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Root Canal Isthmus: Clinical Significance in Orthograde and Retrograde Endodontics

Medical Science

KEYWORDS :

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A wise old endodontist once said, "What is removed from the root canal may be more important than what is placed inside." True words indeed, as successful endodontic therapy demands a thorough debridement and disinfection of the root canal space. To achieve this, along with knowledge, skill and dexterity, the clinician needs to keep his mind's eye open to travel along the intricate pathways of the root canal system.

The root canal system comprises of a complex anatomy of main root canal along with lateral and accessory canals, fins, deltas, anastomoses, intricate curvatures and isthmuses. Early works on tooth anatomy by Hess and Zurcher to the most recent studies have highlighted the complexities of the same.

In medical terminology, an isthmus is a narrow anatomic part or passage connecting two larger structures or cavities. Isthmus can be defined as a narrow connection between two root canals in the same root containing pulp tissue1. It has also been described as a web-like connection between two root canals, which can be either complete or incomplete. Other names include 'a ribbon-shaped passage', fin, corridor (Green), lateral connection (Pineda), anastomoses (Vertucci) 2-4. The presence of isthmus was completely ignored till the early 80's.Cambruzzi and Marshall (1983) in a Canadian Journal emphasized on the existence and clinical significance of the isthmus5.

The isthmus has an endodontic significance in both orthograde endodontics (i.e. conventional endodontic treatment) and retrograde endodontics (as in periradicular surgery).

When it occurs, an isthmus becomes an important factor in the ability to thoroughly clean and debride the root canal system. It also becomes a significant factor in design and placement of root -end preparation. If neglected, the remaining necrotic pulp tissue and debris housed in the isthmus may serve as a nidus for recurrent infection and subsequent treatment failure. A large percentage of failure of root canal treatment or endodontic surgery has been attributed to untreated isthmus. Needless to say, the isthmus needs to be located, cleaned, shaped, filled, sealed or retrosealed.

DEVELOPMENT

The formation of isthmus is embryonic in origin. During root development, Hertwig's epithelial root sheath determines the size and shape of the root/roots. An isthmus is formed through this sheath, when an individual root projection is unable to close itself off. If there is partial fusion of root projections, then there is formation of two root canals with an intervening isthmus. No fusion of the root projections leads to a large ribbon shaped canal, which also forms an isthmus throughout the entire root.

PREVALANCE

The incidence of canal isthmuses varies for type of tooth and level within a given root. Highest incidence has been found in mesial root of mandibular first molar (54 to 89% prevalence), followed by mesio-buccal root of maxillary first molar(30.1%).Mandibular anteriors show low incidence at 15% .Isthmuses are usually prevalent at 2mm-5mm from the apex. At 3mm level from apex, 90%of MB roots of maxillary molars, 80% of mesial roots of mandibular molars, and 30%of maxillary and mandibular premolars show presence of isthmus.6-11

Another study concluded that isthmus is widely found in flat roots, with the highest incidence at 2.5-7 mm from the apex.12

CLASSIFICATION

Classified by Hsu and Kim (1997)
Type I- 2 or 3 canals with no visible communication (Incomplete isthmus)
Type II – 2 canals showing definite connection with two main canals. This can be a straight line between two canals or a C-shaped connection (complete isthmus)
TYPE III –3 canals showing definite connection with main canals.
Type IV- Similar to type II or Type III with canals extending to Isthmus area.
Type V -A true connection throughout the section of the root.
According to Teixeira classification, it is classified as no isthmus, incomplete isthmus and complete isthmus.

AIDS FOR ISTHMUS LOCATION

Following are the methods/ aids to locate an isthmus-

1. ANATOMICAL FAMILIARITY-

A comprehensive knowledge of tooth anatomy gained from textbooks, journals and studies indicates possible presence of isthmus in the concerned tooth. Commonly, isthmus is found between two canals present in one root like mesial root of mandibular molars. The clinician should be aware of the possible anatomical variations in the tooth prior to starting the endodontic treatment.

2. EXPLORATION-

Access cavities should be expanded and finished to improve vision and access to the root canal orifices. A coronally placed isthmus can be probed with an endodontic explorer to find a "catch". Likewise, during endodontic surgery, after root-end resection, a sharp fine explorer can locate an isthmus

LN Burs or Munce discovery burs can also aid in isthmus detection. Munce discovery burs are used in low speed handpiece. They are long, stiff and have a thin shank and thus allow better visualization when working deep in the chamber or root.

