

Review

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Review

Management of Deep Caries in Primary Molars: A Comparative Analysis of the American, European, and International Guidelines

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Abstract

Background: Early Childhood Caries (ECC) remains a pervasive global health challenge. Historically managed through aggressive mechanical excavation, contemporary pediatric dentistry has evolved toward biologically driven, minimally invasive therapies. This study aims to critically compare the most recent clinical practice guidelines from the American Academy of Pediatric Dentistry (AAPD 2024), the European Academy of Paediatric Dentistry (EAPD 2022), and the International Association of Paediatric Dentistry (IAPD 2026) regarding the management of deep carious lesions in primary molars. **Methods:** A comparative critical review was conducted focusing on four core clinical variables: caries removal strategies, direct pulp capping (DPC) utility, pulpotomy medicaments, and the implementation of the Hall Technique (HT). Data were systematically extracted and synthesized to establish points of global consensus and therapeutic divergence. **Results:** A definitive paradigm shift toward conservative management was identified across all organizations. There is unanimous consensus strongly recommending Selective Caries Removal (SCR) as the gold standard over complete excavation to minimize iatrogenic pulp exposure. For vital pulpotomies, Calcium Silicate Cements (CSCs), particularly Mineral Trioxide Aggregate (MTA), have categorically superseded traditional fixatives like formocresol due to superior biocompatibility and success rates. Furthermore, the Hall Technique is highly endorsed, predominantly by the EAPD and IAPD, as a definitive, cost-effective biological intervention. Conversely, Direct Pulp Capping remains cautiously restricted due to low success predictability. **Conclusions:** The synthesis of the AAPD, EAPD, and IAPD guidelines confirms a global convergence on minimally invasive dentistry. Given the inherent unreliability of traditional pulpal diagnostics in pediatric patients, clinicians are strongly urged to prioritize pulp vitality through SCR, HT, and CSC-based therapies, establishing a unified biological approach to deep caries management.

Keywords: early childhood caries; primary teeth; minimally invasive dentistry; selective caries removal; vital pulp therapy; hall technique; clinical practice guidelines

1. Introduction

1.1. Global Burden of Early Childhood Caries

Dental caries in primary teeth, commonly known as Early Childhood Caries (ECC), remains one of the most prevalent and challenging chronic non-communicable diseases globally [1]. Despite advancements in preventive dentistry, recent extensive systematic reviews and meta-analyses reveal an alarming reality: the global prevalence of ECC affects approximately 46% to 49% of preschool children worldwide [2–4]. This staggering prevalence translates to over 500 million children currently suffering from untreated caries in their primary dentition [1,2]. The persistence of this disease underscores a critical global health dilemma, as the widespread distribution of ECC imposes severe biological and economic burdens that demand immediate, standardized clinical interventions [1,3].

1.2. Impact on Quality of Life and Development

The consequences of untreated ECC extend significantly beyond localized dental pain, initiating a cascade of severe clinical and developmental complications [5]. As carious lesions progress to involve the dental pulp, children frequently experience chronic pain and advanced odontogenic infections, such as abscesses and fistulae [5,6]. This chronic infectious state directly impairs essential physiological functions, leading to severe sleep disturbances and nutritional deficiencies that ultimately hinder the child’s physical growth and development [7,8]. Furthermore, the burden of early childhood caries encompasses profound psychological and social challenges, including heightened dental anxiety, reduced self-esteem, and impaired social adaptation [7]. Consequently, these multifaceted complications severely deteriorate the overall oral health-related quality of life (OHRQoL) of the affected children, while simultaneously imposing significant psychological and economic distress on their parents and caregivers [9–11].

1.3. The Paradigm Shift Towards Minimally Invasive Dentistry

Historically, the management of deep carious lesions in primary teeth was dictated by the traditional mechanical principles of complete caries excavation, often resulting in unnecessary structural loss and inadvertent pulp exposure [12]. However, contemporary pediatric dentistry has experienced a revolutionary paradigm shift toward biological and minimally invasive dentistry (MID) approaches [13,14]. This modern philosophy prioritizes the preservation of healthy tooth structure, the maintenance of pulp vitality, and the reduction of treatment-induced anxiety in young patients [13,15]. Advanced clinical strategies, such as selective caries removal (SCR), the Hall Technique (HT), and vital pulp therapy (VPT), have emerged as evidence-based alternatives to conventional aggressive treatments [12,16,17]. By altering the cariogenic environment and sealing the lesion, these conservative techniques not only halt disease progression but also significantly enhance the longevity of the primary dentition and improve the child's overall compliance [13,18]. Consequently, evaluating and comparing global clinical guidelines on these minimally invasive techniques is imperative to standardize pediatric dental care and optimize clinical outcomes.

