Minimally Invasive Endodontics - A Review

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Abstract
This review compares the various methods of Minimally Invasive Treatment approaches with Traditional approaches in Endodontics. The MEDLINE, PubMed databases, bibliographies of all relevant articles and textbooks were searched. As Devan once quoted “Our goal should be perpetual preservation of what remains rather than meticulous restoration of what is missing” which is achieved by the shift of endodontics from extension for prevention to the minimal invasion with the systematic respect of original tissue. Preserving the integrity of tooth by following means mentioned in this article one can achieve minimal invasion with maximum appropriateness. Minimally invasive approach requires in-depth knowledge of Root Canal Anatomy, Diagnosis and Decision Making, Preservation of Structural Integrity of Tooth, Alternate Access Designs, Image Guided Endodontic Access, Dynamically Guided Endodontic Access, Microguided Endodontic Access, Modern Bur Designs, Cleaning and Shaping, 3D Irrigation and Disinfection, Root Strengthening and Magnification aids like Loupes and Surgical Operative Microscope.

Keywords: Minimally Invasive Endodontics, Access Designs, Image Guided Endodontic Access, Dynamically Guided Endodontic Access, Microguided Endodontic Access, Loupes and Surgical Operative Microscope

1. INTRODUCTION

With the extensive research, it is seen that it is virtually impossible to render root canal systems of teeth bacteria-free. The objective of root canal treatment is eliminating microorganisms and pathologic debris from the root canal system and preventing reinfection¹. Dr. Herbert Schieldeir in 1974, gave the mechanical objectives of cleaning and shaping which would promote the success of root canal therapy.

In the quest of eliminating the microorganisms from the canal system one should also make sure that there is no extensive loss of tooth structure in the process. During the endodontic procedures diagnosis to Treatment Planning involves minimal invasive approach which includes correct diagnosis and decision making, minimal but decisively crafted access openings depending on anatomical challenges, during access opening minimal removal of dentin, cleaning and shaping of the root canal to retain as much sound dentin as possible, retention of tooth structure, performing a crown lengthening procedure to establish sound tooth margins for core/crown restorations rather than planning a tooth extraction and implant or bridge placement. The article here by lists out a few of the approaches of Minimally Invasive Endodontics (MIE) which changes the future of dental practice.

2. DIAGNOSIS AND TREATMENT PLANNING

Usually cases of mature teeth diagnosed with irreversible pulpitis or apical periodontitis, often root canal treatment is the treatment of choice to save the tooth, which lead to loss of dental hard tissue and subsequently weakening the tooth, making them more prone to fracture². With advancement in research new insights in pulp biology have developed overtime, a clinical research on vital pulp therapy now provides options for enveloping new biologically driven treatment protocols³. Minimally invasive endodontics treatment modalities include two major rewards: firstly, preservation and maintaining physiological and defensive functions; secondly, lesser removal of hard tissue

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which preserves structural integrity of tooth. Thorough knowledge of pulp biology and insight into why traditional treatment methods leads to shift in thinking about endodontic treatment. Possibly avoiding full pulpectomies (complete removal of the pulp to the apical constriction), wherever possible biological response of immune system could be enhanced by even a partially retained pulp thus improving the treatment outcome, prevents further infection of the apical area, and studies have proven that results of vital pulp treatments are comparable to conventional root canal treatment. As stated in Seltzer & Bender 1963, Garfunkel et al. 1973, Dummer et al. 1980 Conventional treatment approaches was thought to have a poor relationship between the histological state of the pulp in mature teeth and clinical signs and symptoms; the recent histological study showed that there is a good correlation between clinical symptoms of pulpitis and the histological state of a diseased pulp. Irreversible pulpitis cases have shown the morphological changes indicating the inflammation or necrosis of coronal pulp while the radicular pulp being viable. This paves way of preserving radicular pulp thus preventing need for a pulpectomy.

This minimally invasive treatment approach called ‘Endolight’ helps

1. To preserve immunological functions and retain the structural integrity of tooth
2. To simplify treatment procedures and to avoid treatment complications related with varying root canal anatomy
3. To reduce cost and inconvenience of patients and society
4. This procedure showed little pain

**The newer proposal for new clinical pulp diagnosis and related treatment modalities**

**Initial Pulpitis**

Sharp but not lengthy response to the cold test, not sensitive to percussion with no spontaneous pain.

