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Minimally invasive caries management in pediatric dentistry

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Abstract

This study discusses the use and effectiveness of minimally invasive treatment techniques in pediatric dentistry. These techniques provide effective and minimally invasive treatment by preserving tooth structure, maintaining pulpal vitality, and reducing the risk of pulp exposure. Methods for correcting aesthetic issues such as discoloration of tooth surfaces and treating early-stage cavities, are less invasive than conventional treatment methods while reducing children's fear and anxiety toward dental treatment. As a result, the treatment process becomes more comfortable for children.

However, there are some limitations to minimally invasive techniques, particularly when dealing with deep dental caries, which may require additional treatment options. Nevertheless, these methods play a crucial role in maintaining children's dental health. Minimally invasive techniques offer a promising alternative to traditional treatments by improving aesthetics without compromising the natural structure of teeth. These approaches provide significant advantages in enhancing dental health in children and making the dental experience less traumatic.

Keywords: dental anxiety; dental caries; pediatric dentistry.

Çocuk diş hekimliğinde minimal invaziv çürük yönetimi
Öz

Bu çalışma, çocuk diş hekimliğinde minimal invaziv tedavi yöntemlerinin kullanımını ve etkilerini ele almaktadır. Bu teknikler, diş yapısını koruyarak, pulpa vitalitesini sürdürerek ve pulpa ekspozisyonu riskini azaltarak etkili ve minimal invaziv tedavi sunmaktadır. Diş yüzeyindeki renk değişikliklerinin düzeltilmesi ve erken aşamalarda çürüklerin tedavi edilmesi gibi estetik sorunların çözülmesinde bu yöntemler, geleneksel tedavi yöntemlerine göre daha az invaziv olup, çocukların tedaviye karşı olan korku ve kaygılarını azaltmaktadır. Bu sayede, tedavi süreçleri daha konforlu hale gelmektedir.

Bununla birlikte, minimal invaziv tedavi yöntemlerinin bazı sınırlamaları bulunmaktadır. Özellikle derin çürüklü dişlerle karşılaşıldığında, ek tedavi seçeneklerine ihtiyaç duyulabilir. Ancak genel olarak bu yöntemler, çocukların diş sağlığını korumada önemli bir rol oynamaktadır. Estetik iyileşme sağlarken dişlerin doğal yapısından ödün vermeden tedavi sunan minimal invaziv teknikler, geleneksel tedavi yöntemlerine alternatif olarak büyük bir potansiyel taşımaktadır. Bu tedavi yaklaşımları, çocukların diş sağlığını iyileştirme ve diş hekimliği deneyimini daha az travmatik hale getirme konusunda önemli avantajlar sunmaktadır.

Anahtar kelimeler: çocuk diş hekimliği; dental kaygı; diş çürüğü.

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Introduction

General information

Dental caries is a multifactorial non-communicable disease characterized by the demineralization of dental tissues, driven by the interplay between pathogenic biofilms and dietary sugars. Its progression is moderated by a complex matrix of biological, environmental, and behavioral determinants (1).

In pediatric populations, traditional restorative interventions may often be counterproductive, as they can induce dental phobia and reduce patient compliance. Consequently, Minimally Invasive Dentistry (MID) has emerged as a preferred paradigm. By replacing invasive surgical procedures with preventive and conservative approaches, MID is widely applied in the management of dental caries in children, with a focus on preserving tooth structure and maintaining pulpal vitality. The preservation of primary teeth remains important, as they contribute to masticatory function, phonetic development, and the proper eruption of permanent successors, ultimately supporting the child's physiological and psychological development (2). In this review, a literature search was conducted in PubMed, Google Scholar, ScienceDirect, and DergiPark for studies published between 2009 and 2025. The search strategy included the following keywords and their combinations: "minimally invasive dentistry", "pediatric dentistry", "dental caries management", "atraumatic restorative treatment", "silver diamine fluoride", "resin infiltration", and "caries removal techniques". Boolean operators (AND, OR) were applied to refine the search strategy. Full-text articles available in English or Turkish were screened. Systematic reviews, meta-analyses, and relevant clinical studies focusing on minimally invasive approaches in pediatric dentistry were included. The aim of this review is to evaluate current minimally invasive treatment approaches in pediatric dentistry, along with their fundamental principles and role in clinical practice, in light of the existing literature. Minimally invasive treatment options and their indications and contraindications are summarized in Table 1.

