Journal of Pediatrics and Neonatology

ISSN 2688-5573

Research Article

Endodontic Obturation Materials in Primary Teeth: A Systematic Review

Alessio Danilo Inchingolo1†, Grazia Marinelli1†, Lucia Casamassima1, Danilo Ciccarese1, Paola Nardelli1, Francesco Inchingolo1, Roberta Scarano2, Andrea Palermo3*, Angelo Michele Inchingolo1,4‡ and Gianna Dipalma[1,5,6‡]*

[1]Department of Interdisciplinary Medicine, University of Bari "Aldo Moro", Italy

[2]Department of Innovative Technology in Medicine and Dentistry, University of Chieti-Pescara, Italy

[3]Department of Experimental Medicine, University of Salento, Italy

[4]Department of Medicine and Surgery, University of Perugia, Italy

[5]Department of Life Science, Health and Health Professional. Link Campus University, Roma, Italy

[6]Department of Biomedical, Surgical and Dental Sciences, Milan University, Milan, Italy

†These authors contributed equally to this work

‡These authors also contributed equally to this work

Abstract

Background: The selection of an optimal obturating material remains a major challenge in pediatric endodontics because no currently available material fulfills all the biological and clinical requirements for primary teeth. Objective: This systematic review aimed to evaluate and compare the clinical and radiographic performance of obturating materials used in primary teeth based on evidence from randomized controlled trials. 1.2. Methods: A systematic search of PubMed, Scopus, and Web of Science identified randomized clinical trials published between January 2016 and July 2026. Studies comparing different root canal filling materials in primary teeth were selected according to PRISMA guidelines and predefined PICO criteria. Methodological quality was assessed using the Cochrane RoB 2 tool.

Results: Eleven randomized clinical trials were included. Conventional materials such as zinc oxide–eugenol (ZOE) and Endoflas demonstrated consistent clinical and radiographic success. Calcium hydroxide–iodoform formulations showed satisfactory short-term outcomes but less favorable long-term performance due to rapid resorption. Bioactive materials containing propolis, neem oil, and ozonated olive oil demonstrated promising results, whereas curcumin-based formulations did not consistently improve treatment outcomes. Overall, no material fulfilled all the characteristics of an ideal obturating material.

Conclusions: Conventional materials remain reliable options for pulpectomy in primary teeth, while bioactive formulations represent promising alternatives. Further high-quality randomized controlled trials (RCTs) with longer follow-up are needed to establish the long-term effectiveness and biological behavior of emerging obturating materials.

Keywords: Primary teeth; Pediatric endodontics; Pulpectomy; Obturating materials; Zinc oxide–eugenol; Endoflas; Bioactive materials

Abbreviations

MPRCF: Maisto Paste Root Canal Filling; MTA: Mineral Trioxide Aggregate; RCTs: Randomized Controlled Trials; ZOE: Zinc Oxide–Eugenol

Introduction

The preservation of primary teeth until their physiological exfoliation is a fundamental objective of pediatric dentistry, as these teeth play an essential role in maintaining arch integrity, preserving masticatory function, facilitating speech development, and guiding the eruption of permanent successors [1-4]. Premature loss of primary teeth may lead to space loss, malocclusion, functional impairment, and psychological consequences, emphasizing the importance of effective treatment strategies aimed at maintaining these teeth whenever possible [5-8].

Among the factors influencing treatment success, the choice of the obturating material is considered one of the most critical [9,10]. In addition to eliminating microorganisms from the root canal system, the filling material should ensure long-term sealing of the canals while exhibiting favorable biological behavior within the surrounding tissues [11-14]. An ideal obturating material should possess antimicrobial activity, excellent biocompatibility, adequate radiopacity, dimensional stability, ease of manipulation, and the ability to resorb at a rate comparable to the physiological resorption of primary roots without affecting the developing permanent tooth germ [15-18]. However, despite continuous advances in material science, no currently available material fulfills all of these ideal characteristics [19-23].

Citation: Inchingolo AD, Marinelli G, Casamassima L, Ciccarese D, Nardelli P, Inchingolo F, et al. Endodontic Obturation Materials in Primary Teeth: A Systematic Review. J Pediatr Neonatol. 2026;6(2):1059.

Publisher Name: Medtext Publications LLC

Manuscript compiled: Aug 20th, 2026

***Corresponding author:** Andrea Palermo, Department of Experimental Medicine, University of Salento, Piazza Tancredi 7, 73100 Lecce, Italy, Fax: +39-331-211-1104; Tel: +39-338-682-4700 Francesco Inchingolo, Department of Interdisciplinary Medicine, University of Bari "Aldo Moro", 70124 Bari, Italy, Fax: +39-331-211-1104; Tel: +39-338-682-4700

For decades, zinc oxide–eugenol (ZOE) has been regarded as the reference obturating material because of its antimicrobial properties and satisfactory clinical performance [24-26]. Nevertheless, concerns regarding its slow resorption and persistence within periapical tissues have encouraged the development of alternative materials [27-31]. Consequently, several obturating agents have been introduced, including calcium hydroxide–iodoform formulations such as Vitapex and Metapex, Endoflas, calcium hydroxide-based pastes, and, more recently, bioactive and naturally derived materials containing propolis, neem oil, curcumin, or ozonated olive oil [32-34]. These newer formulations have been proposed to improve antimicrobial activity, enhance tissue healing, and provide a more physiological resorption pattern while maintaining adequate clinical performance [35-40].

Although numerous randomized controlled trials (RCTs) have investigated these materials, their findings remain heterogeneous, and no clear consensus has been reached regarding the optimal obturating material for primary teeth [41-45]. Differences in study design, sample characteristics, follow-up duration, and outcome assessment have contributed to inconsistent conclusions, making it difficult for clinicians to identify the material offering the best balance between clinical effectiveness, radiographic healing, and biological compatibility [46-50]. A schematic overview of the currently available obturating materials and their main clinical characteristics is presented in Figure 1 to facilitate understanding of the evidence summarized in this review.

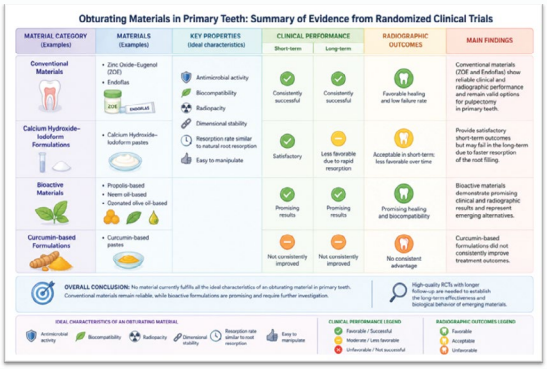

Figure 1: Overview of obturating materials used in primary teeth and a summary of current evidence from randomized clinical trials. Conventional materials (ZOE and Endoflas) remain the most reliable options. Calcium hydroxide–iodoform formulations show satisfactory short-term performance but undergo rapid resorption. Bioactive materials demonstrate promising results, whereas curcumin-based formulations have not shown consistent clinical advantages.

Objective

Therefore, the aim of this systematic review was to critically evaluate and compare the available evidence from RCTs investigating obturating materials used in primary teeth. By analyzing both conventional and novel formulations, this review sought to assess their clinical and radiographic performance, identify their respective advantages and limitations, and provide an updated overview to support evidence-based decision-making and guide future research in pediatric endodontics.

