



Modern Endodontics Reimagined – A Shift Towards Minimalism: A Narrative Review.

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ABSTRACT:

Modern endodontics is experiencing a paradigm shift from traditional, invasive techniques toward a conservative, biologically oriented approach known as Minimally Invasive Endodontics (MIE). This narrative review highlights the evolving philosophy of preserving natural tooth structure without compromising the primary goal of endodontic treatment—elimination of microbial infection from the root canal system. Conventional techniques often involve extensive access cavity preparations and aggressive canal shaping, which, while effective in cleaning, significantly weaken the tooth's structural integrity and compromise long-term restorative success. In contrast, MIE focuses on conserving the coronal, cervical, and radicular dentin using advanced diagnostic tools, conservative cavity designs, and modern instrumentation techniques. Technological advancements such as cone-beam computed tomography (CBCT), dental operating microscopes, flexible nickel-titanium rotary files, enhanced irrigation systems, and biocompatible obturation materials have made it feasible to adopt minimal intervention strategies without reducing treatment efficacy. MIE techniques can be applied throughout various phases of endodontic care, including access preparation, root canal disinfection, obturation, and even surgical endodontics. The review also emphasizes the importance of proper case selection, detailed understanding of root canal morphology, and the clinician's skill in integrating new technologies into practice. While minimalism is the goal, it is not synonymous with under-treatment but rather signifies a precise and tailored approach that respects the tooth's natural architecture. By preserving the maximum amount of healthy tooth structure, MIE supports improved biomechanical stability, better esthetic outcomes, and enhanced longevity of the treated tooth. This shift represents a future-forward model in endodontic therapy, aligning with the broader objective of sustainable and patient-centered dental care.

INTRODUCTION and BACKGROUND:

A successful outcome in endodontic therapy is closely linked to both the functional longevity of the treated

tooth and the preservation of its natural structure. Traditionally, root canal procedures focused primarily on thorough disinfection and shaping of the canal system, often at the expense of significant tooth structure loss.



However, emerging evidence highlights that long-term success is influenced not only by microbial control but also by the conservation of residual dentin and the integrity of the peri-cervical region.[1] The structural durability of endodontically treated teeth is directly related to the amount of remaining sound dentin, especially in critical zones like the cervical and radicular areas. Over time, excessive removal of dentin during access cavity preparation and canal shaping has been associated with increased risk of fractures and restorative failure. In response, the field of endodontics has embraced a minimally invasive approach, known as Minimally Invasive Endodontics (MIE), which aims to retain as much healthy tooth structure as possible without compromising disinfection and treatment quality. This evolution has been supported by the integration of modern technologies such as cone beam computed tomography (CBCT), dental operating microscopes, bioceramic sealers, flexible rotary file systems, and ultrasonics, all contributing to safer and more conservative techniques.[2] The MIE philosophy not only addresses pulpal and periapical pathology but also ensures long-term biomechanical stability and improved restorative outcomes. Understanding root canal anatomy, coupled with careful case selection and biologically driven treatment strategies, forms the backbone of this modern endodontic era. Thus, MIE represents a progressive shift in dental care—focusing on preservation, function, and the longevity of the natural tooth.

REVIEW:

Preservation of Tooth Structure - The Foundation of Minimally Invasive Endodontics:

The evolution of endodontic practice in recent years has marked a transition from traditional, invasive approaches to more biologically respectful techniques centered around the preservation of tooth structure. A critical determinant of the long-term prognosis of endodontically treated teeth (ETT) is the amount and quality of residual dentin, particularly in the peri-cervical area. This region, located around the cemento-enamel junction, plays a crucial role in distributing occlusal forces and maintaining the tooth's biomechanical stability.

Traditional access cavity designs, often based on the outdated philosophy of “extension for prevention,” involve excessive removal of healthy dentin and enamel

in an attempt to ensure complete debridement. However, this compromises the structural integrity of the tooth, increasing its susceptibility to fracture and reducing its longevity. Extensive loss of dentin, especially in the cervical region, weakens the tooth's ability to resist functional and parafunctional forces.[3]

Minimally Invasive Endodontics (MIE) redefines these principles by focusing on strategic conservation of dentin during access preparation and canal shaping. Research has shown that even small reductions in cavity size can lead to significantly lower loss of tooth mass. Studies have also confirmed that teeth with preserved dentin exhibit improved fracture resistance, tensile strength, and structural durability when compared to extensively prepared teeth.