Treatment: Indirect Pulp therapy

**Mild Pulpitis**

Sharp and lengthy reaction to cold, hot and sweet stimuli that last up to 20s and then subsides, maybe percussion sensitive. On histology, it shows limited local inflammation confined to the coronal pulp.

Treatment: Indirect Pulp therapy

**Moderate Pulpitis**

Clear symptoms, strong, sharp and prolong reaction to cold, lasting for minutes, maybe percussion sensitive and spontaneous dull pain. On histology, it shows extensive local inflammation confined to the crown pulp.

Treatment: Coronal pulpotomy partly/completely

**Severe Pulpitis**

Severe, clear, spontaneous pain reaction to hot and cold stimuli, regularly, sharp to dull throbbing pain, very sensitive to touch and percussion patients’ experiences pain which gets worse when lying down).

Treatment: pulpectomy or tooth extraction.

This treatment strategies are evaluated and revised in order to maintain the pulp vitality with minimally invasive approach.

**3. STRUCTURAL INTEGRITY OF TOOTH**

Remaining structural integrity of the tooth is important factor that determines prognosis as it relates to the post endodontic survival rate of tooth. Maintenance of strength and stiffness that resists structural deformation becomes the goal of all restorative procedures, mainly in endodontics.

A study compared the impact of endodontic versus restorative procedures on tooth strength. They found that endodontic access openings by themselves have only 5% impact on tooth stiffness in comparison to any restorative preparation that removes the tooth’s marginal ridges which reduces the cuspal stiffness by 63%. Marginal ridges are a key factor in retaining tooth strength. Widely held clinical perception is that endodontically treated teeth are more brittle and hence more vulnerable to fracture.
Endodontic treatment major etiologic factor for tooth fracture,Brittleness of teeth due to loss of moisture\(^\text{12}\), insignificant difference in the moisture content between endodontically treated teeth and teeth with vital pulp\(^\text{13}\).

More Emphasis is given on the importance of conserving the bulk of dentine to maintain the structural integrity of post-endodontically restored teeth. The question arises here is why endodontically treated teeth fail and how to prevent it?

When endodontically treated teeth fail under function, that outcome is determined primarily by 2 aetiologies

Those causes stated most simply are:

1) Degree of stress experienced by the tooth under load

2) Inherent biomechanical properties of the remaining structure responsible for resisting fracture.

Attempts made to prevent the fracture rates are by Preservation of:

a) Peri Cervical Dentin
b) 3D Ferrule
c) 3D Soffit

a) **Peri Cervical Dentin (PCD)**

The dentin surrounding the alveolar crest often regarded as the “Irreplaceable Critical Most Zone”.\(^\text{14}\) Compromising PCD is not acceptable as no man-made material can replace the original tissues.

It is round 4mm above and 4mm below to the crestal bone. It is insisted to preserve PCD in order to prevent fracture, preserve the ferrule and dentinal tubule orifice proximity inside to out. The survival rate increases with its preservation proportionately.

Fig. 1 Pericervical Dentin

b) **3D Ferrule**

Axial wall of dentin covered by axial wall of crown. 3D refers to the components of ferrule namely:

Fig. 2 Ferrule

It has

1. **Vertical component** - around 1.5 to 2.5 mm\(^\text{14}\)
2. **Dentin thickness (Girth)** - Absolute minimum thickness – 1-2 mm\(^\text{14}\)
3. **Total occlusal convergence/ Net Taper** - Total draw of 2 opposing axial walls to receive a fixed crown which is 10\(^\circ\) in 3mm of vertical ferrule, 20\(^\circ\) in 4mm, possible in the traditional stainless-steel crowns whereas the newer porcelain crowns demands 50\(^\circ\) or more taper owing to its deep chamfer marginal zones.\(^\text{14}\)

b) **Soffit/Banking**

In English literature, the underside of a ceiling, at the corner of the ceiling and wall is referred to as soffit but in dentistry it is the stepped access\(^\text{14}\) which is 360\(^\circ\). Maintain a small border amount of the chamber roof; near the point where it curves 90\(^\circ\) and becomes the wall.
These 360 soffits - metal ring that stabilizes a wooden barrel and increased moment of inertia. In the tooth, this tiny “lip” or “cornice” could be as small as 0.5 mm, or as large as 3.0 mm in some cases (where extra strength is needed, or when the anatomy allows it).