Materials & Methods

Protocol and registration

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO registration number: CRD420261460266).

Search processing

A systematic electronic search was conducted to identify randomized clinical trials evaluating endodontic materials used in primary teeth. PubMed, Scopus, and Web of Science were searched for studies published between January 2016 and July 2026.

In the advanced search string of the databases, the following keywords were applied using the Boolean operators to combine terms pertinent to the study's purpose:

(("pediatric dentistry" OR "paediatric dentistry" OR pediatric* OR paediatric* OR child* OR "primary teeth" OR "primary tooth" OR "deciduous teeth" OR "deciduous tooth" OR "primary molars" OR "primary molar") AND (endodontic* OR "pulp therapy" OR "vital pulp therapy" OR pulpotom* OR pulpectom* OR "root canal treatment" OR "root canal therapy") AND ("dental materials" OR "endodontic materials" OR "pulpotomy materials" OR "root canal filling materials" OR medicament* OR irrigant* OR cement* OR sealer* OR bioceramic* OR "mineral trioxide aggregate" OR MTA OR Biodentine OR "calcium silicate cement" OR "calcium hydroxide" OR formocresol OR "ferric sulfate" OR "ferric sulphate" OR "zinc oxide eugenol" OR ZOE OR iodoform OR Vitapex OR Metapex OR Endoflas) AND ("randomized controlled trial" OR "randomised controlled trial" OR "randomized clinical trial" OR "randomised clinical trial" OR random* OR trial*)).

The search strategy was adapted to the syntax and indexing requirements of each database (Apendix A). The main indicators used for the database searches are presented in Table 1.

Table 1: Indicators used for the database searches.

Search-strategy component	Search indicators
Population	"Pediatric dentistry"; "paediatric dentistry"; pediatric*; paediatric*; child*; "primary teeth"; "primary tooth"; "deciduous teeth"; "deciduous tooth"; "primary molars"; "primary molar"
Endodontic treatment	Endodontic*; "pulp therapy"; "vital pulp therapy"; pulpotom*; pulpectom*; "root canal treatment"; "root canal therapy"
Endodontic materials	"Dental materials"; "endodontic materials"; "pulpotomy materials"; "root canal filling materials"; medicament*; irrigant*; cement*; sealer*; bioceramic*; "mineral trioxide aggregate"; MTA; Biodentine; "calcium silicate cement"; "calcium hydroxide"; formocresol; "ferric sulfate"; "ferric sulphate"; "zinc oxide eugenol"; ZOE; iodoform; Vitapex; Metapex; Endoflas
Study design	"Randomized controlled trial"; "randomised controlled trial"; "randomized clinical trial"; "randomised clinical trial"; random*; trial*
Boolean operators	OR within each concept; AND between different concepts
Timespan	January 2016 to July 2026
Language	English
Electronic databases	PubMed; Scopus; Web of Science

The reference lists of the included studies and relevant systematic reviews were also manually screened to identify additional eligible articles that might not have been retrieved through the electronic database searches. No restrictions were applied regarding the type

of endodontic material evaluated. Only studies published in English were considered eligible.

Inclusion and Exclusion criteria

The eligibility criteria were established according to the PICO framework and the objectives of the present systematic review.

Studies were considered eligible when they met all the following inclusion criteria:

1. RCTs or randomized clinical trials;
2. Studies involving pediatric patients with primary teeth requiring pulpectomy, root canal treatment, or non-instrumental endodontic treatment;
3. Studies comparing at least two endodontic materials used as root canal filling materials, obturating pastes, or intracanal medicaments;
4. Studies reporting clinical, radiographic, postoperative, or material-related out-comes;
5. Articles published between 1 January 2016 and 14 July 2026;
6. Studies published in English;
7. Full-text articles available for assessment.

Studies were excluded when they met one or more of the following criteria:

1. *In vitro*, *ex vivo*, animal, laboratory, or microbiological studies without clinical evaluation;
2. Observational studies, retrospective studies, prospective non-randomized studies, case reports, case series, narrative reviews, systematic reviews, meta-analyses, conference abstracts, editorials, letters, and expert opinions;
3. Studies involving exclusively permanent teeth;
4. Studies evaluating pulpotomy materials rather than materials used for root canal treatment;
5. Studies comparing only instrumentation systems, irrigation techniques, obturation techniques, or methods of material delivery without comparing different endodontic materials;
6. Studies in which the allocation of participants or teeth was not randomized;
7. Studies that did not report separate results for primary teeth;
8. Duplicate publications or secondary analyses of the same study population, unless they reported different follow-up periods or additional relevant outcomes.

No restrictions were imposed on the type of endodontic material, the number of treatment sessions, the tooth type, or the duration of follow-up. Studies with follow-up periods shorter than 12 months were retained for qualitative analysis but were considered separately from studies reporting medium- or long-term clinical and radiographic success.

PICO question

The PICO framework, Population, Intervention, Comparison, and Outcome was used to formulate the research question and evaluate the clinical effectiveness of different endodontic materials used in primary teeth.

In pediatric patients requiring endodontic treatment of primary teeth (P), do different root canal filling materials or intracanal medicaments (I), compared with conventional endodontic materials such as ZOE, calcium hydroxide–iodoform pastes, or other commonly used materials (C), provide better clinical and radiographic success, fewer postoperative symptoms and adverse effects, and more favorable resorption and long-term tooth retention outcomes (O)?

Accordingly, the PICO components were defined as follows:

Population (P): Pediatric patients with primary teeth requiring pulpectomy, non-instrumental endodontic treatment, or another form of root canal treatment.

Intervention (I): Endodontic materials used as root canal filling materials or intracanal medicaments in primary teeth, including zinc oxide-based materials, calcium hydrox-ide-based pastes, iodoform-containing pastes, antibiotic pastes, and modified or natural compounds.

Comparison (C): Conventional or alternative endodontic materials used for the same clinical indication.

Outcome (O): Clinical and radiographic success, absence of pain, swelling, sinus tract or pathological mobility, resolution or reduction of periapical or furcation radiolucency, appropriate resorption of the material in relation to physiological root resorption, retention of the treated tooth until normal exfoliation, and occurrence of adverse events.

Data processing

Three independent reviewers (L.C., D.C. and P.N.) assessed the included studies' quality using selection criteria, methods of outcome evaluation, and data analysis. This enhanced 'risk of bias' tool additionally provides quality standards for selection, performance, detection, reporting, and other biases. All differences were settled through conversation or collaboration with other researchers (G.D., A.D.I. and A.M.I.). The reviewers screened the records according to the inclusion and exclusion criteria.

Results

Selection and Characteristics of the study

This PRISMA diagram (Figure 2) illustrates a rigorous and systematic selection process to ensure that only relevant studies were included in the final review [51]. In total, 1.760 records were identified through database searching: PubMed (n=749), Scopus (n=847) and Web of Science (n=164). After the removal of 356 duplicate records, 1.404 records were screened by title and abstract. Of these, 1.244 were excluded for the following reasons: systematic reviews (n=257), *in vitro* studies (n=320), studies conducted in permanent dentition (n=149), and off-topic (n=167). Finally, 11 studies met the inclusion criteria and were included in the qualitative review. The selection process and summary of included records are illustrated in Figure 3, while the characteristics of the selected studies are presented in Table 2.