Principles of minimal invasive dentistry

Principles of minimal invasive dentistry can be summarized as follows:

- Assessment of individual risk determinants
- Early identification of dental caries
- Categorization of caries depth and stages of progression
- Application of evidence-based preventive measures for caries
- Facilitation of remineralization in early-stage lesions
- Employment of minimally invasive surgical approaches for managing carious lesions
- Focus on restorative repair instead of complete replacement of damaged restorations
- Systematic evaluation of disease management outcomes at designated intervals (3)

Minimal invasive dentistry applications

Atraumatic restorative treatment (ART)

Atraumatic Restorative Treatment (ART) is a conservative clinical approach utilizing manual instrumentation for the excision of carious tissue. By eliminating the need for electrical equipment and local anesthesia, ART minimizes patient distress, making it an ideal intervention for pediatric, geriatric, and anxious populations (4).

The ART protocol involves the systematic removal of dentin caries using excavators of varying dimensions, while enamel surfaces are managed with burs and separators to ensure conservative access. Given that occlusal caries typically progresses in a pyramidal pattern along enamel prisms, clinical success relies on accurately identifying the lesion's morphology and removing only the tissue necessary to facilitate restorative access. However, the technique may be limited by thick enamel or narrow proximal openings, which may necessitate conventional rotary instruments. Following debridement and surface conditioning, the procedure concludes with the application of high-viscosity glass ionomer cement (HVGIC), ensuring a functional seal of the cavity and vulnerable pits or fissures (5).

The literature indicates that the longevity of glass ionomer cement used in ART for proximal cavities is significantly lower than that observed in occlusal restorations, with failures primarily attributed to cervical marginal gaps, partial or total restoration loss, and pronounced marginal defects (6,7). To address these limitations, recently developed glass hybrid glass ionomer restorative materials (GH-GICs) have been introduced. These materials demonstrate improved mechanical strength, enhanced wear resistance, and favorable fluoride release properties, making them a promising option for minimally invasive restorative procedures in pediatric dentistry

(8). Furthermore, recent clinical evidence suggests that ART can achieve success rates comparable to composite resin in one- and two-surface restorations over a 12-month follow-up period (9).

Limitations

ART is a minimally invasive approach for managing dental caries; however, its long-term effectiveness may be limited by moisture sensitivity of restorative materials, reduced longevity, and variability in clinical evaluation criteria (10).

Resin infiltration

Resin infiltration is a minimally invasive treatment approach for managing non-cavitated enamel lesions, particularly white spot lesions, by allowing low-viscosity resin monomers such as triethylene glycol dimethacrylate (TEGDMA) to penetrate the porous enamel structure, occlude interprismatic spaces, reduce lesion permeability, and thereby inhibit further demineralization and lesion progression while preserving tooth structure and improving esthetic outcomes (11).

Among the available systems, the ICON® resin infiltration system (DMG, Hamburg, Germany) is the most widely used and clinically established material for this purpose. Clinical evidence has demonstrated that resin infiltration is an effective approach for the management of post-orthodontic white spot lesions, with studies indicating that low-viscosity resins such as ICON can significantly improve esthetic outcomes and arrest caries progression. Moreover, two-year follow-up studies support its clinical performance, highlighting its potential to preserve dental tissue through a minimally invasive protocol (12).

Technique and application (ICON system)

According to the manufacturer's protocol, the lesion is etched with ICON® Etch for approximately 2 minutes, rinsed, and air-dried for about 30 seconds, followed by the application of ICON® Dry (99% ethanol) to enhance resin penetration and assess the masking effect. If necessary, the etching process may be repeated. The infiltrant (ICON® Infiltrant) is then applied for 3 minutes and light-cured, with a second application for 1 minute recommended to improve penetration and compensate for polymerization shrinkage. This technique enables effective sealing of enamel microporosities and supports the arrest of lesion progression (13).

Limitations

Despite its advantages, it may be insufficient for deep enamel defects, necessitating combined approaches such as microabrasion or composite restoration (14).