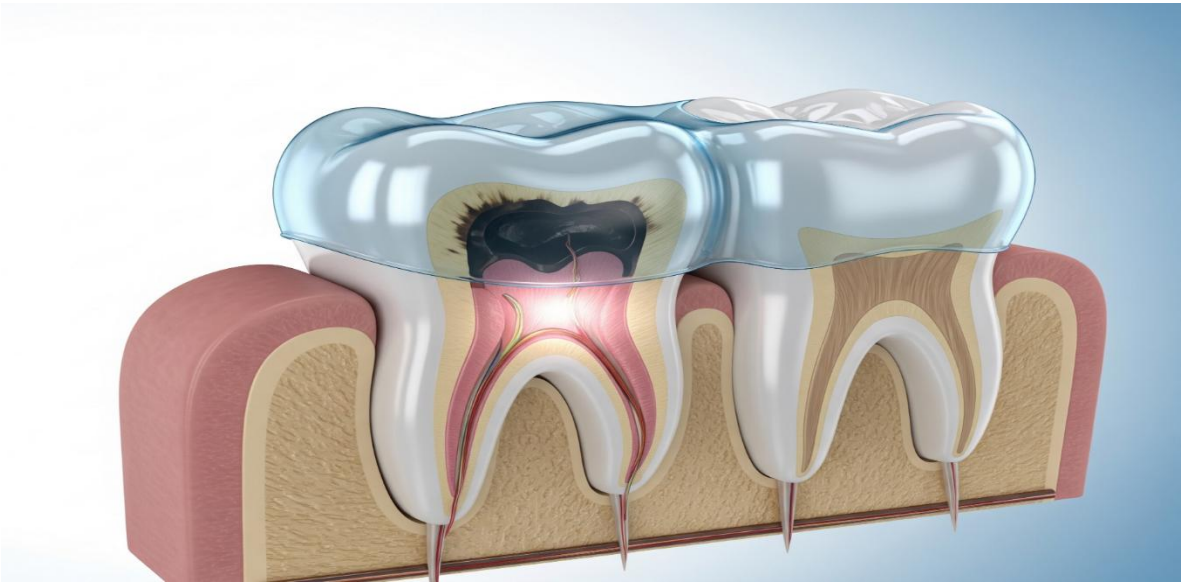


Figure 1. A 3D schematic illustration demonstrating the minimally invasive dentistry concept: achieving a biological hermetic seal over a deep carious lesion to isolate the cariogenic biofilm, halt disease progression, and preserve pulp vitality.

2. Materials and Methods

2.1. Study Design and Source Selection

This study was designed as a comparative critical review of the current clinical practice guidelines regarding the management of deep carious lesions in vital primary teeth. To ensure the inclusion of the most up-to-date and globally recognized standards, the official guidelines from three major pediatric dentistry organizations were purposively selected for analysis:

1. The American Academy of Pediatric Dentistry (AAPD): "Use of Vital Pulp Therapies in Primary Teeth 2024".
2. The European Academy of Paediatric Dentistry (EAPD): "Best clinical practice guidance for treating deep carious lesions in primary teeth: an EAPD policy document 2022".
3. The International Association of Paediatric Dentistry (IAPD): "Consensus-Based Recommendations on Pulp Therapies in Primary and Permanent Teeth: IAPD Porto Forum 2026".

2.2. Inclusion and Exclusion Criteria

The inclusion criteria for the analyzed documents were strictly limited to the most recent, official, evidence-based guidelines focusing on vital pulp therapies (VPT) in primary dentition. Guidelines addressing permanent teeth, non-vital primary teeth, or irreversible pulpitis requiring pulpectomy or extraction were excluded from the primary comparative variables, except where differential diagnosis was discussed.