Quality assessment and Risk of bias of included articles

The methodological quality of the included studies was assessed by one reviewer (D.C.) using the revised Cochrane Risk of Bias tool for randomized trials (RoB 2), which evaluates the risk of bias in estimates of the effect of assignment to an intervention. Any

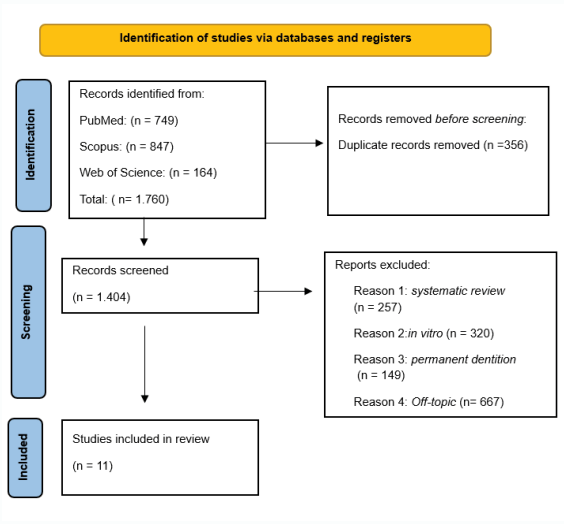

Figure 2: PRISMA flowchart.

uncertainties were discussed with a senior reviewer (F.I.) until consensus was reached. The assessment included all 11 randomized clinical trials, as reported in Table 3, and considered five domains: bias arising from the randomization process (D1), bias due to deviations from the intended interventions (D2), bias due to missing outcome data (D3), bias in the measurement of the outcome (D4), and bias in the selection of the reported result (D5). An overall judgment was assigned to each study according to the RoB 2 algorithm. The color-coded system indicates a low risk of bias in green, some concerns in yellow, and a high risk of bias in red. Overall, five studies were judged to be at low risk of bias, whereas six studies raised some concerns. Regarding the randomization process (D1), six studies were considered at low risk and five raised some concerns, mainly indicating that the methods used to generate or conceal the allocation sequence may not have been fully described. A similar distribution was observed for deviations from the intended interventions (D2), with six studies rated at low risk and five showing some concerns. Missing outcome data (D3) was adequately managed in six studies, while five studies raised some concerns regarding losses to follow-up

Table 2: Analysis of the studies included in the discussion section from 2016 to 2026.

Author et al.	Study design	Participants (Age)	Intervention	Aim	Main findings
Al-Ostwani et al. (2016) [52]	Randomized clinical trial	39 children (64 primary molars); 3–9 years old	Comparison of ZOE, Metapex, Endoflas-CF and zinc oxide–propolis. Follow-up: 12 months.	To compare the clinical and radiographic performance of four obturating materials.	All materials showed similar success; zinc oxide–propolis demonstrated favorable biological properties and may represent a promising alternative.
Chen et al. (2017) [53]	Randomized controlled trial	155 children (160 primary molars); 3–8 years old	Comparison of MPRCF, ZOE and Vitapex. Follow-up: 18 months.	To evaluate the long-term performance of three obturating materials.	MPRCF achieved the highest long-term success, whereas Vitapex showed lower clinical and radiographic performance because of rapid resorption.
Pandranki et al. (2018) [54]	Randomized clinical trial	50 children; 4–9 years old	Endoflas versus ZOE. Follow-up: 24 months.	To compare the effectiveness of Endoflas and ZOE.	Both materials were effective; treatment success depended largely on the quality of obturation.
Cassol et al. (2019) [55]	Double-blind randomized controlled trial	23 children (27 teeth); 2–7 years old	Iodoform paste versus Calen®/zinc oxide paste. Follow-up: 12 months.	To compare two calcium hydroxide-based obturating materials.	Both materials showed high success rates; Calen®/ZO presented better filling quality.
RojaRamya et al. (2020) [56]	Randomized controlled trial	40 children; 4–8 years old	Zinc oxide–propolis versus ZOE. Follow-up: 24 months.	To evaluate zinc oxide–propolis as an obturating material.	Zinc oxide–propolis achieved significantly higher long-term success than ZOE.
Patel et al. (2022) [57]	Randomized double-blind split-mouth clinical trial	24 children (48 molars); 5–7 years old	Zinc oxide–neem oil versus ZOE. Follow-up: 12 months.	To investigate the effectiveness of a neem-based obturating material.	The neem-based material showed excellent clinical and radiographic outcomes and may represent a promising alternative.
Bommareddy et al. (2022) [58]	Randomized controlled trial	64 primary molars; children with irreversible pulpitis	Comparison of curcumin, curcumin + calcium hydroxide, calcium hydroxide and Metapex. Follow-up: 6 months.	To evaluate curcumin-based obturating materials.	Curcumin-based formulations showed lower success than Metapex, particularly when curcumin was used alone.
Kumar et al. (2023) [59]	Randomized controlled clinical trial	36 children (60 molars); 4–9 years old	Comparison of ZOE, Metapex and Endoflas. Follow-up: 9 months.	To compare three commonly used obturating materials.	ZOE and Endoflas demonstrated superior clinical and radiographic performance compared with Metapex.
Dalal et al. (2023) [60]	Randomized controlled trial	30 children (30 molars); 4–8 years old	ZOE versus ZOE + curcumin. Follow-up: 9 months.	To determine whether curcumin improves the performance of ZOE.	Curcumin did not improve treatment outcomes and was associated with greater pathological root resorption.
El-Desouky et al. (2023) [47]	Randomized controlled trial	90 primary molars; 4–8 years old	Comparison of zinc oxide–ozonated olive oil, zinc oxide–olive oil and ZOE. Follow-up: 12 months.	To evaluate ozonated olive oil as an alternative obturating vehicle.	Ozonated olive oil promoted favorable radiographic healing and showed promising clinical outcomes.
Khadilkar et al. (2024) [61]	Double-blind randomized clinical trial	75 primary mandibular second molars; 4–8 years old	Comparison of Endoflas, Metapex and calcium hydroxide–zinc oxide mixture. Follow-up: 6 months.	To compare three widely used obturating materials.	All three materials achieved similarly high short-term clinical and radiographic success.

or incomplete outcome information. The measurement of outcomes (D4) was generally reliable, with seven studies rated at low risk and four presenting some concerns, potentially because assessor blinding or outcome-evaluation procedures were not always clearly reported. The selection of the reported result (D5) was the domain with the most favorable assessment: nine studies were classified as being at low risk, while only two raised some concerns.

Overall, the findings indicate an acceptable methodological quality across the evidence included. Nevertheless, the six studies with yellow indicators in the overall assessment should be interpreted with greater caution, particularly in relation to randomization procedures, deviations from the intended interventions, and missing outcome data (Table 3).

Table 3: A tabular summary of the risk of bias assessment of 11 studies, evaluated across six domains.

