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# Minimal access, maximum impact: Current trends in cavity preparation techniques

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**Abstract**
This literature review explores the concept of minimally invasive endodontics, emphasizing the preservation of natural tooth structure through reduced access cavity preparations. The traditional access cavity design has remained largely unchanged since its introduction, but technological advancements have enabled the development of minimally invasive techniques. These techniques prioritize preserving the pulp chamber roof, reducing dentine removal, and utilizing advanced materials and instruments. The review categorizes access cavity designs into eight types, highlighting their applications and benefits. Minimally invasive endodontics offers improved long-term survival of endodontically treated teeth, reduced risk of tooth fracture, and enhanced patient satisfaction. However, challenges include accurate case selection, operator skill, material limitations, and cost considerations. The review emphasizes the need for retraining dentists and educating the public on modern diagnostic, preventive, and minimal intervention techniques, aligning with the shift towards prevention and early intervention in dentistry.

**Keywords:** Minimally invasive endodontics, endodontic access cavity, tooth preservation, dental conservation, endodontic treatment, root canal therapy, dental restoration, tooth structure preservation, advanced endodontics, conservative dentistry

## Introduction
Minimally invasive endodontics embodies a paradigmatic shift in the discipline, advocating the meticulous preservation of natural tooth structure by judiciously downsizing the preparation of the access cavity, canal taper, and apical size [1]. This approach enables the unobstructed visualization of the pulp chamber's entire floor and facilitates a comprehensive exploration of its intricate anatomy [2]. The seminal description of traditional access cavity design dates back almost a century to Crane's seminal work in 1920 [3]. While the fundamental principles of access cavity preparation have remained relatively consistent since their inception, it wasn't until John Ingle's seminal textbook in 1965 that a comprehensive treatise on traditional access cavity designs was articulated. Ingle's magnum opus adapted the cavity preparation concept originally posited by Black in 1908, which entails a systematic sequence of operative stages, including outline form, convenience form, cavity toilet, retention form, resistance form, and extension for prevention [4].

In essence, traditional access cavity preparation can be distilled into three salient points: (i) complete unroofing of the pulp chamber with the exposure of pulp horns, (ii) creation of a smooth, unimpeded pathway to the root canal orifices, and (iii) preservation of sound tooth structure [5]. However, the past two decades have witnessed a plethora of technological innovations in various aspects of endodontic treatment, including instrumentation (metallurgy, design, and kinematics) [8], imaging (cone-beam computed tomography) [9], optics (operating microscope with high illumination), ultrasonics, and supplementary irrigation devices. These advancements have collectively enabled the execution of access cavities with reduced dimensions, dubbed minimally invasive or contracted access cavities, without compromising the technical and biological foundations of root canal treatment [6].

**Rationale for Minimal Access Cavity Preparation**
The minimally invasive paradigm prioritizes the preservation of the structural integrity of the original tissues, underscoring the importance of maintaining the tooth's natural architecture. The most efficacious approach to achieving this objective is by partially preserving the pulp chamber roof, thereby reducing cusp flexion and concomitantly preventing damage to the tooth's structural integrity [7]. Minimally invasive endodontic access cavities play a crucial role in maintaining the long-term survival of endodontically-treated teeth (ETT) by avoiding unnecessary dentine removal, thereby enhancing the resistance of ETT against tooth fracture [10].
Studies have consistently demonstrated the efficacy of minimally invasive procedures in improving the clinical properties of defective restorations. For instance, a two-year recall examination conducted by Gustavo Moncada *et al.* revealed that treatments such as sealant application, repair, and refurbishing significantly improved the clinical properties of defective amalgam and resin-based composite restorations, effectively increasing the longevity of the restorations while minimizing the need for extensive procedures [11]. This study unequivocally demonstrated that marginal sealing of restorations is a minimally invasive treatment that may be employed as an alternative to the replacement of restorations with localized marginal defects [12].
Moreover, minimally invasive procedures have been shown to be effective in preventing and arresting early carious lesions, although their efficacy is diminished in the case of large lesions due to the challenges posed by dentin composition and bacterial persistence.
Enhancing the antimicrobial properties of these interventions is crucial for optimal efficacy. The materials employed in these procedures are prone to hydrolytic and enzymatic degradation, which can lead to treatment failure. Therefore, enhancing the biostability of these materials is essential to extend their lifespan and delay the need for surgical intervention. Consequently, augmenting the antimicrobial and anti-degradative properties of minimally invasive techniques is imperative to improve their effectiveness and expand their range of applications [13].