2.3. Data Extraction and Comparative Variables

A systematic data extraction framework was developed to critically compare the recommendations across the three guidelines. Data were categorized and synthesized based on the following four core clinical variables:

1. Caries Removal Strategies: Evaluating the endorsement of selective, stepwise, or complete non-selective caries tissue removal.
2. Direct Pulp Capping (DPC): Assessing the clinical indications, success predictability, and the academies' stance on DPC following carious exposure.
3. Pulpotomy Medicaments: Comparing the recommended pharmacological agents and biomaterials (e.g., Calcium Silicate Cements, Ferric Sulfate, Formocresol) based on their biological rationale and reported success rates.
4. The Hall Technique: Analyzing the integration of non-restorative or no-caries-removal approaches (using preformed metal crowns) into the standard of care for deep carious lesions.

3. Results

Table 1. Comparative summary of clinical recommendations for the management of deep caries in primary teeth across AAPD (2024), EAPD (2022), and IAPD (2026) guidelines.

Clinical Variable	AAPD (2024)	EAPD (2022)	IAPD (2026)
Caries Removal Strategy	Strongly recommends Selective Caries Removal (IPT) over complete or stepwise excavation to minimize pulpal trauma.	Advocates for Selective or Stepwise removal as the standard of care to avoid iatrogenic pulp exposure.	Strongly recommends Selective Caries Removal over complete excavation (except in extremely deep, unmanageable lesions).
Direct Pulp Capping (DPC)	Based on very low certainty evidence; IPT or pulpotomy is conditionally preferred over DPC.	Limited clinical utility; strictly restricted to non-infectious, mechanical exposures in completely asymptomatic teeth.	Considered viable for pinpoint exposures (<1 mm) in reversible pulpitis, though overall success remains inferior to pulpotomy.
Pulpotomy Medicament	Strongly recommends Calcium Silicate Cements (MTA/Biodentine). Recommends against Formocresol,	Recommends Ferric Sulfate and MTA. Formocresol is strictly contraindicated due to toxicity	Strongly recommends Calcium Silicate Cements (CSCs) exclusively to promote optimal

	Ferric Sulfate, and Calcium Hydroxide.	concerns. Calcium Hydroxide is not recommended.	biological healing and hermetic sealing.
The Hall Technique (HT)	Conditionally recommended; yields comparable clinical outcomes to selective or complete caries removal.	Strongly recommended; significantly reduces patient discomfort and is highly preferred by pediatric patients and caregivers.	Highly recommended (sealing caries with a preformed crown without mechanical excavation) for multi-surface or large single-surface lesions.

3.1. Caries Removal Strategies

The comparative analysis revealed a strong paradigm shift across all three guidelines toward conservative caries excavation in deep lesions. The AAPD strongly recommends selective caries removal (also known as indirect pulp treatment) over both nonselective (complete) and stepwise removal to minimize pulp exposure [19]. Similarly, the EAPD and IAPD advocate for selective or step-wise caries removal [20,21]. This strong consensus is driven by quantitative data showing that selective caries removal significantly reduces the risk of pulp exposure, with studies reporting exposure rates as low as 2% for selective removal compared to 27% in non-selective complete excavation [22].

3.2. Direct Pulp Capping (DPC)

The guidelines exhibit varying degrees of caution regarding DPC in primary dentition. The AAPD notes that DPC is supported by very low certainty evidence and conditionally suggests that indirect pulp treatment or pulpotomy may be preferred over DPC. The EAPD restricts the use of DPC significantly, stating it has limited use in daily clinical practice and should only be considered in very restricted, non-infectious conditions on asymptomatic teeth. The IAPD considers DPC a viable option for small exposures (less than 1 mm) in teeth with healthy pulp or reversible pulpitis, provided Calcium Silicate Cements (CSCs) are used, but explicitly notes its success rate is lower compared to pulpotomy.

3.3. Pulpotomy Medicaments

A significant consensus was found regarding the superiority of bioactive materials, alongside a collective move away from traditional medicaments [19–21]. The AAPD and IAPD strongly recommend Calcium Silicate Cements (such as MTA and Biodentine) over formocresol (FC) [19,21]. The EAPD no longer recommends formocresol due to potential toxic effects [20]. This global shift is supported by meta-analyses demonstrating that MTA yields a significantly higher overall clinical and radiographic success rate compared to formocresol (OR = 3.535) [23].

3.4. The Hall Technique

The integration of the Hall Technique into official guidelines is strongly supported by recent quantitative data. Meta-analyses reveal that the Hall Technique is 49% more likely to succeed overall compared to other caries management techniques, and over six times less likely to fail [24]. When compared specifically to direct restorations, the Hall Technique shows an 80% higher success rate, while demonstrating comparable clinical success to conventional preformed metal crowns (PMCs) [24]. Long-term survival rates for the Hall Technique are highly favorable and predictable, reported at approximately 73.4% after three years and 67.6% after five years [25].