Authors and Year	D1	D2	D3	D4	D5	OVERALL
Al-Ostwani et al. (2016) [52]	🟡	🟢	🟡	🟢	🟡	🟡
Chen et al. (2017) [53]	🟢	🟡	🟢	🟢	🟢	🟢
Pandranki et al. (2018) [54]	🟢	🟡	🟢	🟢	🟢	🟢
Cassol et al. (2019) [55]	🟢	🟡	🟢	🟡	🟡	🟡
RojaRamya et al. (2020) [56]	🟡	🟡	🟡	🟢	🟢	🟡
Patel et al. (2022) [57]	🟡	🟢	🟡	🟢	🟢	🟡
Bommareddy et al. (2022) [58]	🟢	🟢	🟡	🟢	🟢	🟢
Kumar et al. (2023) [59]	🟡	🟢	🟡	🟡	🟢	🟡
Dalal el al. (2023) [60]	🟢	🟡	🟢	🟢	🟢	🟢
El- Desouky et al. (2023)[47]	🟡	🟢	🟢	🟡	🟢	🟢
Khadilkar et al (2024)[61]	🟢	🟢	🟢	🟡	🟢	🟡

Domanins:	Judgment:	
D1: Bias due to confounding.		
D2: Bias arising from the measurement of the exposure.	High	✖
D3: Bias in the selection of participants in the study (or in the analysis).	Some Concerns	-
D4: Bias due to post-exposure interventions.	Low	+
D5: Bias due to missing data.	No Information	?

Discussion

The selection of an appropriate obturating material remains one of the most debated aspects of pediatric endodontics. Over the past decades, numerous materials have been introduced in an attempt to overcome the limitations of traditional formulations and to achieve the characteristics of an ideal root canal filling material. Such a material should combine adequate antimicrobial activity with excellent biocompatibility, provide a stable seal within the root canal system, resorb in harmony with physiological root resorption, and promote periapical healing without interfering with the eruption of the permanent successor. Despite continuous advances in material development, no obturating material has yet fulfilled all of these biological and clinical requirements.

The present systematic review synthesized the available evidence from RCTs comparing the clinical and radiographic performance of different obturating materials in primary teeth. Although the included studies investigated a wide range of conventional, modified, and bioactive formulations, they evaluated comparable clinical and radiographic outcomes, allowing an overall assessment of their effectiveness. The findings suggest that while several materials achieve satisfactory short-term clinical success, important differences emerge in terms of radiographic healing, resorption behavior, and long-term performance. Consequently, the choice of an obturating material should be based not only on its ability to resolve clinical symptoms but also on its biological properties and long-term radiographic behavior.

Performance of novel and bioactive obturating materials

The development of novel obturating materials has focused on improving the biological properties of conventional formulations while maintaining comparable clinical effectiveness [62-64]. Among the emerging materials evaluated in the included studies, formulations containing propolis, neem oil, and ozonated olive oil showed the most promising results, whereas curcumin-based materials demonstrated less consistent performance [13,65,66].

The most encouraging findings were reported for propolis-based materials. Both RojaRamya et al. and Al-Ostwani et al. demonstrated favorable clinical and radiographic outcomes for zinc oxide–propolis, with success rates comparable or superior to those of conventional materials such as ZOE and Endoflas [52,56]. These results may be explained by the well-documented antimicrobial, anti-inflammatory, and antioxidant properties of propolis, which could contribute to improved periapical healing. However, the current evidence is based on only a limited number of randomized clinical trials, making it difficult to establish its superiority over conventional obturating materials [52,56].

Similarly, Patel et al. reported excellent clinical and radiographic outcomes for zinc oxide mixed with neem oil, while El-Desouky et al. observed favorable healing following the use of zinc oxide–ozonated olive oil, particularly in terms of furcation repair and periodontal ligament healing [47,57]. Although these findings suggest that natural and bioactive compounds may enhance the biological performance of obturating materials, further clinical studies with longer follow-up periods are required before their routine use can be recommended [47,57].

In contrast, the available evidence does not support the use of curcumin-based formulations. Both Bommareddy et al. and Dalal et al. reported inferior outcomes compared with conventional materials, with higher rates of radiographic failure and pathological root resorption [58,60]. These findings indicate that the biological activity of curcumin observed in experimental studies does not necessarily translate into improved clinical performance when incorporated into obturating materials [58,60].

Overall, the current evidence suggests that the incorporation of bioactive compounds alone is insufficient to guarantee superior clinical outcomes. While propolis-, neem-, and ozonated olive oil-based materials appear promising, additional high-quality RCTs are necessary to confirm their long-term effectiveness and biological behavior before they can be considered reliable alternatives to conventional obturating materials [67-71].

Performance of novel and bioactive obturating materials

The increasing interest in novel obturating materials has been driven by the need to overcome some of the limitations associated with conventional formulations, particularly concerning antimicrobial activity, biocompatibility, inflammatory response, and resorption characteristics. In recent years, several randomized clinical trials have investigated the incorporation of natural products and bioactive compounds into root canal filling materials, with the aim of improving both clinical and radiographic outcomes. However, the evidence emerging from the present review suggests that the performance of

these materials is heterogeneous and largely dependent on the specific formulation rather than on the presence of natural or bioactive components alone.

Among the evaluated materials, propolis-based formulations demonstrated the most encouraging results. RojaRamya et al. reported significantly higher long-term clinical and radiographic success rates for zinc oxide–propolis compared with conventional ZOE, maintaining favorable outcomes throughout the 24-month follow-up [56]. Similarly, Al-Ostwani et al. found that zinc oxide–propolis achieved clinical and radiographic success comparable with ZOE, Metapex, and chlorophenol-free Endoflas, while exhibiting favorable biological behavior [52]. The antimicrobial, anti-inflammatory, and antioxidant properties of propolis may contribute to the reduction of residual bacterial contamination and promote tissue healing, providing a biological rationale for these positive findings [52,56]. Nevertheless, although both studies support the potential of propolis-containing materials, the limited number of available randomized trials prevents definitive conclusions regarding their superiority over conventional obturating materials [52,56].

Similarly, herbal-based formulations containing neem oil also showed promising results. Patel et al. demonstrated that zinc oxide mixed with neem oil achieved excellent clinical and radiographic outcomes, with all treated teeth remaining successful after 12 months [57]. Although the differences compared with ZOE were not substantial, the experimental material consistently produced numerically higher success rates. Neem has well-documented antimicrobial and anti-inflammatory properties, and its incorporation into obturating materials may enhance antibacterial activity without compromising biocompatibility [57]. However, these findings originate from a single randomized trial with a relatively limited sample size, highlighting the need for further multicenter studies before this material can be recommended for routine clinical use [57].

Encouraging results were also reported for zinc oxide combined with ozonated olive oil. El-Desouky et al. observed that the ozonated formulation promoted greater improvement in furcation radiodensity and a more pronounced reduction in periodontal ligament widening than either conventional ZOE or zinc oxide mixed with non-ozonated olive oil [47]. Ozone is recognized for its antimicrobial and immunomodulatory effects, while olive oil may improve the physical characteristics of the paste, potentially explaining the favorable radiographic healing observed during follow-up [47]. Although the overall clinical success was high across all study groups, these radiographic findings suggest that ozonated formulations may positively influence periapical tissue repair. Nevertheless, confirmation through longer follow-up periods is still required to determine whether these advantages translate into superior long-term clinical outcomes [47].

