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Minimally Invasive Techniques In Endodontics: Maximising Preservation, Minimising Intervention- A Review

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Abstract:
This article presents a comprehensive review of the transformative concept of Minimally Invasive Endodontics (MIE) within the realm of modern dentistry. The core objective of MIE is to preserve the natural integrity of tooth structure while achieving optimal outcomes in root canal treatments. By embracing patient-centered care, MIE integrates innovative technologies and evidence-driven practices to mitigate discomfort and secure long-term oral health. The review covers various facets of MIE, from access cavity preparations and advanced techniques like Photon-Induced Photoacoustic Streaming (PIPS) and the Self-Adjusting File (SAF) system to the evolution of three-dimensional obturation methodologies. Throughout the discussion, a recurring emphasis on conserving tooth structure emerges as a pivotal theme. The article underscores the potential of MIE to revolutionize dental practices by prioritizing minimally invasive interventions, thereby paving the way for enhanced patient satisfaction and long-lasting treatment outcomes.

Keywords: *Minimally Invasive Endodontics (MIE), Tooth Preservation, Patient-Centered Care, Endodontic Innovations, Treatment Efficiency, Tooth Structure Integrity*
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I. INTRODUCTION

Modern dentistry has transformed how we address oral diseases, with Minimally Invasive Endodontics (MIE) standing out as a significant advancement. This technique revolutionizes endodontics by preserving natural tooth structure and effectively treating root canal issues. MIE prioritizes patient-centered care, using innovative technologies and evidence-based methods to enhance treatment outcomes, minimize discomfort, and ensure long-term oral health. Unlike traditional approaches that remove substantial tooth structure, MIE follows the principle of 'biological dentistry,' focusing on preserving tooth health and vitality while resolving root canal problems. By adopting this conservative approach, dental practitioners extend the lifespan of natural teeth and decrease the need for more invasive future restoration procedures

Minimally invasive endodontics treats pulpal issues with minimal damage to dental hard tissues, prioritizing tooth strength and longevity. Like medicine, dental surgeons adapt to limited pulp space, using advanced tools and skills for effective root canal cleaning. Imaging and software enhance treatment precision, while magnification improves pulp space visibility. New materials aid in restoring tooth structure and preserving natural dentition.[1]

Minimally Invasive Endodontics (MIE) preserves natural dentin across three root canal phases:
Access Preparation: MIE retains tooth integrity by minimal dentin removal.
Apical Preparation: Precise dentin removal maintains tooth structure.
Canal Flaring: MIE minimizes dentin removal for long-term tooth stability[2]

Following MIE principles in these phases ensures effective endodontic results with minimal tooth trauma. Dentin preservation is vital for strength and longevity, enhancing lifelong function. Staying current with technology, methods, and skills is essential for optimal patient outcomes

II. MINIMALLY INVASIVE ACCESS CAVITY PREPARATIONS

The initial step in nonsurgical endodontic treatment is creating an endodontic access cavity (EAC). This step aims to remove decay, expose the pulp chamber, locate canal openings, and establish a clear path to canals while preserving tooth structure. Medical and dental fields are increasingly embracing minimally invasive approaches due to advances in sciences, magnification tools like microscopes, and imaging like cone-beam computed tomography

Traditional access preparations achieve goals, yet raise concerns for treated teeth's long-term strength. Minimally invasive approaches aim to preserve more natural structure but might compromise some goals. Clinicians seek to minimize lost tooth structure, balancing treatment efficiency and integrity. Yet, embracing minimally invasive methods requires critical evaluation of pros and cons by dental professionals before adoption.[3]