3. ENHANCED MAGNIFICATION-

This can be achieved by means of

a) Dental Loupes

Single-lens or Multiple-lens loupes are available for enhancing magnification. All loupes employ convergent lenses to form a magnified image. To overcome the disadvantages of single lens loupe optics (Poor image resolution and

ergonomics), the use of multi-lens optic system is recommended. A x2.5 magnification is ideal for endodontic use.13

b) Dental Operating Microscope (DOM)
The Dental Operating Microscope has caused a visual evolution in modern endodontics. Its magnification ranges from 3x to 30x.DOM has its application at all stages, from detection of an isthmus to assessing its cleaning, shaping and filling/retrofilling. The use of DOMs along with microsurgical instruments and ultrasonics has revolutionized both orthograde and retrograde endodontics. On January 1, 1998, the American Dental Association standards for advanced specialty education programs in endodontics made it mandatory to include formal microscope training in surgical and non-surgical endodontic treatment. 14

c) Endoscope-
The use of rod-lens endoscope was first reported in 1979 and was recommended for endodontic procedures in 1996. Endoscope comprises of glass rods, camera, light source, monitor and a digital recorder. Though an endoscope offers greater magnification than loupes or microscope, its disadvantage is its bulk and requirement of haemostasis in operating field. It is used mainly in surgical endodontics.

d) Orascope-
It is a fibre-optic endoscope mainly used for intra-canal visualization. The image quality from fiber optic magnification has a direct correlation to the number of fibers and size of the lens used. Fibre-optics are made of plastics, so they are small, flexible and light-weight. It gives better imaging of apical third of the canal.

4. DYES-
Dyes like methylene blue, Fluorescein sodium dyes and India ink can be used to locate isthmus or fin areas as they stain vital pulp tissue. The dye is irrigated in the pulp chamber and subsequently rinsed with water, dried and visualized. It gets absorbed into orifices, fins and isthmus areas and serves as a 'road-map'. Similar procedure can be adopted in root-end preparations.

5. TRANSILLUMINATION-
Can be accomplished by positioning a fibre optic wand and directing it on the tooth. At times, shutting off the microscope light or overhead light source aids in better location of an isthmus.

6. HIGH RESOLUTION COMPUTED TOMOGRAPHY (CT)-
It provides a three-dimensional picture of the root canal system using computer image processing. Cone Beam Computed Tomography (CBCT) has gained immense popularity as a tool to investigate root canal anatomy. Extensive research has confirmed that it is a precise method to detect root isthmus. 15-17 Micro-CT has also been used successfully for evaluation of root canal anatomy18-20. It offers the advantages of being a rapid, highly accurate and nondestructive method for in vitro evaluation.

7. MAGNETIC RESONANCE IMAGING (MRI)-
It produces data on computer, which helps in assessing canal morphology. MRI offers simultaneous three-dimensional hard and soft tissue imaging of teeth without the use of ionizing radiation. It also enables the clinician to image minute dental structures within clinically relevant scanning times. MRI has many potential applications in dentistry and may radically change the face of diagnostic imaging. 21

8. IN-VITRO METHODS-
Sectioning of teeth, Dyes, Clearing of roots, SEM analysis, Contrasting or Hypaque media are the various methods employed for in-vitro assessment of tooth morphology.

Many of the above methods can be used in conjunction for better diagnosis. Studies have proved that use of DOM or Orascope with high magnification along with Transillumination and Methylene blue dye give the best visualization of anatomical variations of the resected root apex22.

CLEANING AND SHAPING OF ISTHMUS: ORTHOGRADE ENDODONTICS-
If an isthmus exists only in the coronal third, it should be eliminated to remove the pulpal tissue. If it extends from coronal to middle third, it should be considered as a separate canal and cleaned, shaped and obturated like any other canal (Nalapatti). In conventional endodontic treatment, no technique is capable of completely cleaning the isthmus area. No endodontic instrument can physically enter into and clean the isthmus, so it is left upon the irrigants and the irrigating systems to achieve three dimensional chemomechanical disinfection. Newer irrigation systems viz. Endovac, Ultrasonic irrigation, Sonic irrigation-Endo Activator by Ruddle, Rinsendo, Irrisafe Passive Ultrasonic irrigation etc. have the ability to reach into the complexities of the root canal system. Thus they are capable of eliminating maximum debris/tissue from the isthmus region. They are ably assisted by irrigating solutions like Sodium Hypochlorite (NaOCl), Ethylene diamine tetra acetic acid (EDTA) 17%, Chlorhexidine 2% etc to achieve optimum results.