In contrast, curcumin-based materials produced less favorable and more inconsistent results. Bommareddy et al. reported that curcumin alone demonstrated the lowest clinical and radiographic success among the evaluated materials, whereas combining curcumin with calcium hydroxide partially improved performance but still failed to achieve the outcomes observed with Metapex [58]. Likewise, Dalal et al. found that the addition of curcumin powder to ZOE was associated with increased pathological root resorption and a higher incidence of interradicular radiolucency compared with conventional ZOE [60]. These findings suggest that, despite the well-recognized anti-inflammatory and antimicrobial properties demonstrated by curcumin in laboratory studies, its incorporation into obturating materials does not necessarily translate into improved clinical performance. The discrepancy between experimental evidence and clinical outcomes may reflect challenges related to material stability, bioavailability, or interactions with the root canal environment [60].

Overall, the available evidence indicates that the introduction of bioactive or naturally derived compounds alone is insufficient to guarantee superior clinical performance. While formulations containing propolis, neem oil, and ozonated olive oil demonstrated encouraging results, these findings are currently supported by a limited number of randomized clinical trials and relatively small study population [60]. Conversely, curcumin-based materials consistently failed to outperform conventional obturating materials, emphasizing that the biological properties of an individual component cannot be directly translated into clinical effectiveness. Future investigations should therefore focus not only on identifying novel bioactive substances but also on optimizing their formulation, physicochemical stability, and resorption characteristics to ensure predictable long-term clinical performance [60].

Biological behavior and resorption characteristics of obturating materials

Besides antimicrobial activity and clinical success, the biological behavior of an obturating material represents a key determinant of long-term treatment outcomes. Ideally, the material should maintain an adequate seal within the root canal system while resorbing at a rate similar to the physiological resorption of the primary root. Both premature resorption and excessive persistence may negatively affect treatment prognosis.

The present review identified material resorption as one of the main factors differentiating the available obturating materials. Chen et al. and Kumar et al. consistently reported lower long-term radiographic success for Vitapex and Metapex, suggesting that rapid intraradicular resorption may lead to early loss of the canal filling and compromise the long-term seal of the root canal system. In contrast, materials such as ZOE and Endoflas generally demonstrated greater stability and more predictable long-term radiographic outcomes [53,59].

However, excessive persistence of the obturating material may also represent a limitation. Al-Ostwani et al. observed that ZOE exhibited the slowest resorption among the evaluated materials, a characteristic that has traditionally been considered a potential disadvantage because residual material may remain after physiological root resorption. Therefore, the ideal obturating material should achieve a balance between adequate stability during function and gradual physiological resorption [52].

Another important finding emerging from the included studies is that treatment success depends not only on the properties of the obturating material but also on the quality of the endodontic procedure. Pandranki et al. demonstrated that overfilled canals were associated with less favorable outcomes, highlighting the importance of accurate working length determination and appropriate obturation techniques. Consequently, material selection and operator technique should be considered complementary factors influencing treatment success [54].

Overall, the available evidence suggests that the ideal obturating material has not yet been identified. Future research should focus on developing materials capable of combining excellent antimicrobial

activity, favorable biocompatibility, physiological resorption, and long-term sealing ability, while maintaining consistent clinical and radiographic performance over extended follow-up periods.

Conclusions

The findings of this systematic review indicate that several obturating materials achieve satisfactory clinical and radiographic outcomes in primary teeth. Conventional materials, particularly ZOE and Endoflas, continue to provide predictable results, whereas emerging formulations containing propolis, neem oil, and ozonated olive oil have shown promising preliminary outcomes. Conversely, curcumin-based materials did not demonstrate consistent clinical advantages.

Overall, no obturating material can currently be considered ideal. Future well-designed RCTs with larger sample sizes and longer follow-up periods are needed to confirm the long-term effectiveness and biological behavior of both conventional and novel obturating materials.

Author Contributions

Conceptualization, P.N., A.M.I., L.C., D.C., F.I., A.P., A.D.I., G.M., and G.D.; methodology, G.D., A.M.I., P.N., A.P., F.I., L.C., D.C., and G.M.; software, A.P., F.I., D.C., L.C., P.N., A.M.I., R.S., and G.M.; validation, G.D., D.C., A.P., G.M., A.M.I., F.I., L.C., P.N., and R.S.; formal analysis, L.C., A.M.I., G.M., G.D., A.D.I., D.C., A.P., and F.I.; resources, D.C., A.P., A.M.I., F.I., L.C., G.M., and R.S.; data curation, L.C., D.C., A.P., A.M.I., P.N., R.S., F.I., G.D., G.M., and A.D.I.; writing-original draft preparation, A.P., P.N., A.M.I., G.M., L.C., F.I., and D.C.; writing—review and editing, G.D., P.N., L.C., A.M.I., F.I., A.D.I., D.C., G.M., and R.S.; visualization, D.C., P.N., A.M.I., F.I., L.C., G.M., and A.P.; supervision, G.D., D.C., L.C., P.N., R.S., A.M.I., F.I., A.P., and G.M.; project administration, P.N., D.C., A.M.I., F.I., G.M., L.C., A.D.I., and G.D. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Data Availability Statement

The data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Apendix A

Advanced query PubMed

(("Pediatric Dentistry"[Mesh] OR "Tooth, Deciduous"[Mesh] OR "pediatric dentistry" OR "paediatric dentistry" OR pediatric OR paediatric OR child OR "primary teeth" OR "primary tooth" OR "deciduous teeth" OR "deciduous tooth" OR "primary molars" OR "primary molar") AND ("Endodontics"[Mesh] OR "Pulpotomy"[Mesh] OR "Root Canal Therapy"[Mesh] OR endodontic OR "pulp therapy" OR "vital pulp therapy" OR pulpotomy OR pulpectomy OR "root canal treatment" OR "root canal therapy") AND ("Dental Materials"[Mesh] OR "Calcium Hydroxide"[Mesh] OR "Mineral Trioxide Aggregate"[Supplementary Concept] OR "dental materials" OR "endodontic materials" OR "pulpotomy materials" OR "root canal filling materials" OR medicament OR irrigant OR cement OR sealer OR bioceramic OR "mineral trioxide aggregate" OR MTA OR Biodentine OR "calcium silicate cement" OR "calcium hydroxide" OR formocresol OR "ferric sulfate" OR "ferric sulphate" OR "zinc oxide eugenol" OR ZOE OR iodoform OR Vitapex OR Metapex OR Endoflas) AND (randomized controlled trial[pt] OR controlled clinical trial[pt] OR random* OR randomised OR randomized OR randomly OR trial OR placebo));

Advanced query Scopus

TITLE-ABS-KEY (("pediatric dentistry" OR "paediatric dentistry" OR pediatric* OR paediatric* OR child* OR "primary teeth" OR "primary tooth" OR "deciduous teeth" OR "deciduous tooth" OR "primary molars" OR "primary molar") AND (endodontic* OR "pulp therapy" OR "vital pulp therapy" OR pulpotom* OR pulpectom* OR "root canal treatment" OR "root canal therapy") AND ("dental materials" OR "endodontic materials" OR "pulpotomy materials" OR "root canal filling materials" OR medicament* OR irrigant* OR cement* OR sealer* OR bioceramic* OR "mineral trioxide aggregate" OR MTA OR Biodentine OR "calcium silicate cement" OR "calcium hydroxide" OR formocresol OR "ferric sulfate" OR "ferric sulphate" OR "zinc oxide eugenol" OR ZOE OR iodoform OR Vitapex OR Metapex OR Endoflas) AND (random* OR trial* OR placebo* OR "controlled clinical trial" OR "clinical trial"));