Hall technique

The Hall technique is a minimally invasive method for managing carious primary molars by sealing decay beneath a stainless-steel crown without caries removal. By isolating bacteria from their substrate, particularly carbohydrates, it arrests lesion progression and offers a pain-free, anesthesia-free, and rapid treatment that improves patient cooperation (15). Although the Hall technique is widely used, it has certain limitations, including a potential risk of pulpal complications due to sealing carious lesions without removal and the occurrence of occlusal disturbances. However, when appropriate case selection is ensured and pulpal pathology is excluded, the risk of pulpal complications is considered to be low (16,17). In addition, although a temporary increase in occlusal vertical dimension may occur, it has been shown to resolve spontaneously within a few weeks (18). A randomized controlled trial indicated that the Hall technique was associated with favorable long-term success rates in treating carious primary molars, showing potential for improved clinical outcomes, reduced pain, and fewer complications compared to conventional restorative and non-restorative treatments, especially in children with dental anxiety (19).

Silver diamine fluoride (SDF)

Silver diamine fluoride (SDF) is recognized as an effective agent for arresting and preventing dental caries in pediatric patients through its antibacterial action and remineralization capacity, rendering it a viable option for young children with limited cooperation (20). Its application is a simple and minimally invasive procedure that involves cleaning and drying the carious surface, followed by direct application of the solution for approximately 60 seconds under proper isolation to ensure effective penetration and prevent soft tissue exposure (21). A characteristic black discoloration of the treated lesion indicates successful caries arrest, and the rapid, painless, and highly effective nature of the procedure enhances its suitability for young or uncooperative pediatric patients. Additionally, the use of fluoride varnish following SDF application is recommended to further support remineralization and enhance treatment effectiveness (22).

Findings from a clinical study indicated that SDF could achieve high success in arresting caries in children with potentially less discomfort than conventional methods. Although black discoloration remains a concern for parents, SDF represents a promising, cost-effective, and minimally invasive alternative, particularly suitable for patients with management challenges or in resource-limited environments (23).

Limitations

The main disadvantage of SDF is the black discoloration of carious lesions following application. In addition, its unpleasant metallic taste and potential to irritate the gingiva or oral mucosa may reduce patient acceptance and compliance, particularly among young children (24). The use of potassium iodide (KI) has been proposed to reduce the discoloration associated with SDF application, while alternative formulations such as silver fluoride (SF) may help minimize adverse effects including unpleasant taste and gingival irritation (25).

Stepwise and selective caries removal

Traditional management of deep carious lesions, involving complete removal of carious dentin, is now considered overtreatment due to the increased risk of pulp exposure. As minimally invasive alternatives, stepwise caries removal (SWR) and selective caries removal (SCR) have been proposed. SWR is a two-stage approach in which carious dentin is initially removed to soft dentin and sealed with a temporary restoration, allowing lesion arrest and dentin remineralization; this is followed by re-entry for further caries removal to firmer dentin and placement of a definitive restoration. In contrast, SCR is performed in a single visit by removing part of the carious dentin and restoring the cavity (26). Recent evidence suggests that both approaches show comparable clinical success, although SCR may reduce the risk of pulp exposure and better preserve pulp vitality (27).

Chemo-mechanical caries removal (CMCR)

Chemo-mechanical caries removal (CMCR) is a minimally invasive technique designed for the selective softening and removal of carious dentin. This approach utilizes enzyme- or hypochlorite-based agents, such as Carisolv or Brix 3000, to facilitate caries dissolution. The chemical agent is applied to the carious lesion for approximately 30–60 seconds, after which the softened tissue is gently removed using hand instruments. Particularly in pediatric dentistry, CMCR preserves sound dentin, reduces the need for local anesthesia, and enhances patient comfort. Clinical studies indicate that this method minimizes the loss of healthy tooth structure while effectively reducing the bacterial load (28). Evidence from a systematic clinical evaluation suggests that chemo-mechanical caries removal can offer clinical success rates similar to conventional methods, with the potential to significantly lower pulp exposure and discomfort. While overall success rates may be slightly lower, CMCR tends to preserve healthy dentin and enhance treatment tolerance, potentially making it a suitable minimally invasive alternative for anxious children (29).

Materials used in chemo-mechanical caries removal

Chemo-mechanical caries removal employs various agents and auxiliary materials to enable selective and minimally invasive removal of carious dentin. Enzymatic agents, such as Papacarie and Brix 3000, are papain-based biocompatible gels designed to facilitate atraumatic caries removal while preserving sound dentin. Hypochlorite-based agents, including Carisolv and Carie-Care, consist of sodium hypochlorite–amino acid formulations that selectively dissolve infected dentin without damaging healthy tissue. In addition, hand instruments and curettes are used for mechanical removal of softened carious tissue, while chlorhexidine solutions serve as adjunctive antibacterial agents to reduce microbial contamination and prevent reinfection (30).