3.5. Consensus on Clinical Indications and Contraindications

To bridge the diagnostic challenges and standardize clinical decision-making, a synthesized framework of indications and contraindications for the primary minimally invasive interventions was established. This framework is based on the convergence of the AAPD, EAPD, and IAPD guidelines, providing a clear clinical pathway for practitioners (Table 2).

Table 2. Synthesized clinical indications and absolute contraindications for minimally invasive deep caries management techniques in primary molars.

Intervention	Primary Clinical Indications	Absolute Contraindications	Recommended Coronal Seal
Selective Caries Removal (SCR)	Deep dentinal caries; vital pulp (normal or reversible pulpitis); absence of spontaneous or nocturnal pain; restorable tooth structure.	Spontaneous/provoked pain lasting after stimulus removal; fistula or swelling; pathologic mobility; radiographic furcation or periapical radiolucency.	Well-sealed direct restoration (Resin Composite/GIC) or Preformed Metal Crown (PMC).
Vital Pulpotomy (using MTA/CSCs)	Carious pulp exposure in a vital tooth (reversible pulpitis); pulpal hemorrhage successfully controlled within 1 to 5 minutes.	Uncontrollable or dark pulpal hemorrhage; purulent exudate; necrotic pulp; physiological or pathologic root resorption exceeding 1/3 of the root.	Preformed Metal Crown (PMC) is strictly recommended to ensure a long-term hermetic seal.
The Hall Technique (HT)	Asymptomatic/reversible pulpitis; proximal (Class II) or multi-surface carious lesions; anxious, pre-cooperative, or uncooperative pediatric patients.	Clinical or radiographic evidence of irreversible pulpitis or necrosis; insufficient remaining tooth structure to retain the crown; imminent physiological exfoliation.	Preformed Metal Crown (PMC) securely cemented with traditional Glass Ionomer Cement (GIC).

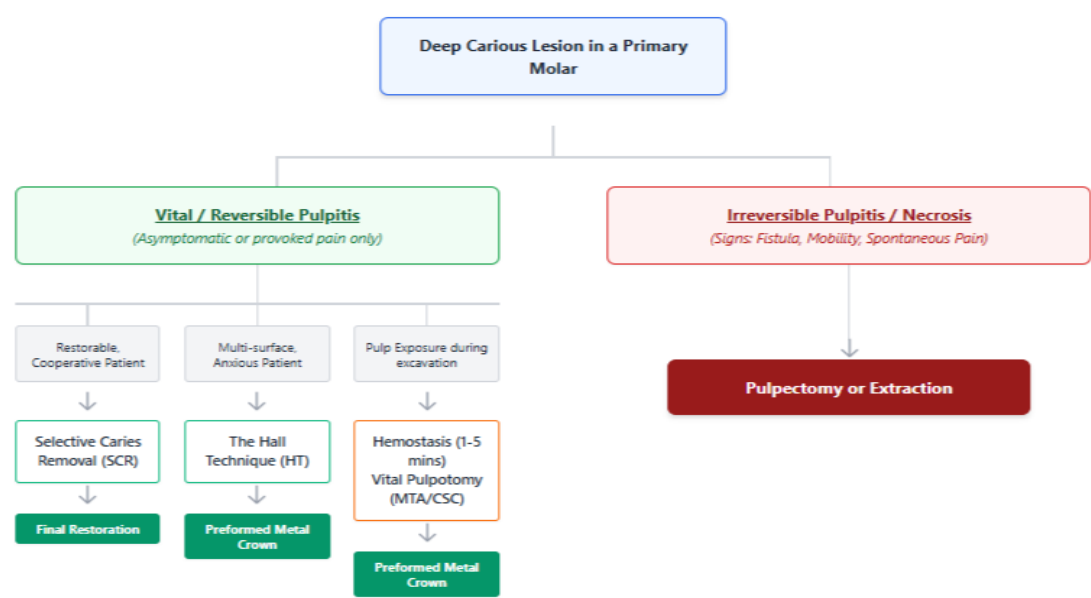


Figure 2. A clinical decision-making flowchart for the management of deep carious lesions in vital primary molars, synthesized from the AAPD (2024), EAPD (2022), and IAPD (2026) consensus guidelines.