Advanced query Web of Science

TS=(("pediatric dentistry" OR "paediatric dentistry" OR pediatric OR paediatric OR child OR "primary teeth" OR "primary tooth" OR "deciduous teeth" OR "deciduous tooth" OR "primary molars" OR "primary molar") AND (endodontic OR "pulp therapy" OR "vital pulp therapy" OR pulpotom OR pulpectom OR (root canal NEAR/2 (treatment OR therapy))) AND ("dental materials" OR "endodontic materials" OR "pulpotomy materials" OR "root canal filling materials" OR medicament OR irrigant OR cement OR sealer OR bioceramic OR "mineral trioxide aggregate" OR "MTA" OR "Biodentine" OR (calcium NEAR/2 silicate NEAR/2 cement) OR "calcium hydroxide" OR formocresol OR "ferric sulfate" OR "ferric sulphate" OR "zinc oxide eugenol" OR "ZOE" OR iodoform OR "Vitapex" OR "Metapex" OR "Endoflas") AND ("randomized controlled trial" OR "randomised controlled trial" OR "randomized clinical trial" OR "randomised clinical trial" OR random OR placebo OR allocat OR trial OR "controlled clinical trial")).

References

1. Pires CW, Lenzi TL, Soares FZM, Rocha RO. Zinc Oxide Eugenol Paste Jeopardises the Adhesive Bonding to Primary Dentine. Arch Paediatr Dent. 2018;19(3):163-9.
2. Behera S, Tiwari A, Vaidya N, Nanda S, Mishra P, Bhushan M. Analysis of Microgap for Root Canal Filling Material Filled with a Hydrophilic and Hydrophobic Obturating System. Bioinformation. 2025;21(8):2586-89.
3. Rajasekharan S, Martens LC, Vandenbulcke J, Jacquet W, Bottenberg P. Efficacy of Three Different Pulpotomy Agents in Primary Molars: A Randomized Control Trial. Int Endod J. 2017;50(3):215-28.
4. Inchingolo F, Marrelli M, Annibali S, Cristalli MP, Dipalma G, Inchingolo AD, et al. Influence of Endodontic Treatment on Systemic Oxidative Stress. Int J Med Sci. 2014;11(1):1-6.
5. Saxena D, Garg N, Pathivada L, Kaur H. Success Rates of Antibiotic Sterilization, Indirect Pulp Treatment, and Pulpotomy in the Management of Primary Teeth with Deep Carious Lesions. Int J Clin Pediatr Dent. 2024;17(3):237-42.
6. Brignardello-Petersen R. Small Trial Shows High Rates of Endodontic Treatment Success with Iodoform or Calcium Hydroxide Paste in Primary Teeth after 1 Year. J Am Dent Assoc. 2019;150(8):e122.
7. Bharuka SB, Mandroli PS. Single- versus Two-Visit Pulpectomy Treatment in Primary Teeth with Apical Periodontitis: A Double-Blind, Parallel Group, Randomized Controlled Trial. J Indian Soc Pedod Prev Dent. 2016;34(4):383-90.
8. Barry MJ, Baghlaf K, Alamoudi N. Silver Diamine Fluoride as a Medicament for the Indirect Pulp Therapy in Primary Teeth: A Review of the Literature. Cureus. 2024;16(5):e60780.
9. Pedrotti D, Bottezini PA, Casagrande L, Braga MM. Root Canal Filling Materials for

Endodontic Treatment of Necrotic Primary Teeth: A Network Meta-Analysis. Eur Arch Paediatr Dent. 2023;24(2):151-66.

10. Santos PSD, Pedrotti D, Braga MM, Rocha RO, Lenzi TL. Materials Used for Indirect Pulp Treatment in Primary Teeth: A Mixed Treatment Comparisons Meta-Analysis. Braz Oral Res. 2017;31:e101.

11. Khan AM, Gangoo IKA, Ali NA, Khan M, Javed MQ, AlAttas MH, et al. The Effect of Calcium Hydroxide, Triple Antibiotic Paste and Chlorhexidine on Pain in Teeth with Symptomatic Apical Periodontitis: A Randomised Controlled Trial. Int J Environ Res Public Health. 2023;20(4):3091.

12. Javed F, Kellesarian SV, Abduljabbar T, Gholamiazizi E, Feng C, Aldosary K, et al. Role of Laser Irradiation in Direct Pulp Capping Procedures: A Systematic Review and Meta-Analysis. Lasers Med Sci. 2017;32(2):439-48.

13. Boutsiouki C, Frankenberger R, Kramer N. Clinical and Radiographic Success of (Partial) Pulpotomy and Pulpectomy in Primary Teeth: A Systematic Review. Eur J Paediatr Dent. 2021;22(4):273-85.

14. Tannure PN, Barcelos R, Farinhas J, Primo LG. Zinc Oxide-Eugenol Paste Retained in Gingival Mucosa after Primary Teeth Pulpectomy. Eur J Paediatr Dent. 2010;11(2):101-2.

15. Zhu Z, Fu G. Research on NiTi Instruments Combined with Ultrasonic Irrigation and Multiantibiotic Paste in Root Canal Therapy of Periapical Inflammation in Deciduous Teeth. Exp Ther Med. 2024;28(3):346.

16. Ding Z, Wang A, Liu Y, Zhu S, Jiang L, chen X. Physiological Occlusal Force Attenuates Replacement Root Resorption of Replanted Teeth: An Experimental Animal Study. BMC Oral Health. 2024;24(1):658.

17. Xing Y, Zhu Y, Shen Y, Xu Y, Xu Z, Wang M, et al. Novel Approaches Involving Curcumin in Endodontic and Periodontal Diseases: A Scoping Review. BMC Oral Health. 2026;26(103).

18. Zhang CF, Wang J, Zhu XY, Wang N. Effect of Ultrasonic Irrigation Combined with Epoxy Resin Paste in Single Visit Root Canal Treatment in Chronic Pulpitis. J Coll Physicians Surg Pak. 2023;33(10):1130-5.

19. Arandi NZ, Thabet M. Minimal Intervention in Dentistry: A Literature Review on Biodentine as a Bioactive Pulp Capping Material. Biomed Res Int. 2021;2021:5569313.

20. Farto J, Boj JR, Sahli C C. Microleakage of MTA in Primary Molar Pulpotomies. Eur J Paediatr Dent. 2017;18(3):183-7.

21. Garrocho-Rangel A, Quintana-Guevara K, Vázquez-Viera R, Arvizu-Rivera JM, Flores-Reyes H, Escobar-García DM, et al. Bioactive Tricalcium Silicate-Based Dentin Substitute as an Indirect Pulp Capping Material for Primary Teeth: A 12-Month Follow-Up. Pediatr Dent. 2017;39(5):377-82.

22. Pozos-Guillen A, Garcia-Flores A, Esparza-Villalpando V, Garrocho-Rangel A. Intracanal Irrigants for Pulpectomy in Primary Teeth: A Systematic Review and Meta-Analysis. Int J Paediatr Dent. 2016;26(6):412-25.