**Techniques and Methods**
Access cavity preparation is delineated as "the opening prepared in a tooth to gain ingress to the root canal system for the purposes of cleansing, shaping, and obturating" [14]. This inaugural technical step of root canal therapy necessitates profound comprehension of both the internal and external dental anatomy; a subpar execution can severely compromise the localization, negotiation, debridement, disinfection, and obturation of root canals [15].

**The following techniques are employed in minimally invasive cavity preparation**
**1. Mechanical High/Low Speed Rotary Systems**
- Fissurotomy burs.
- Polymer burs (smart burs).

**2. Chemomechanical Cavity Preparation Systems**
- Application of Carisolv agent.
- Application of Papacarie agent.

1. Air Abrasion.
2. Ultrasonics and Sono Abrasion.
3. Atraumatic Restorative Treatment (ART).
4. Ozone Therapy.

Laser Application 8. Antibacterial Photodynamic Therapy (APDT) [16].
With the advent of novel dental restorative materials and strides in adhesive dentistry, a refined understanding of the caries process, the tooth's potential for remineralization, and changes in caries prevalence and progression, the management of dental caries has transitioned from G.V. Black's paradigm of "extension for prevention" to a "minimally invasive" approach [17].
Silva *et al*. proposed a new taxonomy, consolidating diverse terminologies related to access cavity geometries into eight distinct categories to establish a unified lexicon with selfexplanatory abbreviations:

**Traditional Access Cavity (TradAC)**
In posterior teeth, this involves complete removal of the pulp chamber roof, followed by achieving straight-line access to the canal orifices, with smoothly divergent axial walls, so all orifices are visible within the outline form (Fig. 1a). In anterior teeth, straight-line access is obtained by removing the pulp chamber roof, pulp horns, and the lingual shoulder of dentine, extending the access cavity to the incisal edge (Fig. 2a).

**Conservative Access Cavity (ConsAC)**
In posterior teeth, preparation typically begins at the central fossa of the occlusal surface and extends, with smoothly convergent axial walls, only as far as necessary to detect the canal orifices, preserving part of the pulp chamber roof (Fig. 1b). In anterior teeth, the entry point is moved from the cingulum towards the incisal edge on the lingual or palatal surface, creating a small triangular or oval-shaped cavity, conserving the pulp horns and maximal pericervical dentine (Fig. 2b).

**Conservative Access Cavity with Divergent Walls (ConsAC.DW):** This variant of ConsAC is executed with divergent walls (Fig. 1c).

**Ultra-Conservative Access Cavity (UltraAC)**
Also known as 'ninja' access, these cavities are initiated as described in ConsAC but without further extensions, maintaining as much of the pulp chamber roof as possible (Figs. 1d and 2c).

**Ultra-Conservative Access Cavity at Incisal Edge (UltraAC.Inc)**
In anterior teeth exhibiting attrition or a pronounced concavity on the lingual aspect of the crown, access is performed in the middle of the incisal edge, parallel to the long axis of the tooth (Fig. 2d).

**Truss Access Cavity (TrussAC)**
This approach preserves the dentinal bridge between two or more small cavities prepared to access canal orifices in each root of multi-rooted teeth. In mandibular molars, for instance, two or three individual cavities may be created to access mesial and distal canals (Fig. 1e).

**Caries-Driven Access Cavity (CariesAC)**
Access to the pulp chamber is achieved by removing caries while preserving all remaining tooth structures, including the soffit structure, which refers to the underside of an architectural feature such as a ceiling or the intersection of the ceiling and wall (Figs. 1f and 2e).

### Restorative-Driven Access Cavity (RestoAC)

In teeth with existing restorations but no caries, access to the pulp chamber is obtained by partially or wholly removing existing restorations and preserving all possible remaining tooth structures (Figs. 1g and 2f) [18].