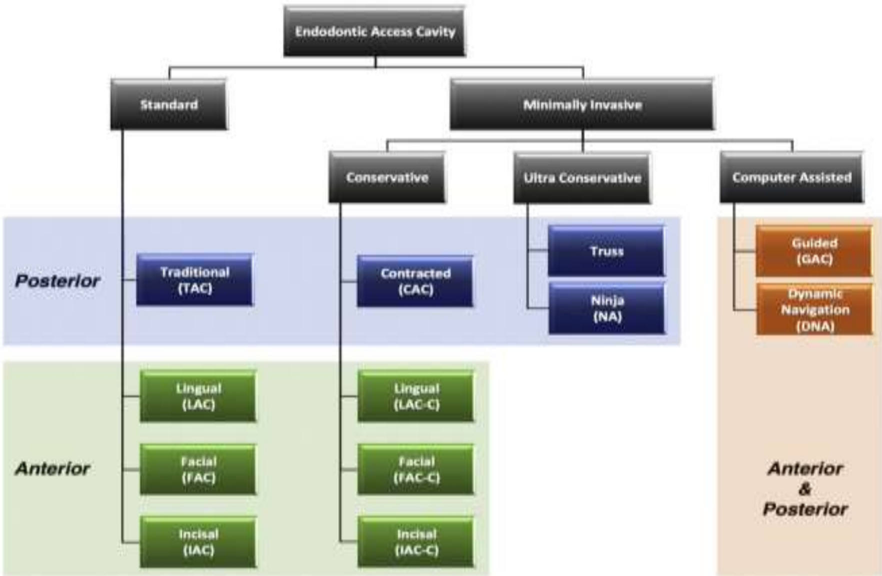


FIGURE 1 – A diagram showing the different types of standard and minimally invasive access cavity preparations in anterior and posterior teeth.

III. NOMENCLATURE OF ACCESS CAVITY

In endodontics, consistent terminology is vital for clarity and shared understanding. Various access cavity designs are emerging without standardized naming, leading to confusion. To address this, a new classification proposes condensing 22 terms into six categories for a shared language with clear abbreviations[4]:

1. Traditional Access Cavity (TradAC) is the standard approach for root canal access in both posterior and anterior teeth. In posterior teeth, the pulp chamber roof is removed for a direct path to canal openings. In anterior teeth, access extends toward the incisal edge, preserving pericervical dentin.
2. Conservative Access Cavity (ConsAC) starts at the central fossa, exposing canal orifices while preserving roof dentin. "Conservative Access Cavity with Divergent Walls" (ConsAC.DW) involves slight wall divergence.
3. Ultra-Conservative Access Cavity (UltraAC) minimizes pulp chamber roof removal. It's useful in situations requiring minimal intervention.
4. Truss Access Cavity (TrussAC) conserves dentinal bridges between small cavities accessing multi-rooted canals.
5. Caries-Driven Access Cavity (CariesAC) removes decayed parts while conserving healthy tooth structures.
6. Restorative-Driven Access Cavity (RestoAC) accesses previously restored teeth without decay, maintaining tooth integrity [4].

Consistently applying these terms can enhance communication and understanding in endodontic practice.

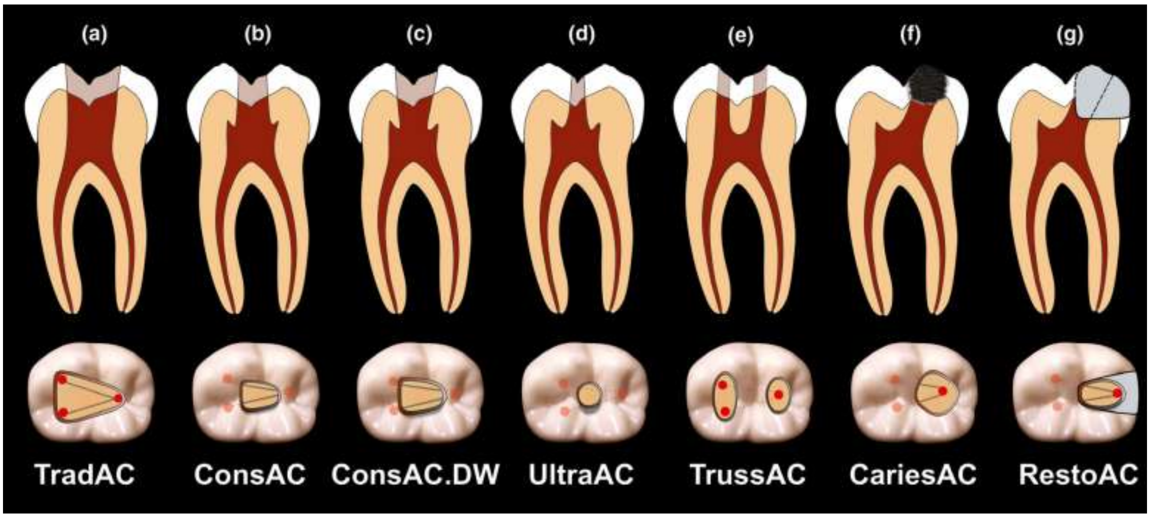


Figure 2 Classification of the access cavity (a) Traditional access cavity (TradAC); (b) conservative access cavity (ConsAC); (c) conservative access cavity with divergent walls (ConsAC.DW); (d) ultra-conservative access cavity (UltraAC); (e) truss access cavity (TrussAC); (f) caries-driven access cavity (CariesAC); (g) restorative-driven access cavity (RestoAC).