4. Discussion

4.1. The Shift to Selective Caries Removal

A unanimous consensus exists among the reviewed guidelines [19–21] advocating for selective (incomplete) caries removal as the definitive gold standard for managing deep lesions in primary teeth. This paradigm shift is heavily supported by cariology evidence demonstrating that leaving affected, demineralized dentin near the pulp deprives cariogenic bacteria of their nutrient supply. Once a hermetic coronal seal is established, these residual microorganisms either perish or enter a state of dormancy [22]. Consequently, this biological approach successfully isolates the pulp from irreversible toxic damage and prevents the cascade of severe complications traditionally associated with iatrogenic pulp exposure [22].

4.2. Superiority of Calcium Silicate Cements (CSCs)

A pivotal area of agreement across the guidelines is the strong recommendation for Calcium Silicate Cements (CSCs)—particularly Mineral Trioxide Aggregate (MTA)—in pulpotomy

procedures [19,21]. Historically, formocresol was considered the gold standard, with some earlier, outdated trials reporting comparable success rates to initial MTA formulations [26]. However, contemporary extensive systematic reviews and meta-analyses have decisively established the clinical and radiographic superiority of MTA [23]. This high success rate is directly attributed to MTA's exceptional biocompatibility, superior sealing capacity, and its unique bioactive potential to induce hard tissue formation and continuous dentinal bridging—reparative properties that traditional fixative agents like formocresol fundamentally lack [23,26].

4.3. Validation of the Hall Technique

The escalating global acceptance of the Hall Technique (HT), explicitly highlighted by both the EAPD and IAPD, represents a monumental shift toward non-invasive biological caries management. By encapsulating the carious lesion beneath a prefabricated metal crown without prior mechanical excavation, HT isolates the superficial plaque biofilm from the oral environment. This isolation subsequently alters the biofilm's ecological composition to a less cariogenic flora, effectively arresting disease progression [25]. Furthermore, HT addresses significant behavioral challenges in pediatric dentistry. Recent literature reports remarkable acceptability rates: 81% of practitioners, 83% of caregivers, and 77% of pediatric patients prefer HT over conventional invasive restorations [25]. Beyond its documented clinical efficacy and patient comfort, HT has been proven to be highly cost-effective, as it eliminates the need for local anesthesia, reduces chair time, and significantly lowers the incidence of costly retreatments [25].

4.4. Challenges in Pulpal Diagnosis

Despite the strong therapeutic consensus, accurately determining the true histological pulpal status in primary teeth remains one of the most formidable diagnostic challenges in pediatric dentistry [27]. The guidelines' collective shift toward conservative management is primarily driven by the inherent unreliability of traditional diagnostic modalities. Recent evidence emphasizes that subjective clinical manifestations (e.g., pain history) and conventional two-dimensional radiographic findings fail to demonstrate a strong correlation with the actual histological state of the pulp [28]. In many clinical scenarios, a pulp diagnosed symptomatically as "irreversibly inflamed" may histologically retain substantial healing potential, whereas entirely asymptomatic teeth might harbor deep, irreversible inflammation [28,29]. Additionally, conventional pulp vitality tests are notoriously unreliable in pediatric cohorts due to factors like cognitive immaturity, dental anxiety, and fear [30]. This persistent "diagnostic gap" strongly validates the unified biological strategy of the AAPD, EAPD, and IAPD: when the exact depth of pulpal inflammation is ambiguous, clinicians are urged to prioritize minimally invasive therapies (such as SCR or VPT) over irreversible pulpectomies or extractions, thereby maximizing the pulp's intrinsic regenerative capacity [27,29].

5. Limitations

While this comparative review provides a comprehensive analysis of the current global guidelines, several critical limitations must be explicitly acknowledged:

- **Methodological and Evidence Constraints:** This review relies fundamentally on the synthesis of established organizational guidelines (AAPD, EAPD, IAPD) rather than a primary meta-analysis of raw patient data. Consequently, the findings are inherently constrained by the specific evidence-grading systems and systematic reviews that these distinct academies chose to include or exclude at the time of their publication.
- **Diagnostic Subjectivity:** A profound limitation in the current global literature—and reflected in this review—is the absence of a universally standardized, objective diagnostic tool to accurately determine the exact depth of carious lesions and the true histological status of the dental pulp. The reliance on subjective clinical symptoms and two-dimensional radiography

introduces inevitable diagnostic ambiguity when differentiating between reversible and irreversible pulpitis.