23. Garrocho-Rangel A, Jalomo-Ávila C, Rosales-Berber MÁ, Pozos-Guillén A. Lesion Sterilization Tissue Repair (LSTR) Approach of Non-Vital Primary Molars With A Chloramphenicol-Tetracycline-ZOE Antibiotic Paste: A Scoping Review. J Clin Pediatr Dent . 2021;45(6):369-75.

24. Monteiro LPB, Guerreiro MYR, de Castro Valino R, Magno MB, Maia LC. Effect of Intracanal Cryotherapy Application on Postoperative Endodontic Pain: A Systematic Review and Metaanalysis. Clin Oral Investig. 2021;25(1):23-35.

25. Castro M, Lima M, Lima C, Moura M, Moura J. Lesion Sterilization and Tissue Repair with Chloramphenicol, Tetracyline, Zinc Oxide/Eugenol Paste versus Conventional Pulpectomy: A 36-Month Randomized Controlled Trial. Int J Paediatr Dent. 2023;33(4):335-45.

26. Moura J, Lima M, Nogueira N, Castro M, Lima C, Moura M. LSTR Antibiotic Paste Versus Zinc Oxide and Eugenol Pulpectomy for the Treatment of Primary Molars with Pulp Necrosis: A Randomized Controlled Trial. Pediatr Dent. 2021;43(6):435-42.

27. Johnson RM, Sharawat N, Mathur VP, Tewari N, Nazzal H, Rahul M, et al. Knowledge, Practice, and Experience of Regenerative Endodontic Therapy among Pediatric Dentists and Postgraduate Students in India. J Indian Soc Pedod Prev Dent. 2026;44(1):48-56.

28. Hesse D, de Araujo MP, Olegário IC, Innes N, Raggio DP, Bonifácio CC. Atraumatic Restorative Treatment Compared to the Hall Technique for Occluso-Proximal Cavities in Primary Molars: Study Protocol for a Randomized Controlled Trial. Trials. 2016;17:169.

29. Olegário IC, Hesse D, Bönecker M, Imparato JC, Braga MM, Mendes FM. Effectiveness of Conventional Treatment Using Bulk-Fill Composite Resin versus Atraumatic Restorative Treatments in Primary and Permanent Dentition: A Pragmatic Randomized Clinical Trial. BMC Oral Health. 2016;17(1):34.

30. Olegário IC, Hesse D, Mendes FM, Bonifácio CC, Raggio DP. Glass Carbomer and Compomer for ART Restorations: 3-Year Results of a Randomized Clinical Trial. Clin Oral Investig. 2019;23(4):1761-70.

31. Olegário IC, Ladewig NM, Hesse D, Bonifácio CC, Braga MM, Imparato JCP, et al. Is It Worth Using Low-Cost Glass Ionomer Cements for Occlusal ART Restorations in Primary Molars? 2-Year Survival and Cost Analysis of a Randomized Clinical Trial. J Dent. 2020;101:103446.

32. Cassol DV, Duarte ML, Pintor AVB, Barcelos R, Primo LG. Iodoform Vs Calcium Hydroxide/Zinc Oxide Based Pastes: 12-Month Findings of a Randomized Controlled Trial. Braz Oral Res. 2019;33:e002.

33. Kalakijuybari FZ, Pasdar N, Ahmadi G, Seyedmajidi A. Investigating the Impact of Flowable Composite Liner on the Fracture Strength and Microleakage of Large Composite Resin Restorations of Primary Anterior Teeth. Eur Arch Paediatr Dent. 2023;24(4):473-9.

34. Day PF, Duggal M, Nazzal H. Interventions for Treating Traumatised Permanent Front Teeth: Avulsed (Knocked out) and Replanted. Cochrane Database Syst Rev. 2019;2(2):CD006542.

35. Kiranmayi T, Vemagiri CT, Rayala C, Chandrappa V, Bathula H. In Vivo Comparison of Bioceramic Putty and Mineral Trioxide Aggregate as Pulpotomy Medicament in Primary Molars. A 12-Month Follow-up Randomized Clinical Trial. Dent Res J (Isfahan). 2022:19:84. eCollection 2022.

36. Subbaraj S, Chenchugopal M, Elangovan A, Jagadeesan A. In Vivo Comparative Evaluation of Four Different Obturation Techniques in Primary Teeth: A Randomized Controlled Clinical Trial. Int J Clin Pediatr Dent. 2025;18(11):1311-7.

37. Moghaddam NE, Tirani FF, Aghaali M, Mehdipour A, Saleh A. In Vitro Comparison of Root Canal Obturation Quality in Primary Molars Using Lentulo Spiral and Reverse Rotary Techniques with Zinc Oxide Eugenol and Endoflas: Microcomputed Tomography Analysis. BMC Oral Health. 2025;25(1):1787.

38. Mahd MA, Moeiny P, Heshmat H, Askarizadeh N. In Vitro Comparison of Fracture Resistance of Severely Damaged Primary Anterior Teeth Restored with Different Post and Core Systems. Int J Dent. 2023;2023:2895892.

39. Agarwal S, Tyagi P, Deshpande A, Yadav S, Jain V, Kumar B. Comparison of Antimicrobial Efficacy of Aqueous Ozone, Green Tea, and Normal Saline as Irrigants in Pulpectomy Procedures of Primary Teeth. Int J Clin Pediatr Dent. 2024;17(5):511-7.

40. Deshpande AN, Joshi NH, Naik SH. In Vitro Comparative Evaluation of Cleaning Efficacy and Volumetric Filling in Primary Molars: Cone Beam Computed Tomography Evaluation. Contemp Clin Dent. 2017;8(1):33-7.

41. Ildeş GÇ, Sezgin BI, Vieira AR, Mentes A. A Randomized Clinical Trial of Hyaluronic Acid Gel Pulpotomy in Primary Molars with 1 Year Follow-Up. Acta Odontol Scand. 2022;80(4):273-80.

42. Sezgin BI, Ildes Sezgin GC, Koyuncu Ö, Mentes A. Hyaluronic Acid as a Pulpotomy Material in Primary Molars: An up to 30 Months Retrospective Study. BMC Oral Health. 2024;24(1):683.

43. Haghgoo R, Molaasadolah F, Taghizade F, Ansari G. THREE-YEAR OUTCOME OF DIODE LASER PULPOTOMY OF PRIMARY MOLARS USING THREE PULP CAPPING AGENTS: A SPLIT-MOUTH RANDOMIZED CLINICAL TRIAL. J Evid Based Dent Pract. 2023;23(4):101920.

44. Haghgoo R, Asgary S, Montazeri R. Histopathological Evaluation of Primary Teeth after Pulp Capping with Calcium-Enriched Mixture and Bioactive Glass. Iran Endod J. 2018;13(4):457-60.

45. Dipalma G, Inchingolo AM, Casamassima L, Nardelli P, Ciccarese D, De Sena P, et al. Effectiveness of Dental Restorative Materials in the Atraumatic Treatment of Carious Primary Teeth in Pediatric Dentistry: A Systematic Review. Children (Basel). 2025;12(4):511.

46. Omer SMM, Elsaied HAF, Alghonemy WY, El-Desouky SS. Histopathological and Immunohistochemical Characterization of Pulp Tissue Reaction to ACTIVA BioACTIVE Base/Liner in Primary Teeth Pulpotomy: A Randomized Clinical Trial. BMC Oral Health. 2025;25(1):885.