The understanding of dentin as a biologically irreplaceable material underscores the importance of preserving it wherever possible, since no restorative material can replicate its mechanical and structural properties.[4] Moreover, the use of advanced imaging techniques, dental microscopes, and flexible rotary instrumentation allows clinicians to negotiate complex root anatomies with precision, further minimizing unnecessary structural removal.

By maintaining the integrity of the coronal and radicular tooth structure, MIE not only improves the tooth's resistance to fracture but also enhances the success of future restorative procedures.[5] This shift toward conservative, anatomy-driven treatment planning forms the foundation of modern endodontics, aiming not just for disinfection but for the long-term survival and function of the natural tooth.

Root Canal Anatomy and Its Role in Conservative Treatment:

An in-depth understanding of root canal anatomy forms the cornerstone of successful endodontic therapy, particularly when adopting a conservative, minimally invasive approach. Root canal systems are complex, with significant anatomical variations not only between different teeth but also within the same type of tooth across individuals. These variations include additional canals, lateral canals, isthmuses, curvatures, and apical deltas—all of which can present challenges to achieving complete debridement and disinfection if not properly identified and addressed.



In traditional endodontics, wide access openings and extensive shaping were often used to visualize and instrument the canals more easily. However, this often led to excessive removal of dentin and compromised the structural integrity of the tooth. Minimally Invasive Endodontics (MIE) shifts the focus from over-preparation to a more calculated and anatomy-respecting strategy. With the help of advanced tools such as cone-beam computed tomography (CBCT), magnification loupes, and dental operating microscopes, clinicians can now diagnose and locate canals more accurately, reducing the need for unnecessary enlargement of the access cavity and canal walls.[6]

Respecting the native anatomy during treatment allows for more targeted cleaning and shaping, thereby preserving valuable tooth structure, especially in critical areas like the cervical and apical thirds. Flexible and heat-treated NiTi instruments also support this goal by adapting to the curvature of the canals without excessive straightening or ledging. Furthermore, irrigation technologies have evolved to aid in effective canal disinfection even in minimally shaped canals, making it possible to achieve clinical success without compromising the tooth's strength.

Ultimately, a thorough understanding of root canal morphology not only facilitates complete disinfection but also aligns with the principles of conservative treatment.[7] By preserving natural anatomy and reducing procedural errors, clinicians enhance the prognosis of endodontically treated teeth, ensuring both functionality and longevity with minimal biological cost.

Modern Access Cavity Designs - Balancing Visibility and Conservation:

The design of the access cavity is a fundamental component of endodontic treatment, as it enables the clinician to locate, clean, and shape the root canal system. Traditional endodontic access cavities prioritized maximum visibility and straight-line entry to all canals, often leading to excessive removal of coronal and peri-cervical dentin. While this approach reduced the chances of missed canals, it inadvertently weakened the tooth structurally and increased the risk of fractures. In the current era of Minimally Invasive Endodontics (MIE), the philosophy has shifted towards conserving as much of the natural tooth as possible—particularly the peri-

cervical dentin, which is crucial for long-term biomechanical integrity.[8]

Conservative Access Cavity (CAC) is a modification of the traditional approach, where the access outline is reduced in size and directed precisely over the pulp chamber, often guided by pre-operative imaging like CBCT. Unlike traditional designs that remove the entire roof of the pulp chamber, CAC preserves portions of the chamber and marginal ridges to retain structural strength. Although the canal orifices may not be directly visible without magnification, the CAC balances efficient canal location with significant structural conservation.[9]

Ninja Access takes this concept even further. It is characterized by an ultra-small access opening made directly above the canal orifices, often created using digital planning and CBCT-guided navigation. The name "ninja" reflects its stealth-like precision and minimal invasiveness. This technique requires a high level of magnification (usually with a dental operating microscope) and operator skill, as canal negotiation must be done through a narrow channel. While the risk of missed canals is slightly higher without sufficient magnification, the structural preservation achieved is unmatched.[10]