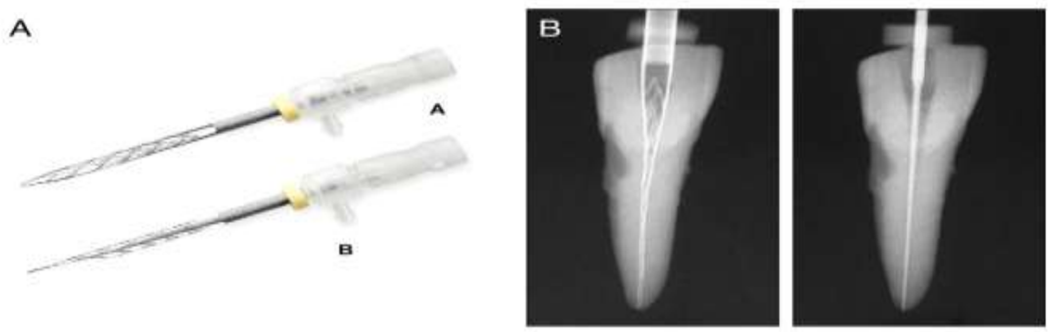
Traditional methods have been effective, but concerns about tooth survival and fractures drive minimally invasive alternatives. Newer approaches prioritize structure and access goals. Selecting the right technique requires evaluating clinical factors, patient needs, and tooth anatomy. By comprehending each approach's pros and cons, clinicians can choose wisely for better patient outcomes and lasting tooth health

IV. BIOMECHANICAL PREPRATION IN MINIMALLY INVASIVE ENDODONTICS

Modern endodontics emphasizes minimally invasive procedures, particularly in biomechanical root canal preparation. Minimally invasive endodontics aims to preserve natural tooth tissue while ensuring effective root canal therapy. Biomechanical preparation focuses on cleaning and shaping the canal system for infection removal and therapy success. It demands a balance between mechanical integrity and tooth structure protection.

V. THE SELF-ADJUSTING FILE (SAF) SYSTEM

The Self-Adjusting File (SAF) system is a transformative innovation in minimally invasive endodontics, aligning with natural tooth preservation and effective treatment. Unlike traditional rotary files, SAF adapts to root canal anatomy, reducing dentin removal. Its compressible, pointed cylinder design, available in 1.5mm and 2.0mm diameters, employs a thin-walled nickel-titanium lattice. Inserted and vibrated, it conforms to canal shape, facilitating meticulous cleaning with minimal trauma to tooth structure.[5]



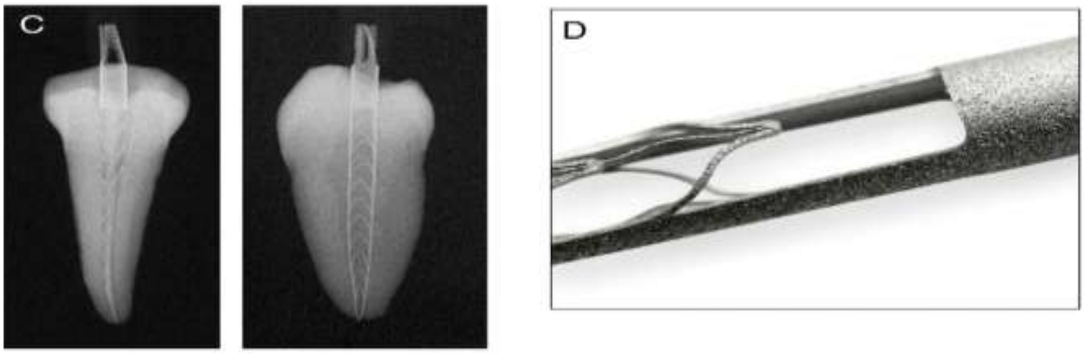


Figure 3. (A) The SAF. (A) Shank for attachment to a transline vibrating handpiece (in-and-out motion). (B) Connector (hub) for the irrigation tube. (B) The SAF compressed into a canal prepared by a # 20 K file. Right: A # 20 K file. (Left) The SAF compressed into the same canal. (C) Three dimensional adaptation of the SAF file. The SAF inserted into the root canal of a lower bicuspid with a flat canal. Left: bucco-lingual projection. (Right) Mesiodistal projection. (D) Abrasive surface of the SAF file (25magnification).