Limitations

Its limitations include a longer treatment time requiring patient cooperation, reduced effectiveness in advanced lesions or sclerotic dentin, the need for complete removal of the chemical agent to prevent tissue irritation, and limited evidence regarding long-term outcomes and cost-effectiveness (31).

Interim therapeutic restorations (ITR)

Interim Therapeutic Restorations (ITR) are a minimally invasive restorative approach primarily used in pediatric and difficult-to-manage patients or those with limited access to dental care. This technique involves selective removal of carious dentin followed by placement of biocompatible materials, such as glass ionomer cement, to slow caries progression while preserving tooth structure and function. Evidence suggests that ITR can minimize the need for anesthesia and support patient comfort, with clinical studies indicating favorable short- to mid-term results. Nonetheless, long-term success appears to depend heavily on regular follow-up and consistent restoration maintenance (32). The procedure involves isolating the tooth, selectively removing softened dentin, and sealing the cavity with glass ionomer cement. Serving as an interim solution until definitive treatment, these restorations can remain functional for months or even years and are particularly beneficial for children in underserved settings with limited access to comprehensive dental care (33).

Materials used in interim therapeutic restorations

- Glass Ionomer Cements (GIC)
- Resin-Modified Glass Ionomer Cements (RMGIC)
- Silver Diamine Fluoride (SDF)
- Composite Resins (32).

The effectiveness of ITR is influenced by the longevity and biocompatibility of the materials used, particularly glass ionomer cements, which reduce bacterial infiltration, preserve tooth structure, and lower the risk of secondary caries. Evidence indicates that ITR demonstrates favorable long-term outcomes and lower failure rates, especially in populations with limited access to dental care (34).

Limitations

Although interim therapeutic restorations (ITR) play an important role in minimally invasive pediatric dentistry, they present limitations such as limited resistance to occlusal forces, reduced long-term durability, and potential seal failure that may increase the risk of secondary caries. Additionally, ITR is unsuitable for cases with extensive enamel defects or pulpal involvement and should be regarded as a temporary measure requiring regular monitoring rather than a definitive restorative solution (32).

Air abrasion technique

Air abrasion is a minimally invasive technique that uses high-pressure air to deliver abrasive particles, typically ranging from 27 to 50 microns, onto the tooth surface for precise caries removal. By operating at low pressure and avoiding heat and vibration, it enhances patient comfort and compliance, making it particularly suitable for pediatric and special-needs patients while allowing controlled cavity preparation in restorative dentistry (35). Evidence indicates that it preserves enamel and dentin more effectively than rotary instruments, facilitates selective removal of carious tissue, and minimizes heat-related pulpal damage. Additionally, the absence of vibration and noise reduces dental anxiety in children, supporting improved cooperation and favorable restorative outcomes (36). A comparative clinical study suggested that air abrasion could achieve higher pit and fissure sealant retention rates than conventional acid etching over a 12-month period, while potentially enhancing patient comfort and minimizing or eliminating the necessity for local anesthesia. These findings support air abrasion as an effective and child-friendly alternative for caries prevention in pediatric dentistry (37).

Materials used in air abrasion technique

Abrasive Particles:

- Aluminum Oxide (Al_2O_3)
- Silicon Carbide (SiC)
- Sodium Bicarbonate ($NaHCO_3$)

Air-Abrasion Devices:

- Pressurized air unit
- Precision spray nozzle

Auxiliary Materials:

- Tooth surface cleaning agents
- Composite or glass ionomer cement (38)

Limitations

Despite its advantages, air abrasion has limitations, including reduced effectiveness in large or deep cavities, less precise cavity margins that may compromise restoration adhesion, and patient discomfort related to abrasive particle dispersion requiring enhanced isolation. Additionally, sensitivity to airborne particles and the need for specialized equipment may limit its accessibility and widespread clinical use (39).

Pit and fissure sealants

Pit and fissure sealants are a highly effective minimally invasive method for preventing occlusal caries in children by sealing deep grooves that favor bacterial accumulation. Evidence shows that this approach significantly reduces caries incidence on treated occlusal surfaces (40).