NaOCL has proved to be a gold standard amongst irrigants, with its pulp dissolution, bactericidal and lubricating properties, which is useful in cleaning inaccessible areas of the root canal system.

Newer methods for root canal disinfection include the following-
a) Photo-activated disinfection (PAD)- It contains a Photosensitiser(PS) and a special light source. The PS attacks the membranes of microorganisms and effectively destroys them. It is not only effective against bacteria, but also against other microorganisms including viruses, fungi and protozoa 23

b) Lasers- Diode,CO2, erbium, Nd:YAG lasers have been used for three-dimensional decontamination of the root canal system. However, there is a risk of thermal injury to the root canal surface.

Laser Activated Irrigation (LAI) and the PIPS technology (Photon-Initiated Photoacoustic Streaming) outlines a new area of interest in the field of endodontic disinfection. LAI generates the expansion and implosion of the irrigant solution, generating a secondary cavitation effect on the intracanal fluids. PIPS produces a profound photoacoustic and photomechanical phenomenon, which generates a faster streaming of fluids distant from the source.

LAI and PIPS avoid the risk of thermal damage, and increase the efficacy of the irrigants. 24,25

c) Ozone- Ozone (O3) is a triatomic molecule which has the capacity to entrap and release oxygen. This oxidative power makes it an effective antimicrobial agent. In vitro studies have shown ozone to be effective over most bacterial strains found in cases of pulp necrosis. 26

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RETROGRADE ENDODONTICS-
In periradicular surgery, after root end resection, the face of the root end has to be inspected minutely to observe the microanatomy. An isthmus is usually seen in the thinner portion of the root, so it has to be 'carved' delicately to avoid perforation or stripping.

Earlier, a small round or inverted cone bur in slow speed handpiece was used in root end preparation. Later, minihead handpieces were introduced. Isthmus preparation was tedious with these instruments as access was difficult, risk of perforation higher, and root end bevel was necessary to visualize and perform the preparation.

Magnification in endodontic surgery has led to miniaturization of endodontic instruments. One of the most significant advances has been introduction of ultrasonic microsurgical tips for root end preparation27-29 They give better accessibility, so the need for root-end beveling has now been eliminated. Ultrasonic retrotips like KiS or Carr tips have increased cutting efficiency, leaving the dentine surface smooth, yet microscopically rough, which results in better adaptation of filling materials and few microfractures. Studies have reported that the root end cavity is much cleaner, smoother and contains less debris / smear layer when prepared with ultrasonic tips as against bur preparations. These retrotips are either stainless steel, diamond coated, or are made of Zirconium nitride. A tip with a diameter of less than 0.2mm is the best to treat the isthmus without causing procedural mishaps30.

A complete isthmus is 'eliminated' by including it in the root end cavity design. The cavity design is planned and outlined by a sharp point of an ultrasonic tip without irrigation. Thereafter, the prepared cavity design is deepened with appropriately sized and angled ultrasonic tips with irrigation. After completion, the cavity is thoroughly irrigated with sterile saline, dried, and examined at high magnification (16X to 25X) for a smooth preparation.

An ideal root end cavity resembles a Class I cavity with minimum 3 mm in the root dentine and walls that are parallel to the anatomic contour of the root canal space. 31

In an incomplete isthmus, a shallow groove or 'tracking groove' is prepared along the isthmus line with a microexplorer to serve as a guideline for the ultrasonic tip.22 Then the tip is activated along the isthmus without water coolant. Before proceeding with preparation of isthmus to the full depth, the tracking groove should be examined at 12X to 16X magnification for correct positioning. After confirmation, the isthmus is fully prepared with a water-cooled KiS-tip or CT-1 tips.

Thus the depth of the prepared isthmus should be the same as the root end preparation. Recent studies indicate the optimum depth of root end preparation to be 3mm in root dentine as it eliminates 95% of the apical ramifications.