Truss Access, another variation under the MIE umbrella, focuses on preserving the dentinal bridges between canal orifices—termed "trusses"—much like architectural trusses that add support to a structure. In this design, separate small access points are made for each canal instead of one large common cavity. This allows for excellent conservation of the tooth's roof and internal dentinal walls. Though more time-consuming and technically demanding, truss access significantly improves the resistance of the tooth to vertical fracture.[11]

Despite their conservative nature, these modern access designs introduce certain clinical challenges, including limited visibility, difficulty in negotiating calcified canals, and increased operator time. However, with the use of advanced technologies such as CBCT, dental operating microscopes, high-definition illumination, and guided endodontic tools, these challenges can be effectively managed.

Ultimately, modern access cavity designs aim to strike a balance between visibility and conservation. They



embody the principles of MIE by allowing effective treatment while preserving structural components essential for the longevity and function of the tooth. When applied thoughtfully and skillfully, these techniques offer a biologically respectful and mechanically sound approach to root canal therapy.

Advancements in Canal Shaping - Efficiency with Preservation:

Canal shaping is a vital step in endodontic therapy, aimed at removing infected tissue and creating a path for effective disinfection and obturation. Traditionally, shaping involved extensive enlargement of the canal to facilitate irrigation and filling, often leading to unnecessary removal of dentin and weakening of the tooth. Modern endodontics, guided by the principles of Minimally Invasive Endodontics (MIE), emphasizes preserving the natural canal anatomy while ensuring thorough debridement.[12]

Recent advancements in instrument design and metallurgy have revolutionized canal shaping. The introduction of heat-treated nickel-titanium (NiTi) files has significantly improved flexibility and resistance to cyclic fatigue, allowing safer navigation of curved and narrow canals with minimal shaping. Reciprocating and adaptive motion systems further reduce stress on both the instrument and the canal walls, minimizing the risk of canal transportation and ledging.

Moreover, the use of minimally tapered files (e.g., 4% or less) allows sufficient shaping without over-preparing the canal. These conservative shaping techniques maintain more dentin, especially in the cervical and mid-root regions, which are critical for structural integrity and fracture resistance.

Enhanced irrigation techniques, such as passive ultrasonic irrigation (PUI) and negative pressure systems, complement minimal shaping by ensuring effective cleaning even in uninstrumented areas.[13] Together, these advancements promote efficient canal disinfection while preserving the tooth's biomechanical properties—striking a critical balance between efficacy and conservation.

Irrigation and Disinfection in Minimally Invasive Endodontics:

In Minimally Invasive Endodontics (MIE), where mechanical canal shaping is deliberately limited to preserve dentin, effective irrigation becomes even more critical for successful disinfection. Since smaller canal preparations restrict direct mechanical contact with all canal walls, the role of chemical debridement is significantly amplified.

Sodium hypochlorite (NaOCl) remains the gold standard irrigant due to its tissue-dissolving and antimicrobial properties. However, to enhance its efficacy within minimally shaped canals, activation techniques such as **passive ultrasonic irrigation (PUI)**, **sonic activation (EDDY)**, and **laser-activated irrigation (e.g., SWEEPS)** are now routinely used. These methods create microstreaming and cavitation, improving irrigant penetration into lateral canals, isthmuses, and apical regions.[14]

In addition, **negative pressure irrigation systems** like EndoVac help deliver irrigants safely to the working length without risk of extrusion, especially valuable in narrow and curved canals. **Chelating agents** such as EDTA are also essential for smear layer removal, which facilitates better sealer penetration and adhesion.

Effective irrigation in MIE depends on a combination of advanced activation techniques and optimized protocols rather than increased canal enlargement.[15] When used correctly, these strategies allow thorough canal disinfection while preserving the natural structure of the tooth, which is the fundamental goal of MIE.

Cervical Dentin and Ferrule Effect - Biomechanical Perspectives:

Cervical dentin, located around the cemento-enamel junction (CEJ), is essential for maintaining the structural integrity of endodontically treated teeth (ETT). It plays a key role in distributing occlusal forces and preventing vertical root fractures. In Minimally Invasive Endodontics (MIE), preserving this region is a priority, as excessive removal during access or shaping can significantly weaken the tooth.