Materials Used in Pit and Fissure Sealants

- Resin-Based Sealants
- Glass Ionomer Cements (GIC)
- Resin-Modified Glass Ionomer Cements (RMGIC)
- Flowable Composite Resins
- Silver-Containing Sealants (41)

Optimal pit and fissure sealant retention requires proper surface preparation, including effective isolation, thorough cleaning of the enamel surface, acid etching with 35–37% phosphoric acid, and careful drying to prevent contamination. When indicated, a bonding agent is applied prior to sealant placement, followed by light curing to ensure adequate polymerization (42).

Limitations

Although pit and fissure sealants effectively reduce caries incidence, their success depends on strict moisture control during application, which can be challenging in young patients. In addition, sealant wear, fracture, and potential microleakage over time may compromise long-term effectiveness and necessitate periodic reapplication (43).

Laser cavity preparation

Dental lasers, such as Er:YAG (erbium: yttrium–aluminum–garnet) and Er,Cr:YSGG (erbium, chromium: yttrium–scandium–gallium–garnet), offer a minimally invasive alternative to rotary instruments in pediatric dentistry by enabling selective removal of enamel and dentin while preserving healthy tissue. Their use reduces discomfort, anxiety, bacterial contamination, and postoperative sensitivity, often eliminating the need for anesthesia and supporting improved restorative outcomes (44). Laser cavity preparation is achieved through selective ablation of enamel and dentin using high-energy laser beams that induce a hydrothermal effect, resulting in water evaporation within hard tissues. This technique reduces bacterial contamination and postoperative sensitivity while enhancing patient comfort due to the absence of mechanical vibration and frequent elimination of anesthesia. Precise control of laser energy settings and pulse duration is essential to achieve adequate cavity preparation while preserving dentin integrity, and effective moisture control is required to optimize laser performance. In cases of deep or extensive carious lesions, adjunctive use of rotary instruments may be necessary, and modified adhesive protocols are often required due to reduced bonding effectiveness in laser-prepared cavities (45). Evidence suggests potential for improved preservation of enamel and dentin, which may support favorable long-term restorative outcomes; however, optimal results depend on appropriate patient selection, precise laser parameter control, and operator expertise (46).

Limitations

Despite its advantages, laser cavity preparation has limitations, including high equipment costs, longer treatment times compared to rotary instruments, and technical challenges when used in uncooperative pediatric patients. Additionally, lasers may be insufficient for extensive cavities, have limited cutting efficiency on certain tissues, and are incompatible with metal restorations, often necessitating adjunctive conventional techniques (47).

Microabrasion technique

Microabrasion is a minimally invasive technique used in pediatric dentistry to manage superficial enamel defects, including white spot lesions, hypocalcification, and hypomineralization, by controlled removal of the outer enamel layer using an acid–pumice slurry. The procedure is generally painless, supports post-treatment remineralization with fluoride application, and has demonstrated high effectiveness, particularly in conditions such as hypocalcified amelogenesis imperfecta (48). The procedure typically involves the application of an acid–abrasive slurry (commonly hydrochloric acid combined with pumice) to the enamel surface, followed by controlled mechanical abrasion to selectively remove the outer hypermineralized layer. This superficial removal reduces enamel opacity and improves the optical properties of the lesion without completely eliminating the underlying defect. Subsequent polishing and, when indicated, remineralization procedures may further enhance surface smoothness and esthetic outcomes (49).

Materials Used in Microabrasion Technique

- Hydrochloric Acid (HCl, 6-18%)
- Pumice Powder
- Phosphoric Acid (35-37%)
- Sodium Bicarbonate Solution
- Fluoride Gel or Varnish
- Resin Infiltration Materials (50)

Limitations

Despite its effectiveness for superficial enamel defects, microabrasion is limited to surface lesions and may increase tooth sensitivity due to enamel reduction. Complete discoloration removal is not always achievable, and additional restorative or aesthetic treatments may be required to obtain optimal outcomes (51).

Ozone therapy

Ozone therapy is a non-invasive, painless approach in pediatric dentistry in which ozone gas is applied to carious lesions for 20–60 seconds to eliminate cariogenic bacteria and arrest disease progression. Often followed by remineralizing agents to support enamel repair, this drill-free technique is effective in managing early childhood caries and is also used for treating gingival infections and oral ulcers, reducing microbial load,

accelerating healing, and preserving primary dentition while minimizing the need for invasive procedures (52). Clinical evidence suggests that ozone therapy can help reduce microbial load and may slow caries progression in pediatric patients, thereby potentially contributing to the preservation of tooth structure. Its bactericidal action, combined with reduced discomfort and improved patient compliance, particularly in anxious children, supports favorable treatment outcomes (53).