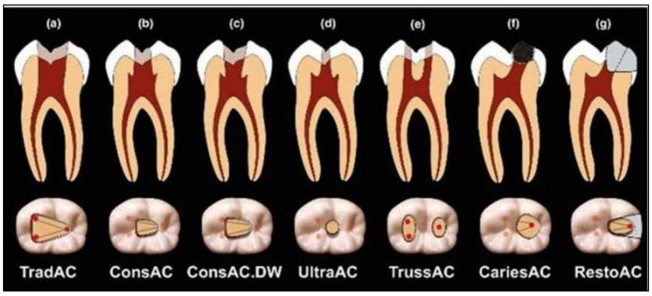


**Fig 1:** Classification of the access cavity designs in posterior teeth consolidating 20 out of 22 overlapping terms used in the selected literature. SLF and SLR do not fit in any category since the final shape of the access cavity obtained using these parameters is dependent on the position of the anatomical landmarks. (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)

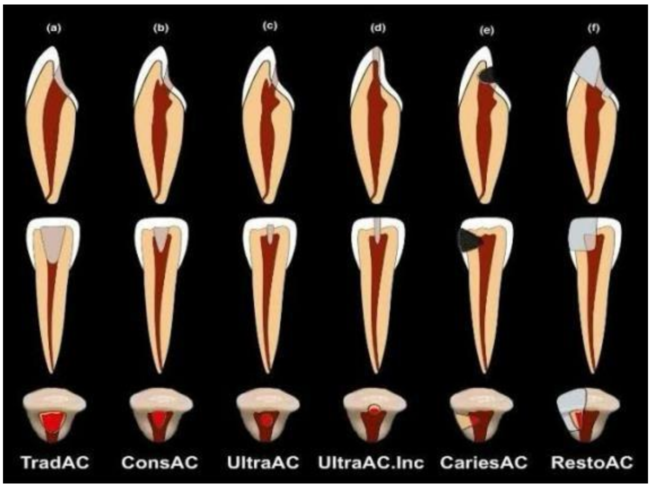


**Fig 2:** Classification of the access cavity designs in anterior teeth consolidating the 20 out of 22 overlapping terms used in the selected literature. SLF and SLR do not fit in any category since the final shape of the access cavity obtained using these parameters is dependent on the position of the anatomical landmarks. (a) Traditional access cavity (TradAC); (b) conservative access cavity (ConsAC); (c) ultra-conservative access cavity (UltraAC); (d) ultra-conservative access cavity performed in the incisal edge (UltraAC.Inc); (e) caries-driven access cavity (CariesAC); (f) restorative-driven access cavity (RestoAC)

### Technological Advances

A seminal study by Mamoun, John, Wilkinson, and Feinbloom (2013) elucidated the fundamental theoretical principles underlying the design of magnifying telescopic surgical binocular telescopes employed in dentistry, enabling the achievement of desired magnification and working lengths [19].

The confluence of novel imaging technologies and surgical microscopy has empowered surgeons to execute complex procedures with enhanced precision, culminating in improved surgical outcomes [20]. Loupes, available in diverse forms, offer varying degrees of barrel mobility, weight, and cost. While through-the-lens (TTL) loupes present ergonomic challenges due to limited frame adjustments, flip-up loupes provide adjustable declination angles, ensuring optimal usability. Dental operating microscopes (DOMs), considered the gold standard in endodontics, offer superior ergonomics and magnification, albeit at a higher cost and with reduced portability [21].

The introduction of NiTi mechanical instruments revolutionized root canal instrumentation, enabling a single instrument to shape the canal with unprecedented efficiency. Despite initial concerns regarding instrument fracture, advancements in instrument geometry, sequences, heat treatments, and motor technologies have significantly enhanced the safety of NiTi use. Contemporary trends focus on minimally invasive approaches, reducing instrument size and preparation dimensions. Emerging non-instrumentation techniques are being explored, although they currently lack substantive clinical evidence, relegating mechanical enlargement with chemical assistance as the prevailing gold standard [22].

The Er:YAG laser has demonstrated remarkable potential for effectively ablating dental hard tissues, rendering it an attractive option for caries eradication and cavity preparation. A comparative study evaluated the efficacy of caries elimination using the Er:YAG laser versus traditional mechanical therapy *in vitro*, revealing the laser's ability to remove carious dentin with minimal heat damage and reduced vibration, albeit with longer treatment times. Scanning electron microscopy (SEM) analysis revealed characteristic micro-irregularities on the lased dentin surface, underscoring the Er:YAG laser system's promise in caries therapy [23].