SEALING/FILLING OF ISTHMUS
ORTHOGRADE ENDODONTICS-
In conventional endodontic therapy, Guttapercha has proven to be material of choice for successful filling of root canals from their coronal to apical extent. However, the cold lateral compaction technique, which is widely used, does not necessarily fill the canal irregularities or isthmuses. Contemporary techniques of obturation like guttapercha carrier based obturators, Thermoplasticized and chemically plasticized guttapercha, Warm vertical condensation method, Continuous wave compaction technique use heat to increase the plasticity of guttapercha. This enables the guttapercha to flow into lateral and accessory canals, isthmuses and other ramifications, thus achieving a better seal.

RETROGRADE ENDODONTICS-
During root end preparation with ultrasonics, the heat generated may thermoplasticize the guttapercha. Microcondensers are used to compact the remnants of gutta percha into the root canals.

Although a plethora of retrograde filling materials is available, no material fulfills all the requisites of an ideal retrofilling material. The recommended materials include Mineral Trioxide Aggregate (MTA),Glass ionomer cement, Ethoxybenzoic acid (EBA) and Super EBA, Intermediate restorative material (IRM), and composite resins. Amalgam, which was popularly used earlier, is not recommended any more due to biocompatibility and safety issues, corrosion, dimensional changes, amalgam tattoos etc 32.

MTA has shown great promise as a root end filling material and is the current material of choice. Its advantages include excellent biocompatibility, hydrophillic nature and radiopacity33, 34. The regeneration of new cementum over MTA is a unique phenomenon not seen with other root end fillings.

Biodentine, a contemporary tricalcium silicate based dentine replacement and repair material, which has been introduced in the recent years, has also been used successfully as a retrofilling material .35 ,36

CLINICAL SIGNIFICANCE:
ORTHOGRADE ENDODONTICS
It has long been established that a root with a tapering canal and a single foramen is an exception rather than the rule. The variations and complexities of the root canal system have been well documented and dissected. The root canal is like a 'Rainforest' with a wide variety of (micro) flora and fauna. This environment provides an ideal ground for biofilm formation. Following pulpal demise, there is a change in nutritional and environmental status within the root canal. The infected root canal becomes more anaerobic and there is depletion in the nutritional level.

Routine endodontic procedures like irrigation, cleaning, shaping and obturation primarily act on the main root canal, which harbors maximum microorganisms. It has been observed that part of the root canal space often remains untouched during cleaning and shaping, regardless of the technique and instruments employed 37

The introduction of new instruments, irrigants, irrigation and obturation techniques has been, to some extent, successful in limiting the microorganisms housed in the isthmuses. One of the aims of obturation is entombment of bacteria within the dentinal tubules and root canal ramifications. So in a well-obturated root canal, these remnant bacteria usually die or are prevented from gaining access to periradicular tissues, thereby preventing reinfection. 38

Thus inability to locate and manage an isthmus rarely causes failure of orthograde endodontic treatment.

On the other hand, recent studies have drawn attention to the fact that coronal leakage through endodontically treated teeth can lead to failure of endodontic treatment. 39-42One of the causes of coronal leakage can be an untreated isthmus in the coronal third of root canal. However, the

failure percentage in these cases is much lower than failure due to apical leakage.

RETROGRADE ENDODONTICS

During periradicular surgery, the risk and complications associated with an untreated isthmus rise exponentially. A neglected isthmus has far more serious implications and complications in retrograde endodontics than in their orthograde counterpart. The micro flora lodged therein are exposed to the periradicular tissues and can cause reinfection and subsequent failure. Researchers have shown that one of the main causes of surgical failure is mismanagement or failure to manage the isthmus. 43,44

With the advent of microsurgical endodontics, enhanced magnification, coupled with an increased awareness of the pulpal aberrations, the success rate of endodontic surgery has shown an incredible rise. The advent of newer retrofilling materials has contributed to the same. The importance of identifying and managing an isthmus is being accepted and implemented. Thus, for successful periradicular surgery, it is absolutely vital to identify and manage the isthmus, if present. Isthmus management may dictate success or failure in retrograde endodontics.

SUMMARY

To summarize, endodontic therapy, both orthograde, and retrograde should be performed giving due respect to the diversity of the root canal system. Armed with highly sophisticated technology, today's clinician looks far more capable of meeting the challenges thrown by the complex pulpal pathways. Also necessary is a positive approach, an open mind and a genuine urge to locate and successfully manage cases with complex root canal anatomy.

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