Materials Used in Ozone Therapy

- Ozone GeneratorsOzone
- Application Tips
- Ozonated Oil
- Ozone Gel
- Remineralizing Agents
- Dental Aspirator (54)

Table 1. Minimally Invasive Dentistry Applications: Indications and Contraindications

Treatment	Indications	Contraindications
Atraumatic Restorative Treatment	Children, disabled, and anxious patients; dentin caries reachable with hand tools; primary and permanent teeth; vital pulp.	Patients with high aesthetic expectations; cavities that cannot be reached with hand tools or seen clearly; affected pulp.
Resin Infiltration	White Spot Lesions; non-cavitated enamel caries; early-stage caries (ICDAS 1-2).	Carious lesions extending into dentin; cavitated enamel; deep structural disorders.
Hall Technique	Management of decayed primary molars; vital pulp without irreversible pulpitis symptoms.	Irreversible pulpitis or pulp necrosis; clinical signs of infection (e.g., abscess); unmanageable occlusion issues.
Silver Diamine Fluoride	Pediatric population to prevent and arrest caries; high-risk patients.	Silver allergy; stomatitis or oral ulcers; pulp exposure or symptomatic teeth; aesthetic.
Stepwise Caries Removal	Teeth with pulp viability but severe dentin cavities; patients with mild or asymptomatic pulpitis signs.	Teeth exhibiting apical periodontitis symptoms or pulp necrosis; advanced pulp infection or severe spontaneous pain.
Chemo-mechanical Caries Removal	Patients with dental anxiety; uncooperative children; cases where local anesthesia should be avoided.	Pulp necrosis or advanced infection; cases requiring very rapid intervention.
Interim Therapeutic Restorations	Uncooperative patients; children at high risk of dental cavities; patients with special medical needs or dental phobia.	Instances of pulp exposure or infected pulp; severe cavities with significant dentin loss; severe enamel flaws.
Air Abrasion Technique	Removal of small to medium carious lesions; surface preparation for restorations and sealants; needle-free/anesthesia-free preference.	Significant carious infections close to the pulp; abrasive particle inhalation risk for patients with respiratory disorders.
Pit and Fissure Sealants	Children susceptible to dental cavities; molars with fissure and deep pit morphology; newly erupted, incompletely mineralized molars.	Shallow fissures that can be cleaned by themselves; teeth with dentin cavitation; oral settings with inadequate salivary regulation.
Laser Cavity Preparation	Pediatric patients needing anesthesia-free/needle-free treatment; selective caries removal.	Very deep caries with high risk of pulp exposure; metallic restorations (like amalgam).
Microabrasion Technique	Minor enamel surface discolorations (brown, yellow, white stains); discoloration from dental fluorosis; superficial enamel defects.	Large, exposed dentin or extensive enamel defects; advanced fluorosis; structural damage or caries near pulp.
Ozone Therapy	Arrestment of initial carious lesions; reduction of dentinal hypersensitivity; disinfection of endodontic infections.	Confirmed allergy to ozone; patients with respiratory conditions.

Abbreviations
ICDAS: The international caries detection and assessment system

Limitations

Despite its benefits, ozone therapy in pediatric dentistry has limitations, including limited evidence on long-term effectiveness, high equipment costs, and challenges in patient cooperation. In addition, improper application may pose health risks, and its reliability as a substitute for conventional restorative treatment in extensive or complex carious lesions remains uncertain (53).

Conclusion

Minimally invasive approaches in pediatric dentistry represent contemporary and effective treatment strategies that prioritize the preservation of tooth structure while enhancing patient comfort and cooperation. These techniques have demonstrated favorable clinical outcomes in the management of early and moderate carious lesions; however, their success is closely dependent on appropriate case selection, individualized treatment planning, and operator expertise. Despite their recognized advantages, minimally invasive approaches vary in the strength of clinical evidence supporting their use. Techniques such as pit and fissure sealants and the Hall technique are supported by robust long-term clinical data and are well integrated into routine practice. In contrast, approaches such as ozone therapy and air abrasion currently have more limited clinical evidence and are less frequently adopted. Therefore, the selection of appropriate techniques should be guided by the level of evidence, clinical indications, and individual patient factors. Further high-quality longitudinal studies are needed to strengthen the evidence base for emerging approaches.

Conflict of interest

The authors declare that there are no conflicts of interest.

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