The advent of digital workflows, particularly Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology, has revolutionized the field of dentistry, though it imposes a formidable learning curve for both educators and students. The myriad benefits of this technology encompass diminished overhead costs, heightened predictability of clinical outcomes, and the capability for same-day restorations. CAD/CAM technology intricately involves digital design and milling processes, necessitating meticulous tooth preparation to avert complications such as overmilling, which is notably problematic in anterior teeth. The integration of multi-axis milling machines significantly augments precision and efficiency; however, these machines introduce considerations of considerable size and cost. The successful adoption of CAD/CAM technology mandates a paradigm shift in mindset and comprehensive training to forestall declines in productivity and efficacy [24].

### Material Used

According to the studies, warm lateral compaction emerged as the optimal method for filling canals in teeth with minimally invasive access preparations, as the diminutive size of these preparations precluded the effective adaptation of gutta-percha in the single-cone technique [3].

In a comprehensive investigation, Pereira *et al*. (2021) restored teeth in all test groups utilizing a diverse range of materials, including conventional composite, regular bulk fill composite, and bulk fill flow combined with conventional composite. A qualitative analysis of the pulp chamber revealed that voids were predominantly situated between remnants of filling materials, localized at the pulp horns and buccal and lingual walls, and the layers of restorative materials, thereby highlighting the complexities of material adaptation in minimally invasive endodontics [25].

**Clinical Applications**

**Indications for minimal invasive techniques encompass a range of dental issues, including**

- Small-to-moderate-sized carious lesions [26].
- Tooth wear [27].
- Enamel defects and discoloration [28].
- Fractured and chipped teeth [29].

**Case Study**

A 25-year-old female patient presented at the postgraduate dental clinic of the Department of Operative Dentistry, Aristotle University of Thessaloniki, Greece, with a primary complaint of sensitivity and pain in her right maxillary lateral incisor upon exposure to cold water. Following a thorough medical and dental anamnesis, clinical and radiographic examinations revealed dental caries affecting the right maxillary lateral incisor.

In light of this diagnosis, a fast and minimally invasive method for caries removal was deemed appropriate. An Er,Cr:YSGG laser (Waterlase MD Turbo, Biolase) was employed for this purpose, utilizing a gold handpiece and a Z-type glass tip of 500 μm in diameter (MZ5). The laser parameters were optimized for efficient caries removal, and all margins received etch modification with the same laser device. The cavity was subsequently treated with an adhesive system (Single Bond Universal Adhesive, 3M ESPE) and restored with composite resin (Clearfil Majesty ES-2, Kuraray Noritake Dental) using a freehand technique. Final polishing was achieved with medium-fine and superfine oxide discs (Sof-Lex, 3M ESPE).

Notably, the laser treatment was performed without local anesthesia, and the patient reported no sensitivity during the procedure, highlighting the efficacy and patient comfort afforded by minimal invasive techniques in dentistry [37].


**Case 1-Fig 1, 2, 3, 4, 5, 6:** Initial situation: dental caries of the right maxillary lateral incisor. Caries removal by Er, Cr: YSGG laser. Area after laser treatment. Restorative procedure performed freehand with composite resin. Final polishing with medium-fine and superfine oxide discs.

**Benefits and Outcomes**

Research in restorative dentistry has consistently demonstrated the efficacy of minimally invasive techniques, yielding favorable long-term outcomes. Notably, composite resin restorations have exhibited high survival rates, ranging from 80% to 95%, over a period of 5 to 10 years [30]. Similarly, ceramic inlays and onlays have shown a remarkable 90% survival rate after 10 years, with minimal complications [31]. Veneer and bonding techniques have also garnered high patient satisfaction, with minimal failures. The success of these techniques hinges on proper case selection, effective adhesive bonding, and regular maintenance [32].

Interestingly, patient satisfaction levels were found to be uninfluenced by factors such as gender, race, caries risk category, or the location of the affected tooth surface. Moreover, no significant difference in satisfaction was observed between patients who underwent invasive versus noninvasive treatments. Notably, a majority of patients who opted for invasive treatment against their practitioner's recommendation still reported satisfaction with their choice. This suggests that patient preference and perceived autonomy in treatment decisions play a crucial role in overall satisfaction, highlighting the importance of patient-centered care in restorative dentistry [33].

