodontics has a few advantages, listed as follows, reduces the error common in conventional visualization treatment, helps to replicate the position and creates accuracy that allows access to smaller cavities, does not require a Dental Operating Microscope and reduced operative time [55].

Acknowledgment

I affirm that We have no financial affiliation (e.g., employment, direct payment, stock holdings, retainers, consultantships, patent licensing arrangements or honoraria), or involvement with any commercial organization with direct financial interest in the subject or materials discussed in this manuscript, nor have any such arrangements existed in the past three years. There is no other conflict of interest.

Conclusion

Thus, with thorough anatomical knowledge along with basic to recent principles of management, one can efficiently sail through the 'Cs' of Root Canal.

References

1. Bumtaria SN, Shah V, Patel M, Patel P (2014) Management of Complex Root Canal Anatomy of Maxillary Central Incisor With Calcified Canal. RRJDS 2(3): 17-22.

2. Garg N, Bogra P (2010) Textbook of Endodontics. In: Garg N (Eds.), 2nd (Edn.), Internal Anatomy pp: 167-185.

3. Ansari I, Maria R (2012) Managing Curved Canals. Contemporary Clinical Dentistry 3(2): 237-241.

4. Castelluci A (2022) Curved Canals. In: Endodontics. Arnaldo Castelluci. IL Tridente 2: 502-517.

5. Weine FS (1996) Endodontic Therapy. In: 6th (Edn.), Intracanal Treatment Procedures, Basic And Advanced Topics. Mosby St. Louis 5: 164-239.

6. Parolia A, Khosla M, De Moraes Porto ICC, Mala K (2013) Endodontic Management Of Dilacerated And Bayonet

Shaped Roots. Rgo - Rev Gaucha Odontol 61(2): 269-274.

7. Tomes J (1848) A Course of Lectures on Dental Physiology and Surgery, Delivered at the Middlesex Hospital School. Am J Dent Sci 8(3): 209-246.

8. Shafer WG, Hine MK, Levy BM (1983) A Textbook of Oral Pathology. In: 4th (Edn.), Philadelphia: WB Saunders.

9. Schilder H (1974) Cleaning and Shaping the Root Canal. Dent Clin North Amer 18(2): 269-296.

10. Estrela C, Bueno MR, Neto SMD, Pecora JD (2008) Method for Determination of Root Curvature Radius Using Cone-Beam Computed Tomography Images. Braz Dent J 19(2): 114-118.

11. Zhu Y, Gu Y, Du R, Li C (2003) Reliability of Two Methods on Measuring Root Canal Curvature. Int Chin J Dent 3: 118-121.

12. Dobo NC, Szabo J, Szabo J (1995) A Mathematically Based Classification of Root Canal Curvatures on Natural Human Teeth. J Endod 21(11): 567-560.

13. Lopes HP, Moreira EJL, Elias CN, Almeida RA, Neves MS (2008) Cyclic Fatigue of Protaper Instruments. J Endod 33(1): 55-57.

14. Pruett JP, Clement DJ, Carnes DL (1997) Cyclic Fatigue Testing of Nickel-Titanium Endodontic Instruments. J Endod 23(2): 77-85.

15. Lopes HP, Elias CN, Estrela C, Siqueira JF (1998) Assessment of the Apical Transportation of Root Canals using the Method of the Curvature Radius. Braz Dent J 9(1): 39-45.

16. Dhingra A, Neetika (2014) Glide Path in Endodontics. Endodontology 26(1): 217-222.

17. Pecora JD, Capelli A (2006) Shock of Paradigms on the Instrumentation of Curved Root Canals. Braz Dent J 17(1): 3-5.

18. Mcspadden JT, Bonaccorso A, Tocchio C, Rapisarda E, Tripi TR (2008) The Zone Technique. Endo (Lond Engl) 2(1): 33-41.

19. Mantri SP, Kapur R, Gupta NA, Kapur CA (2012) Type III Apical Transportation of Root Canal. Contemporary Clinical Dentistry 3(1): 134-136.

20. Tavares WLF, Lopes RCP, Menezes GB, Henriques LCF, Ribeiro Sobrinho AP (2012) Non-Surgical Treatment of Pulp Canal Obliteration Using Contemporary Endodontic Techniques: Case Series. Dental Press Endod 2(1): 52-58.

21. Thomas B, Chandak M, Patidar A, Deosarkar B, Kothari H (2014) Calcified Canals – A Review. Journal of Dental And Medical Sciences 13(5): 38-43.

22. Kumar GS (2009) Pulp Orban's Oral Histology and Embryology. In: 12th (Edn.), Elsevier, pp: 109-136.

23. Mccabe PS, Dummer PMH (2012) Pulp Canal Obliteration: An Endodontic Diagnosis and Treatment Challenge. International Endodontic Journal 45(2): 177-197.

24. Mahajan P, Monga P, Bahunguna N, Bajaj N (2010) Principles of Management of Calcified Canals. Indian Journal of Dental Sciences 2(5): 3.

25. Khabbaz MG, Serefoglou MH (1996) The Application of the Buccal Object Rule for the Determination of Calcified Root Canals. International Endodontic Journal 29(4): 284-287.

26. White SC, Pharoah MJ (2009) Oral Radiology: Principles and Interpretation, In: 6th (Edn.), Mosby Elsevier Missouri, USA, pp: 1-639.