- **Socioeconomic and Geographic Applicability:** The analyzed guidelines predominantly reflect idealized clinical settings equipped with advanced biomaterials (e.g., MTA, bioceramics) and specialized instruments. They frequently lack scalable, cost-effective algorithms tailored for Low- and Middle-Income Countries (LMICs), where the high cost of bioactive cements or prefabricated metal crowns may render these "gold-standard" recommendations clinically impractical.
- **Temporal Lag in Biomaterial Innovation:** The rapid and continuous evolution of dental biomaterials, particularly in the realm of nano-dentistry and novel pulp-capping agents, often outpaces the bureaucratic process of updating clinical guidelines. Thus, some recommendations discussed may not fully capture the efficacy of the absolute newest materials available in contemporary practice.

6. Recommendations

To bridge the diagnostic and therapeutic gaps identified in this comparative analysis, the following strategic avenues for future research are strongly recommended:

- **Long-term, Multi-center Clinical Trials:** There is a critical imperative for robust, well-designed Randomized Controlled Trials (RCTs) with extended follow-up periods (exceeding 5 years) to directly compare the longevity and success rates of the Hall Technique (HT) versus Selective Caries Removal (SCR), particularly focusing on the exfoliation stage of the treated primary molars.
- **Integration of Advanced Diagnostic Modalities:** Future research must prioritize the development and clinical validation of objective diagnostic technologies. Investigating the use of artificial intelligence (AI) in radiographic interpretation, as well as the utility of salivary or pulpal molecular biomarkers, could eliminate clinical subjectivity and revolutionize the decision-making process for vital pulp therapies.
- **Health Economics and Policy Research:** Comprehensive cost-effectiveness and cost-benefit analyses are urgently required. Evaluating the long-term economic impact of minimally invasive approaches compared to conventional treatments will provide health policymakers with the data necessary to subsidize and implement these techniques globally, especially in underprivileged communities.
- **Patient-Reported Outcome Measures (PROMs):** Future studies should pivot towards patient-centered metrics. Quantifying the impact of techniques like HT and SCR on the Oral Health-Related Quality of Life (OHRQoL), reduction of dental anxiety, and overall behavioral compliance in pediatric populations is essential to validate the holistic success of minimally invasive dentistry.
- **Global Consensus Development:** It is highly recommended that major international organizations (such as the IAPD, AAPD, and EAPD) establish a unified, dynamic, and globally adaptable joint task force. Creating a single, harmonized consensus protocol would significantly reduce clinical ambiguity and standardize the management of deep caries worldwide.

7. Conclusions

This comprehensive comparative analysis of the AAPD (2024), EAPD (2022), and IAPD (2026) guidelines confirms a definitive global paradigm shift toward biologically driven, minimally invasive management of deep carious lesions in primary molars. Based on the synthesized quantitative and qualitative evidence, the following clinical conclusions are established:

1. Selective Caries Removal (SCR) is validated as the absolute clinical gold standard, significantly minimizing the risk of iatrogenic pulp exposure compared to non-selective (complete)

- excavation, while effectively arresting caries progression when a hermetic coronal seal is guaranteed.
2. Calcium Silicate Cements (CSCs), particularly MTA and novel bioceramics, have categorically superseded traditional fixative medicaments (e.g., formocresol) for vital pulp therapies, demonstrating significantly higher long-term clinical and radiographic success rates.
 3. The Hall Technique (HT) is strongly endorsed as a highly effective, cost-efficient, and patient-friendly non-restorative approach, yielding survival and success rates that are comparable—or superior—to conventional direct restorations and traditional stainless steel crowns.
 4. Due to the inherent unreliability of traditional pulp testing modalities in pediatric populations and the documented lack of correlation between subjective clinical symptoms and true histological pulpal status, practitioners must prioritize conservative, minimally invasive therapies to preserve pulp vitality whenever the extent of pulpal inflammation remains ambiguous.

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Conflicts of Interest: The author declares no conflict of interest.

Abbreviations

AAPD: American Academy of Pediatric Dentistry; **EAPD:** European Academy of Paediatric Dentistry; **IAPD:** International Association of Paediatric Dentistry; **ECC:** Early Childhood Caries; **SCR:** Selective Caries Removal; **HT:** Hall Technique; **MTA:** Mineral Trioxide Aggregate; **VPT:** Vital Pulp Therapy.

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