**Fig. 3** Dotted line shows the typical cut made to remove the entire pulp horn. Area between the lines is referred to as the soffit. 14

**Complete Deroofing** attempts at removing the soffit that are far more damaging to the surrounding PCD. The primary reason to maintain the soffit is to avoid the collateral damage that usually occurs, namely the gouging of the lateral wall. Thus, a more appropriate access shape is overlaid

**Partial deroofing and maintenance of a robust amount of PCD is demonstrated below:**

**Fig. 4** A soffit that includes pulp horns on mesial and distal is depicted

4. **ALTERNATE ACCESS DESIGNS**

Traditional access designs (TECs) aims at straight line access into the root canals which increases biomechanical preparation efficacy and reduces the procedural errors.

**Fig. 5** Traditional access designs (TECs)

With the emphasis on surgical operative microscope and newer instruments, the New vision-based mental model is **Look, Groom, and Follow**

New instruments are all **round-ended tapers**. The rounded ends are to increase the radii of the gouges and nicks that can act as stress concentration points. The flat sides help create smoother, flatter walls and minimize the gouges and dings that inevitably occur even with the most careful technique. Small, cone-shaped, low-speed bur (such as the EG2 [SS White])

**Newer access designs include**

a) Conservative Endodontic Access Cavity  
b) Ninja Endodontic Access Cavity  
c) Orifice-Directed Dentin Conservation Access Cavity  
d) Incisal Access  
e) Cala Lilly Enamel Preparation

**a) Conservative Endodontic Access Cavity (CECs)**

John Khademi and David Clark modified traditional access cavities and developed the constricted or conservative endodontic access cavities to minimize the tooth structure removal while maintaining the mechanical stability of the tooth for long-term survival and function of the endodontically treated teeth. Here, teeth are accessed at central fossa and extended only as necessary to detect canal orifices, thus preserves the pericervical dentin and part of the chamber floor.
b) Ninja Endodontic Access Cavity (NECs)

An access with a ‘Ninja’ outline, the oblique projection is towards the central fossa of the root orifices in an occlusal plane. It is parallel with the enamel cut of 90° or more to the occlusal plane, making it easier to trace the root canal orifices from the varying visual angulations.

c) Orifice-Directed Dentin Conservation Access Cavity / ‘Truss’ Access Cavity

Purpose of this design is to preserve the dentin ie. Leaving a truss of dentin between the two cavities that has been prepared. Separate cavities are made to approach the canals. Mandibular molars, two separate cavities are made to approach the mesial and the distal canals where as in maxillary molars, the mesiobuccal and the distobuccal cavities is approached in one cavity and a separate cavity for the palatal canal is made.

CECs, TECs and NECs and found that TECs presented lower fracture strength than CECs and NECs in maxillary and mandibular premolars and molars and no statistical significance was found in the fracture resistance mean values of CECs and NECs.

CEC was associated with the risk of compromised canal instrumentation only in the molar distal canals, it conserved coronal dentin and conveyed a benefit of increased fracture resistance in mandibular molars and premolars. TECs may lead to a better preservation of the original canal anatomy during shaping compared with CECs, particularly at the apical level.

Instrumentation efficacy and biomechanical responses in conservative and traditional
preparations in maxillary molars and found no significant difference between the two\textsuperscript{19}. MB2 detection rate of CEC (53.3\%) and TEC (60\%) are higher than statistically that of NEC (%31.6). There was no significant difference between CEC and TEC in terms of determining MB2 canals\textsuperscript{20}. No significant difference in the fracture strengths of teeth prepared using the TEC and CEC methods, the types of fractures were less serious with CEC preparation\textsuperscript{21}.