A crucial concept related to cervical dentin is the **ferrule effect**—a 360-degree collar of sound dentin above the margin of a restoration. This effect improves fracture



resistance by reinforcing the tooth, absorbing functional stress, and enhancing the stability of restorations, especially those involving posts.[16]

Studies have consistently shown that teeth with an adequate ferrule have better clinical outcomes. Loss of cervical dentin reduces this effect, increasing the risk of structural failure. Therefore, conservative techniques in MIE aim to retain as much dentin as possible in this region. By preserving cervical dentin and enabling a proper ferrule, MIE not only supports effective disinfection but also enhances the long-term strength and restorability of the tooth.[17] This approach aligns endodontic and restorative goals, ensuring both functional and durable outcomes.

Imaging and Magnification - Enablers of Conservative Precision:

The integration of advanced imaging and magnification tools has played a transformative role in enabling the principles of Minimally Invasive Endodontics (MIE). These technologies allow clinicians to precisely diagnose, plan, and execute procedures with minimal structural compromise, ensuring both effectiveness and conservation. Among these, **cone-beam computed tomography (CBCT)** has emerged as a key diagnostic tool, offering three-dimensional visualization of root canal anatomy, periapical pathology, and canal curvatures that are often missed in conventional two-dimensional radiography. Preoperative CBCT scans allow for accurate assessment of root canal morphology and aid in designing conservative access cavities tailored to the tooth's internal anatomy.[18]

Intraoperative magnification tools such as **dental operating microscopes (DOM)** and **high-powered loupes** have further revolutionized endodontic procedures by enhancing visibility within the pulp chamber and root canal system. These devices allow for precise location of canal orifices, identification of microfractures, and controlled instrumentation within the confined space of conservative access cavities. Enhanced illumination from integrated light sources improves depth perception and procedural accuracy, significantly reducing the risk of iatrogenic errors such as perforations or missed canals.

Together, imaging and magnification serve as critical enablers of conservative endodontics.[19] They

empower clinicians to shift from traditional, invasive techniques to anatomically guided, tissue-preserving approaches. By providing clarity and precision, these tools ensure that minimal intervention does not compromise the quality of treatment, but instead enhances clinical outcomes and promotes long-term tooth preservation.

Restorative Considerations Post-Minimally Invasive Endodontics:

Following the completion of minimally invasive endodontic therapy, the choice and execution of restorative treatment play a vital role in determining the long-term success of the tooth. Since Minimally Invasive Endodontics (MIE) prioritizes the preservation of dentin and enamel, it provides a more favourable substrate for restorative procedures. However, careful planning is required to ensure that the remaining tooth structure is adequately protected and reinforced under functional loading.

One of the key restorative principles after MIE is maintaining or recreating the **ferrule effect**, which involves having at least 1.5–2 mm of sound tooth structure above the crown margin to resist fracture. When this ferrule is intact, less invasive restorative options—such as adhesive onlays or overlays—can often be considered instead of full-coverage crowns. The use of **adhesive dentistry** and **fiber-reinforced composite materials** supports the conservative ethos of MIE by bonding directly to the tooth, providing strength while avoiding excessive preparation.[20]

Post placement may still be indicated in some cases, especially when coronal structure is severely compromised. In such scenarios, **fiber posts** are preferred over metal posts due to their modulus of elasticity being closer to that of dentin, which helps distribute stress more evenly and reduce fracture risk. Importantly, the restorative decision must be based on factors such as the volume of residual dentin, occlusal load, esthetic demands, and the patient's long-term oral health goals.