27. Nair MK, Levin MD, Nair UP (2011) Radiographic Interpretation. In: 11th (Edn.), Cohen's Pathways of Plup Elsevier pp: 33-70.

28. Khaled Balto K, Saif R, Hassan FE (2011) A Novel Method for Locating Calcified Orifices during Root Canal Treatment. Thesis. King Abdulaziz University.

29. Manning SA (1990) Root Canal Anatomy of Mandibular Second Molars. Part II C-Shaped Canals. International Endodontic Journal 23(1): 40-45.

30. Baisden MK, Kulild JC, Weller RN (1992) Root Canal Configuration of the Mandibular First Premolar. J Endod 18(10): 505-508.

31. Cooke HG, Cox FL (1979) C-Shaped Canal Configurations in Mandibular Molars. J Am Dent Assoc 99(5): 836-839.

32. Barnett F (1986) Mandibular Molar with C-Shaped Canal. Endod Dent Traumatol 2(2): 79-81.

33. Bolger WL, Schindler WG (1988) A Mandibular First Molar with a C-Shaped Root Configuration. J Endod 14(10): 515-519.

34. Sidow SJ, West LA, Liewehr FR, Loushine RJ (2000) Root Canal Morphology of Human Maxillary and Mandibular Third Molars. J Endod 26(11): 675-678.

35. Yang ZP, Yang SF, Lin YC, Shay JC, Chi CY (1988) C-Shaped Root Canals in Mandibular Second Molars in a Chinese Population. Endod Dent Traumatol 4(4): 160-163.

36. Newton CW, Mcdonald S (1984) A C-Shaped Canal Configuration in a Maxillary First Molar. J Endod 10(8): 397-399.

37. Al Shalabi RM, Omer OE, Glennon J, Jennings M, Claffey NM (2000) Root Canal Anatomy of Maxillary First and Second Permanent Molars. Int Endod J 33(5): 405-414.

38. Vertucci FJ (1984) Root Canal Anatomy of the Human Permanent Teeth. Oral Surg Oral Med Oral Pathol 58(5): 589-599.

39. Weine FS, Pasiewicz RA, Rice RT (1988) Canal Configuration of the Mandibular Second Molar Using a Clinically Oriented In-Vitro Method. J Endod 14(5): 207-213.

40. Kotoku K (1985) Morphological Studies on the Roots of the Japanese Mandibular Second Molars. Shikwa Gakuho 85(1): 43-64.

41. Walker RT (1988) Root Form and Canal Anatomy of Mandibular Second Molars in a Southern Chinese Population. J Endod 14(7): 325-329.

42. Haddad GY, Nehme WB, Ounsi HF (1999) Diagnosis, Classification and Frequency of C-shaped Canals in Mandibular Second Molars in the Lebanese Population. J Endod 25(4): 268-271.

43. Gulabivala K, Opasanon A, Ng YL, Alavi A (2002) Root and Canal Morphology of Thai Mandibular Molars. Int Endod J 35(1): 56-62.

44. Sutalo J, Simeon P, Tarle Z, Prskalo K, Pevalek J, et al. (1998) "C"-Shaped Canal Configuration Of Mandibular Second Permanent Molar. Coll Antropol 22(1): 179-186.

45. Gulabivala K, Aung TH, Alavi A, Ng YL (2001) Root and Canal Morphology of Burmese Mandibular Molars. Int Endod J 34(5): 359-370.

46. Sikri VK, Sikri P (1994) Mandibular Premolars: Aberrations in Pulp Space Morphology. Indian J Dent Res 5(1): 9-14.

47. Jafarzadeh H, Wu YN (2007) The C-Shaped Root Canal Configuration: A Review. J Endod 33(5): 517-523.

48. Cheung GSP, Yang J, Fan B (2007) Morphometric Study of the Apical Anatomy of C-Shaped Root Canal Systems in Mandibular Second Molars. International Endodontic Journal 40(4): 239-246.

49. Gao Y, Fan B, Cheung GSP, Gutmann JL, Fan M (2006) C-Shaped Canal System in Mandibular Second Molars Part IV: 3-D Morphological Analysis and Transverse Measurement. JOE 32(11): 1062-1065.

50. Kirilova J, Pirinska TS (2014) C-Shaped Configuration of the Root Canal System-Problems and Solutions. Journal of IAMB – Annual Proceedings (Scientific Papers) 20(1): 504-509.

51. Fernandes M, Ataide I, Wagle R (2014) C-Shaped Root Canal Configuration: A review of literature. Journal of Conservative Dentistry 17(4): 312-319.

52. Thomas MS, Parolia A, Kundabala M (2009) A Rare Case of Mandibular Second Molar with Single Canal Obturated using a New Poldiamethylsiloxane-Based Root Canal Filling Material. Manipal Odont 1: 92-94.

53. Bishnoi N, Ataide IN, Fernandes M, Lambor R, Sandhu B (2020) Management of C-Shaped Root Canal Configuration: Case Reports. IP Indian J Conserv Endod 5(3): 131-134.

54. Chaniotis A, Zapata OR (2022) Present Status and Future Directions: Management of Curved and Calcified Root Canals. Int Endod J 55(S3): 656-684.

55. Bansode P, Wavdhane M, Pathak S, Jadhav A (2023) Guided Endodontics: A Literature Review. International Journal Dental and Medical Sciences Research 5(4): 617-622.