Fracture resistance was higher when accessed through CEC than TEC. The dentin conservation afforded an increased resistance to fracture in CEC group which is doubled the fracture resistance in TEC group\textsuperscript{22}. Both traditional and conservative access designs have their own pros and cons as concentrating on too much conservative designs can lead to inefficient cleaning and shaping and also inability to get the extra canals can in turn lead to failure of the treatment. Therefore, one must know when to use based on the right tooth and situation in order to avoid failures.

d) Incisal Access

Blind Tunnelling: Gouging commonly observed with round burs which are aggressive in nature and cingulum access. Buccal-lingual gouging (not easily seen in x-rays) occurs in nearly every traditionally-accessed case.\textsuperscript{15} Figure 10.

- Precious peri-cervical dentin is lost each time the bur enters the tooth

5. IMAGE GUIDED ENDODONTIC ACCESS

It Utilizes image modalities available to clinicians. Instead of “one size fits all” determine location and size of access cavity. The objective is to strategically remove and conserve dentin and Smallest access cavity possible is made. Customization of access based on the tooth.

\textbf{Fig. 10: Blind Tunneling}

The Inverse Funnel: As the access grows internally, an inverse funnel is created.\textsuperscript{15} Precious peri-cervical dentin is lost each time the bur enters the tooth.

\textbf{Fig. 11: Incisal Access Design}

e) Cala Lilly Enamel Preparation

Traditional parallel-sided access compared with the Cala Lilly enamel preparation. Unfavourable C factor and poor enamel rod engagement are typically present when removing old amalgam or composite restorations or with traditional endodontic access 90\degree to the occlusal table. The enamel is cut back at 45 with the Cala Lilly shape.\textsuperscript{15} This modified preparation will now allow engagement of nearly the entire occlusal surface.

\textbf{Fig. 12: (a and b) Traditional parallel-sided access (left), compared with the Cala Lilly enamel preparation (right). Left - Unfavourable C factor and poor enamel rod engagement are typically present when removing old amalgam or composite restorations or with traditional endodontic access of 90\degree to the occlusal table. Right - The enamel is cut back at 45\degree with the Cala Lilly shape}
6. DYNAMICALLY GUIDED ACCESS

Dynamic guidance used for dental implants. In endodontics - first introduced by Dr. Charles M. It uses information from the patient’s CBCT volume to plan an access cavity. Overhead tracking cameras relate the position of the patient’s jaw and the clinician’s bur in 3-dimensional space. The clinician, by looking at the software interface, gets immediate feedback about the position of the bur as it relates to the position of the planned access and the tooth.

7. MICROGUIDED ENDODONTIC ACCESS

With the help of special software (coDiagnostixTM, Dental Wings Inc., Montreal, Canada), alignment with a CBCT and surface scan allows virtual planning of an ideal access cavity. Subsequently, a template can be produced by means of a 3D printer. This template guides a minimally invasive drill to the calcified root canal.

8. MODERN ENDODONTIC BURS

Traditionally used round bur technique relied on tactile feedback as the round bur drops into pulp chamber. Round burs are aggressive in nature, the walls are overextended and gouged in other areas. Newer burs like ck and endoguide burs have a tip size less than half as wide as round bur available from SS White Burs.

9. CLEANING AND SHAPING OF CANALS

Negotiating and a complete shaping of canal being the primary goal. A 3D cleaning and shaping ensuring minimal mechanical shaping and a thorough irrigation protocol. Important things to be included during cleaning and shaping are: Small apical terminal diameters but wide tapers apically, while ensuring sufficient dentin remaining in the body of the root canal.
Studies vary on which size diameter will accomplish maximum cleaning. Apical overpreparation invites fracture of tooth as it weakens tooth structure.

a. **Apical Preparation Geometry**: Significant difference was not found in intracanal bacterial reduction used with or without apical enlargement preparation, stating it is not necessitated to remove excessive dentin in the apex if sufficient coronal taper is present which allows enough irrigation. Root canal enlargement to sizes larger than #25 appeared to improve the performance of syringe irrigation. The minimum instrumentation size needed for penetration of irrigants to the apical third of the root canal is a #30 file.

b. **Self-Adjusting File System**: Hollow file - compressible, thin-walled, pointed cylinder of 1.5 mm or 2.0 mm diameter and composed of 120-μm-thick Ni-Ti lattice. File adapts itself to the three-dimensional canal morphology both longitudinally and cross-sectionally. Effectively shapes up to 92% of the of root canal walls, while allowing for the continuous flow of fresh NaOCl through the hollow file by using a peristaltic irrigation device.

c. **Endo-Eze anatomic endodontic technology**: Introduced as a minimally invasive endodontic preparation system. Used in a special reciprocating/ oscillating handpiece for instrumentation of the coronal part of the root canal about 3 mm short of the apex. Apical files are hand files with shortened cutting flutes to cut only in the apical region of the canal and are used in a clockwise turn and pull motion.