Ultimately, the restorative phase following MIE is not just a mechanical step but an extension of the minimally invasive philosophy. By respecting the preserved tooth structure and using modern adhesive techniques,



clinicians can maximize the strength, function, and longevity of the endodontically treated tooth.[21]

Regenerative and Surgical Applications of Minimally Invasive Endodontics:

Minimally Invasive Endodontics (MIE) has extended its influence beyond conventional root canal treatment into the realms of **regenerative** and **surgical endodontics**, offering new possibilities for tissue preservation and biologically oriented care. In regenerative endodontics, MIE supports procedures like **revascularization and pulp-dentin complex regeneration**, which rely heavily on maintaining the native canal architecture and minimizing mechanical disruption. By preserving apical tissues and dentinal walls, MIE creates a favourable environment for the migration, adhesion, and proliferation of stem cells and growth factors necessary for tissue regeneration. Techniques such as gentle irrigation, the use of biocompatible scaffolds, and controlled bleeding protocols all align with the goals of minimal invasion and biological healing.[22]

In surgical applications, MIE plays a vital role in procedures such as **apicoectomy** and **retrograde filling**, where precision and conservation are equally critical. With the use of **microsurgical instruments, ultrasonic retro-tips**, and **bioceramic materials**, clinicians can limit the size of osteotomy and root-end resections while ensuring complete decontamination and sealing. Enhanced magnification and imaging through CBCT enable accurate diagnosis and precise localization of pathology, minimizing unnecessary tissue removal during surgery.

Both regenerative and surgical aspects of MIE reflect a shift from mechanical dominance to biologically guided care. By combining advanced technology with conservative technique, these approaches improve outcomes while preserving the natural architecture and healing potential of the periradicular tissues.[23] This broadens the scope of MIE and reinforces its role as a comprehensive, future-ready approach in endodontic therapy.

Future Directions in Minimally Invasive Endodontics:

The future of Minimally Invasive Endodontics (MIE) lies in the continued integration of advanced technologies, biologically driven materials, and digitally guided

treatment protocols. As the field evolves, there is a growing emphasis on precision, preservation, and personalization. One of the most promising advancements is the use of **3D-guided endodontics**, where digitally planned access cavities are created using templates or navigation systems, allowing for accurate and ultra-conservative cavity designs, particularly in calcified or anatomically complex teeth.

Additionally, **artificial intelligence (AI)** and **machine learning** are expected to play a larger role in diagnostics, treatment planning, and outcome prediction. AI-assisted CBCT interpretation and automated canal detection could enhance the accuracy and efficiency of minimally invasive procedures.[24] The development of **bioceramic materials**, bioactive sealers, and regenerative scaffolds also aligns with the goals of MIE, promoting healing and sealing with minimal mechanical intervention.

Another key area of progress is **nanotechnology**, which may lead to more effective disinfection techniques using nano-irrigants and antibiofilm agents that can penetrate complex anatomy without excessive canal shaping. Similarly, innovations in **robotic endodontics** and **microsurgical instrumentation** may allow for even more controlled, less invasive procedures in both orthograde and surgical endodontics.[25]

As MIE continues to mature, the emphasis will shift from simply minimizing intervention to **optimizing tissue preservation with maximum biological and mechanical success**. These future directions hold the potential to redefine endodontic standards by combining minimal invasiveness with maximum effectiveness.

Challenges and Limitations in Minimally Invasive Endodontics:

Minimally Invasive Endodontics (MIE), while beneficial in preserving tooth structure, comes with notable challenges. Limited access and visibility in conservative cavity designs can increase the risk of missed canals, especially in complex or calcified anatomies. Minimal canal shaping may also reduce mechanical debridement, placing greater reliance on advanced irrigation methods for effective disinfection.

MIE is highly technique-sensitive and requires skilled operators, magnification tools, and digital imaging. Without proper training and equipment, there is a higher



risk of procedural errors. Additionally, in teeth with significant structural damage or deep caries, MIE may not be practical or safe. Therefore, careful case selection and clinical judgment are essential to balance conservation with complete treatment.

Conclusion:

Minimally Invasive Endodontics (MIE) marks a significant evolution in endodontic philosophy, shifting the focus from aggressive intervention to thoughtful conservation. By prioritizing the preservation of tooth structure—particularly cervical dentin—while leveraging modern tools like CBCT, operating microscopes, and advanced irrigation systems, clinicians can achieve both biological and mechanical success. The path forward in conservative endodontic care lies in embracing evidence-based innovation, refining techniques, and ensuring proper case selection. As technology continues to evolve, the integration of precision-driven methods with a preservation-focused mindset will further enhance treatment outcomes. Ultimately, MIE reflects a patient-centered approach that values longevity, function, and respect for natural tooth anatomy—defining the future of modern endodontic care.

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