SAF works with 3,000-5,000 vibrations per minute and 0.4mm amplitude via handpieces like KaVoGENTLEpower. Its hollow structure allows continuous irrigation with devices like VATEA or implantologyphysiodispensers. Procedure steps involve insertion, vibrating, gentle pushing to working length, and manual in-and-out motions with continuous irrigation. SAF is designed for single use.[6]

This system revolutionizes endodontics by harmonizing with minimally invasive ideals, adapting to canal anatomy, and reducing excessive dentin removal. Its three-dimensional flexibility, vibrating action, and irrigation ensure efficient dentin removal for superior outcomes. Proper training is key for effective use, enabling informed decisions based on patient cases. As SAF progresses in endodontics, its integration advances conservative yet highly effective root canal treatments, enhancing patient care in modern practices

VI. PHOTON INDUCED PHOTO ACOUSTIC STREAMING TECHNIQUE (PIPS)

The Photon-Induced Photoacoustic Streaming (PIPS) technique is an innovative laser-based approach in endodontics. Using laser technology, PIPS generates photoacoustic waves that disinfect root canals non-invasively. By utilizing laser-induced acoustic waves, PIPS targets bacterial elimination, biofilms, and debris from challenging areas, enhancing root canal treatment success.

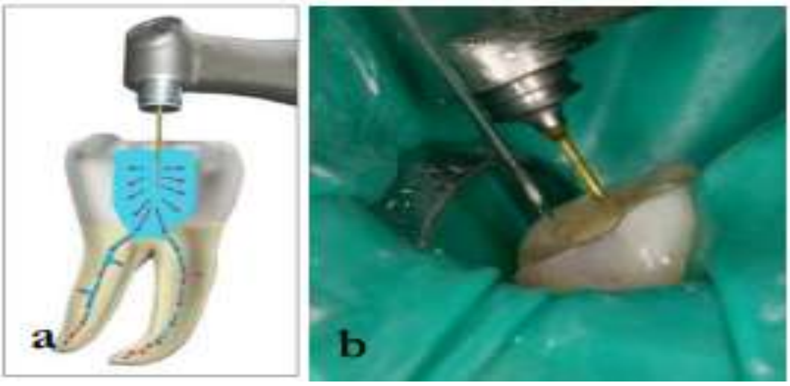


Fig. 4 a, b: PIPS™ technique: the tip must be placed in the coronal chamber with open access to the canals

In 2009, an innovative irrigation system introduced a modified radial firing erbium/YAG laser tip. This system generates a photoacoustic shockwave, aiding irrigant flow into intricate canal areas. Called photon-induced photoacoustic streaming (PIPS), this technology was studied by Malterud (2013), DiVito et al. (2011), and Lloyd et al. (2014). PIPS improves cleaning in challenging root canal zones, boosting treatment outcomes (Jaramillo 2015).[7]

This method utilizes a specific Er/YAG laser with a radial, stripped tip design, operating at subablative power (0.3 W). Peters et al. (2011), Pedulla et al. (2012), and Zhu et al. (2013) found no extra bacteria reduction benefits, but DiVito et al. (2012) noted significant smear layer removal improvement. Peeters&Suardita (2011) used a plain fiber tip for irrigating activation, inducing cavitation for enhanced smear layer removal. Another study found the plain fiber tip directs irrigation solution to the canal end without harming apical tissues (Peeters&Mooduto 2013).[8]

Traditional laser applications require root canal prep up to size 30, reaching the apical third. In contrast, PIPS tip is placed only in the coronal canal reservoir, enabling minimally invasive root prep (DiVito& Lloyd 2012a, DiVito et al. 2012b). PIPS's enhanced effectiveness relates to increased sodium hypochlorite (NaOCl) reaction kinetics activated by the laser (de Groot et al. 2009, Macedo et al. 2010).[8]

Both PIPS and ultrasonic irrigation use acoustic energy to treat root canal irrigant (Ahmad et al. 1987, DiVito et al. 2012b). Ultrasonic irrigation's acoustic streaming is more efficient than syringe irrigation in removing debris from simulated extensions and irregularities (Lee et al. 2004).[8]

Unlike conventional laser techniques, PIPS doesn't require apical third access. Positioned in the coronal canal reservoir, it minimizes invasiveness, reducing reliance on extensive instrumentation, lowering procedural risks, and preserving tooth structure. In summary, PIPS excels in removing apical debris compared to sonic and ultrasonic methods. With its minimally invasive approach and improved NaOCl reaction, PIPS offers a promising option for root canal cleaning and disinfection

VII. ADVANCEMENTS IN THREE DIMENSIONAL OBTURATION TECHNIQUES

Advancements in three-dimensional obturation techniques have transformed endodontics, introducing innovative methods to seal root canals conservatively and efficiently post-cleaning. These techniques prioritize natural tooth structure preservation while ensuring a sealed canal without harming surrounding tissues. With better insights into canal anatomy and material/technology progress, diverse minimally invasive obturation methods address treatment complexities. This article explores these cutting-edge techniques, analyzing their benefits, limitations, and contributions to modern endodontic practices.