Fig. 17: Self-Adjusting Files

Fig. 18: Endo-Eze Technology

10. **3D DISINFECTION**

a. **Endoactivator system** – In a root canal system, Endoactivator activates the intracanal reagents thereby produces a vigorous hydrodynamic phenomenon utilizing sonic energy. The flexible vibrating tip which is non cutting generates an intracanal waves and fluid activation creating bubbles that oscillate within the canal, bubbles then expand and become unstable, then it collapses and implodes. The implosion creates the shockwaves which dissipates at 25,000 to 30,000 times/sec.

Fig. 19: Endoactivator

b. **Ultrasonic**: Acoustic streaming creates sufficient shear forces to dislodge debris in instrumented canals. Files activated with ultrasonic energy acoustic streaming was sufficient to produce significantly cleaner canals compared with hand filing alone. The flushing action of irrigants is enhanced. Improves the efficacy of irrigation solutions in removing organic and inorganic debris from root canal
walls. A much higher velocity and volume of irrigants flow is created in the canal during ultrasonic irrigation

c. **Photoactivated Disinfection**

**Photon Induced Photoacoustic Streaming (PIPS):**

Requires any given canal which is prepared upto size 20 files. Striped and tapered tip of PIPS is placed still in the pulp chamber alone. Upon activation of the tip, it creates non-thermal photoacoustic shockwaves, that travel 3 Dimensionally, also into the complex apical regions. It eradicates both biofilm and planktonic contaminates, sterilizing more than 1000 μm depth into the dentinal tubules.

![Fig. 20: Photon Induced Photoacoustic Streaming (PIPS)](image)

**d. GentleWave**

It is a multisonic technology with a specific wide spectrum wavelength with different frequencies. The reagents flow through the closed system. With this a 3-dimensional cleaning of canal is achieved including the complex areas like isthmuses, lateral canals and dentinal tubules.

Collaborative research has shown that this disinfection method can 3D clean a canal, the lateral anatomy, and related dentinal tubules.

![Fig. 21: GentleWave System](image)

**11. ROOT STRENGTHENING**

Advancing principle promoting minimally invasive therapy directs the nominal use of posts in endodontically treated teeth. Tooth structure is more valuable than the use of a post in almost every circumstance where adequate structure exists for a ferrule. Adhesive materials are minimally invasive.

**Posts:** Traditional post space preparation resulted in excessive tooth preparation with the use of peeso reamers which in turn leads to loss of structural integrity the newer posts like Ribbond and Everstick increases the flexibility and requires minimal tooth preparation. Fibre-reinforced resin posts are more elastic support to core.

![Fig. 22a. Traditional Post](image)

![Fig. 22b. Ribbond Post](image)
12. MAGNIFICATION

DH Lawerence quoted “what the eye doesn’t see the mind doesn’t know, doesn’t exist even if it does!” Magnification magnifies the look in endodontics to the extent that one sees it clearer which has made possible to look through the difficulties of root canal treatment. RCT is no longer a blind procedure with aids like loupes and surgical microscopes.

Limits of human eye: The resolution of human eye is 0.2mm. This can be enhanced upto 6 micrometre with the help of Surgical Operative Microscope.

Surgical microscopes are no longer a luxury but a necessity in the field of dental practice.

13. CONCLUSION

Minimally invasive endodontics is in the interest of the patient, and preserving tooth structure requires optical magnification aids (surgical microscope), ultrasonic-assisted preparation techniques, modern file systems, and in-depth knowledge of the tooth and root canal anatomy.

Focusing on too much of minimal technique my lead to a higher rate of procedural errors and benefit may be outweighed by poor clinical outcome. Hence, the clinician should strike the right balance between minimal preparation and traditional endodontic preparation with their own pros and cons, thus achieving the objectives of endodontic treatment.

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