47. El-Desouky SS, Omer SMM, Ghouraba RF, Latif RMAA, Kabbash IA, Hadwa SM. Zinc Oxide-Ozonated Olive Oil as a New Root Canal Filling Material in Primary Molars: A Clinical Randomized Controlled Trial. Clin Oral Investig. 2023;27(12):7395-405.

48. Kendre SB, Bhatane AU, Dadpe MV, Kale YJ, Dahake PT. Comparative Evaluation of Antibacterial Efficacy of Sequential Herbal Irrigation with Conventional Irrigation in Endodontic Therapy of Primary Teeth: A Randomized Controlled Trial. J Indian Soc Pedod Prev Dent. 2025;43(3):410-7.

49. Agarwal S, Gupta S, Tandon S, Mathur R, Rai TS, Kumar M. Comparative Evaluation of Ocimum Sanctum and Calcium Hydroxide Mix as an Obturating Material in Deciduous Molars: An In Vivo Study. Int J Clin Pediatr Dent. 2020;13(6):617-21.

50. Darshini CSS, Peethambar P, Konde S, Agarwal M. Volumetric Analysis of Root Canal Filling in Deciduous Teeth after Using Different Canal-Drying Methods: An In-Vitro Study. Contemp Clin Dent. 2019;10(4):622-6.

51. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. Int J Surg. 2021;88:105906.

52. Al-Ostwani AO, Al-Monaqel BM, Al-Tinawi MK. A Clinical and Radiographic Study of Four Different Root Canal Fillings in Primary Molars. J Indian Soc Pedod Prev Dent. 2016;34(1):55-9.

53. Chen X, Liu X, Zhong J. Clinical and Radiographic Evaluation of Pulpectomy in Primary Teeth: A 18-Months Clinical Randomized Controlled Trial. Head Face Med. 2017;13(1):12.

54. Pandranki J, Vanga NRV, Chandrabhatla SK. Zinc Oxide Eugenol and Endoflas Pulpectomy in Primary Molars: 24-Month Clinical and Radiographic Evaluation. J Indian Soc Pedod Prev Dent. 2018;36(2):173-80.

55. Cassol DV, Duarte ML, Pintor AVB, Barcelos R, Primo LG. Iodoform Vs Calcium Hydroxide/Zinc Oxide Based Pastes: 12-Month Findings of a Randomized Controlled Trial. Braz Oral Res. 2019;33:e002.

56. RojaRamya KS, Vinay C, Uloopi KS, Chandrasekar R. In Vivo Evaluation of Zinc Oxide-Propolis Mixture as Root Canal Filling Material in the Primary Molars: A 24-Month Follow-up Randomized Controlled Trial. J Indian Soc Pedod Prev Dent. 2020;38(2):171-6.

57. Patel DG, Fernandes S, Bafna Y, Choksi K, Chaudhary S, Mishra P. Comparative Evaluation of Zinc Oxide-Eugenol and Zinc Oxide with Neem Oil in Root Canal Treatment of Primary Teeth: Split-Mouth Study with 12 Months Follow-Up. Ayu. 2022;43(1):8-12.

58. Bommareddy CS, Ramkumar H, Dakshinamurthy S, Paulindraraj S, Jayakaran TG, Clinical and Radiographic Evaluation of Curcumin as an Obturation Material in Deciduous Teeth: A Randomized Controlled Trial. Int J Clin Pediatr Dent. 2022;15(Suppl 1):S35-S39.

59. Kumar KS, Asokan S, Geethapriya PR, Sivakumar K, Yamunadevi A. Survival Function of Clinical and Radiographic Success of Three Obturating Materials in Primary Teeth at 3, 6 and 9 Months Periodic Intervals - A Randomized Controlled Clinical Trial. J Pharm Bioallied Sci. 2023;15(Suppl 1):S747-S751.

60. Dalal R, Gupta A, Srivastava A, Garg S, Sharma V, Sharma, V. To Evaluate the Success of Natural Compound: Curcumin as Obturating Material in Primary Teeth. Int J Clin Pediatr Dent. 2023;16(6):793-9.

61. Khadilkar AS, Kapur A, Goyal A, Gauba K, Singh SK. Comparison of Clinical Performance of Obturating Materials in Pulpectomies: A Randomized Clinical Trial. J Indian Soc Pedod Prev Dent. 2024;42(1):28-36.

62. Sobhnamayan F, Sahebi S, Moazami F, Malekzadeh P, Hasani S. Combination of Metformin and Double Antibiotic Paste for the Regeneration of Non-Vital Immature Teeth: A Preliminary Randomized Clinical Study. BMC Oral Health. 2023;23(1):847.

63. Junqueira MA, Cunha NNO, Caixeta FF, Marques NCT, Oliveira TM, Moretti ABDS, et al. Clinical, Radiographic and Histological Evaluation of Primary Teeth Pulpotomy Using MTA And Ferric Sulfate. Braz Dent J. 2018;29(2):159-65.

64. Chak RK, Singh RK, Mutyala J, Killi NK. Clinical Radiographic Evaluation of 3Mixtatin and MTA in Primary Teeth Pulpotomies: A Randomized Controlled. Int J Clin Pediatr Dent. 2022;15(Suppl 1):S80-S86.

65. Guang J, Li J, Hao L. Clinical Observation and Histopathological Evaluation of Pulp after Pulpotomy of Primary Teeth with Formocresol and Biodentine. Cell Mol Biol (Noisy-le-grand). 2022;68(5):83-8.

66. Amend S, Boutsiouki C, Bekes K, Kloukos D, Lygidakis NN, Frankenberger R, et al. Clinical Effectiveness of Restorative Materials for the Restoration of Carious Primary Teeth without Pulp Therapy: A Systematic Review. Eur Arch Paediatr Dent. 2022;23(5):727-59.

67. Hugar SM, Kukreja P, Hugar SS, Gokhale N, Assudani H. Comparative Evaluation of Clinical and Radiographic Success of Formocresol, Propolis, Turmeric Gel, and Calcium Hydroxide on Pulpotomized Primary Molars: A Preliminary Study. Int J Clin Pediatr Dent. 2017;10(1):18-23.

68. Aghazadeh S, Haghgoo R, Mehran M, Kadkhodaei F. Comparative Evaluation of Clinical and Radiographic Success of MTA and Propolis in Pulpotomy of Primary Molars. Iranian Endodontic J. 2018;13(4):508-14.

69. Singh S, Saxena A, Khandelwal V, Verma N, Jain A. Evaluation of Zinc Oxide-Eugenol, Zinc Oxide-Propolis and Endoflas as an Obturating Materials in Primary Molar Pulpectomies - A Comparative Study. Indian J Dent Res. 2025;36(1):54-9.

70. Hassan EM, Elasser DM, Abdel-Ghany DM, Fathy S. Radiographic Evaluation of Nano-Propolis, Nano-Curcumin and MTA as Direct Pulp Capping Agents in Young Permanent Teeth. J Clin Exp Dent. 2025;17(9):e1108-e1115.

71. Goinka C, Galla PK, Madhavi K, Malempet A, Suryadevara S. A Histopathological Comparison of Formocresol, Propolis, and Growth Factor as Pulpotomy Medicaments in Primary Teeth: An in Vivo Study. Dent Res J (Isfahan). 2023:20:15. eCollection 2023.