Various methods exist for complete root canal obturation, often using a solid core with cement or adaptable plastic material. This review emphasizes new cementing agents, plasticized gutta-percha systems, and alternative obturation approaches, moving toward comprehensive three-dimensional root canal sealing

VIII. THERMOPLASTICIZED INJECTABLE GUTTA-PERCHA

Thermoplasticized injectable gutta-percha is a leading-edge method in endodontics for achieving three-dimensional root canal obturation. This advanced procedure employs heated gutta-percha, which becomes flowable and flexible at a specific temperature. This molten material is then injected into the root canal, precisely adapting to complex canal shapes and ensuring a secure, airtight seal. This technique offers benefits like enhanced adaptation to canal walls, improved filling of lateral/accessory canals, and minimized voids or gaps compared to traditional methods.

Since injectable thermoplasticized gutta-percha's introduction (Yee et al. 1977) for root canal obturation, numerous studies have assessed its efficacy (Torabinejad et al. 1978, Michanowicz&Czonstkowsky 1984, ElDeeb 1985, Evans & Simon 1986, Michanowicz et al. 1986, George et al. 1987, Mann &McWalter 1987) and clinical use (Marlin et al. 1981, Marlin &Desilets 1984a, Flores &Musulc 1985). While mostly positive, criticisms (Abou-Rass, 1984) have emerged. These include material control challenges, canal enlargement for injection, measurement guidelines absence, rapid material cooling affecting condensation and causing voids, equipment issues (needle breakage, leaks), and undercondensed fillings in the apical third of the canal.[9]

Despite criticisms, efforts have been focused on refining thermoplasticized injectable gutta-percha techniques. Researchers and clinicians are actively seeking innovations to enhance efficacy and overcome limitations. Technological advancements have yielded improved heating systems, precise temperature control, and innovative injection devices, enabling better material handling and reducing the risk of rapid material cooling

Ongoing research and root canal instrumentation advancements have improved shaping and cleaning procedures, creating a favorable setting for thermoplasticized gutta-percha obturation. Better instrumentation reduces the need for extensive canal enlargement to fit injection needles, promoting conservative and minimally invasive root canal treatments.

IX. THERMAFIL TECHNIQUE: ACHIEVING THREE-DIMENSIONAL OBTURATION WITH TAPERED PLASTIC CARRIERS

The Thermafil technique is an innovative and leading approach in endodontics, enabling three-dimensional obturation of root canals using tapered plastic carriers. This method ensures a reliable seal within the canal, promoting disinfection and preventing reinfection. Specially designed gutta-percha carriers mimic the root canal's natural shape, facilitating excellent adaptation to canal walls and complex anatomy. When heated, the thermoplastic material flows into the canal's intricacies, creating a compact and uniform filling.

The Thermafilobturation technique was introduced by Dr. Ben Johnson in the 1978 article "A new gutta-percha technique" published in the Journal of Endodontics. This approach aimed to deliver thermoplasticized gutta-percha to the prepared root canal. Initially, metallic carriers coated with α phase gutta-percha were used. These carriers were heated and inserted into the dried and sealed root canal. Thermafil offered benefits like apical sealing, ease of use, length control, and conservative canal enlargement. The technique has evolved with plastic carriers, dedicated ovens, and cross-linked gutta-percha cores. The Thermafil system includes obturators, Thermaprep oven, verifiers, and specialized burs.[10]

Fig 5: Thermafil obturators

The Thermafil obturators feature a radiopaque plastic core (carrier) surrounded by gutta-percha. The colored handle of the carrier corresponds to its tip diameter based on ISO standardization. It is 25 mm long and has a flexible groove for easy removal. Circular projections at different distances from the tip aid penetration into the root canal. Available in 17 sizes (0.20 to 1.40 mm tip diameter) with a 4% taper, Thermafil obturators accommodate various shaping protocols like Protaper Universal, Protaper Next, Protaper Gold, and Wave-One.[10]