**Challenges and Limitations**

While minimally invasive techniques in restorative dentistry offer a plethora of benefits, they are not without significant challenges and constraints. Specifically:

1. **Case Selection and Complexity:** The accurate assessment of case complexity is paramount, as not all cases are amenable to minimally invasive approaches. Cases involving extensive damage or multi-tooth restorations may necessitate more invasive treatments.
2. **Operator Skill and Learning Curve:** The effective implementation of minimally invasive techniques requires specialized skills, which can be acquired only through dedicated training and experience. A steep learning curve may impact outcomes if practitioners lack sufficient expertise.
3. **Material Limitations and Durability:** Despite advancements in restorative materials, composites and ceramics still have limitations in terms of durability compared to natural tooth structure. This necessitates careful consideration in treatment planning to ensure optimal outcomes.
4. **Cost Considerations:** The utilization of advanced materials and equipment increases treatment costs, potentially limiting accessibility for some patients. The initial investment and ongoing training costs may be prohibitive for some practitioners, hindering the widespread adoption of minimally invasive techniques [32].

**Impact on Dental Education and Training**

The University of Adelaide's dental curriculum has successfully integrated minimally invasive dentistry (MID) and patient-centered care (PCC) principles, fostering a holistic approach to dental education. By emphasizing empathic communication and tailored patient management, the program ensures that students develop a comprehensive understanding of dental science and practice.

Structured under the auspices of Dental Science and Practice, the curriculum focuses on applying skills in clinical settings, leveraging integrated learning activities and assessments to ensure students meet defined outcomes. A coordinated teaching team, comprising trained external tutors proficient in MID and PCC concepts, supports this approach [34].

It is heartening to note that international research conferences now allocate dedicated time to discuss the translation of research evidence into teaching and practice within undergraduate curricula. Preventive and minimal intervention dentistry are recognized as vital topics, and this paper illustrates the concept with examples from cariology, highlighting the philosophy's applicability across all dental specialties.

This integrated approach has far-reaching implications, influencing the entire undergraduate curriculum and shaping the next generation of dental professionals to prioritize minimally invasive and patient-centered care. By embracing this philosophy, dental education can ensure that future practitioners are equipped to provide optimal care, emphasizing prevention, conservation, and patient well-being [35].

## Future Directions

In a prescient prediction, Dr. Black foresaw a paradigm shift in dentistry from a focus on repair to one of prevention, a vision that has now come to fruition. The discipline is transitioning from a emphasis on restoring decayed teeth to a proactive approach prioritizing disease prevention and early intervention. The prevalence of recurrent caries, a leading cause of restoration failure, underscores the imperative of preventive measures. The advent of CAMBRA (Caries Management by Risk Assessment) and Minimal Intervention Dentistry (MID) embodies this shift, heralding a new era in dental care.

The successful implementation of MID necessitates a twofold approach: retraining dental professionals to embrace modern diagnostic, preventive, and minimal intervention techniques, and educating the public on the long-term biological and financial benefits of this paradigm shift. As dentistry continues to evolve, the focus on prevention and early intervention will become increasingly pronounced, revolutionizing the way we approach oral healthcare [36].

## Conclusion

In conclusion, this literature review has elucidated the paradigm shift in endodontic treatment from traditional access cavity preparations to minimally invasive techniques, prioritizing the preservation of natural tooth structure and pulp chamber roof integrity. The rationale for this approach is rooted in the imperative to reduce dentine removal, prevent tooth fracture, and enhance long-term survival of endodontically treated teeth. Technological advancements in instruments, imaging, optics, ultrasonics, and supplementary irrigation devices have facilitated the development of minimally invasive access cavities, categorized into eight distinct designs. While challenges persist, including accurate case selection, operator skill, material limitations, and cost considerations, the benefits of minimally invasive endodontics are unequivocal. As dentistry continues to evolve, the integration of minimally invasive techniques into dental education and training is crucial, emphasizing empathic communication, tailored patient management, and preventive care. Ultimately, this shift in paradigm will revolutionize the discipline, prioritizing patient-centered care and optimal oral healthcare outcomes.

## Conflict of Interest

Not available.

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Not available.

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