Fig.6 :Thermaprep oven

The Thermaprep oven heats Thermafil obturators through the Joule effect. In the OLDEST version, one obturator is heated at a time, and there's no soft-released button. Maximum heating program is recommended. In the NEWEST version, two obturators can be heated simultaneously using selected programs, with a release-controlled damper. Selecting the obturator button diameter and pressing start warms the gutta-percha effectively

Fig.7 :NI-TI VERIFIER Thermafil verifiers

The Thermafil verifiers are Ni-Ti alloy instruments in 12 sizes (0.20 to 0.90 mm tip diameter, 5% taper). They resemble manual Profile instruments, ideal for precise adjustments and refinements in the root canal. The plastic verifier is the carrier without gutta-percha, used for accurate evaluation of canal adaptation without creating a smear layer.

Fig. 8: THERMACUT BUR

Thermacut burs are stainless steel burs with a spherical tip, designed for turbine use. They create heat through friction for cutting the carrier and are used dry. Available in four diameters, they are 25 mm long.

The Thermafil system is a reliable technique for precise and complete root canal filling. It's unique in directly delivering warm gutta-percha to the apex, showing exceptional effectiveness, especially in narrow, long, and curved canals. Traditional methods struggle in reaching the last 4 mm of such canals.[10]

X. DISCUSSION

New techniques, such as conservative access cavities (CACs), ultraconservative access cavities (UCACs), and truss access cavities (TRACs), have been introduced to minimize structural weakening during endodontic procedures, as noted by Celikten B et al. These alternatives aim to reduce the removal of tooth structure compared to traditional endodontic cavities (TECs). Studies have produced varied outcomes regarding different cavity designs. For instance, Isufi et al. found that dentin and enamel removal increased in the order of UCAC, CAC, and then TAC.

However, Shabbir J et al. hold a differing view. They argue that minimally invasive access cavity designs might bring more risks than benefits in endodontic treatment. They suggest that such approaches should be used cautiously, reserving them for specific cases with proper tools and equipment available. Minimally invasive endodontics aims to preserve healthy tooth structure, benefitting from modern techniques like magnification tools and cone beam computed tomography (CBCT). This approach maintains tooth strength and reduces the likelihood of future issues.[11]

Metzger Z et al. introduced the Self-adjusting File (SAF) technology, which employs a flexible NiTi file without a metal core for root canal procedures. This design allows continuous irrigant flow, ensuring effective cleansing even in oval canals. Unlike conventional rotary files, SAF technology minimizes unnecessary dentin removal by uniformly eliminating dentin along the canal perimeter, avoiding circular bores and potential micro-cracks.[12]

Paqué et al.'s 2009 study revealed that rotary files are less efficient in canals near isthmuses, compacting debris there instead of removing it. De-Deus et al. (2011) challenged the assumption that "the file shapes, the irrigant cleans," especially in long oval canals where debris persists even after irrigation. Siqueira et al.'s 2010 study demonstrated SAF's better disinfection in flat oval canals compared to rotary files.[13]

Conversely, Kocak S et al.'s 2013 study found no significant differences in effectiveness between SAF and rotary systems, focusing on potential apical debris extrusion. Instrument design impacts debris removal efficiency, considering factors like geometry, flexibility, cutting, and irrigation. Understanding this relationship is crucial for safer and more efficient endodontic techniques. Further research is needed to explore this complex interplay between instrument design, working principles, and debris extrusion during root canal procedures for improved endodontic practices.[14]

Minimally invasive dentistry prioritizes patient-centered care, preserving tooth structure, and improving outcomes. Cavity and endodontic approaches are tailored to oral health, anatomy, and patient needs. Factors like decay, root canals, and restorations guide technique selection.

These findings underscore minimally invasive methods' role in conserving tooth structure and preventing restoration issues. Laser treatments and alternatives show promise in adapting margins and preventing secondary cavities. By maintaining structure, enhancing comfort, shortening treatment, improving results, and ensuring long-term preservation, minimally invasive endodontics offers significant advantages over traditional procedures.

XI. CONCLUSION

In conclusion, the landscape of modern dentistry has been reshaped by the emergence of Minimally Invasive Endodontics (MIE), which focuses on preserving natural tooth structure and optimizing root canal treatment outcomes. This patient-centered approach incorporates innovative technologies and evidence-based methodologies to minimize discomfort and ensure long-term oral health.

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