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Recent advances in medicaments used for indirect pulp treatment in primary teeth: A narrative review

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Abstract
Dental caries remains one of the most widespread chronic disease affecting humans across the lifespan. In response to this challenge, therapeutic strategies have evolved toward minimally invasive, biologically driven approaches. Indirect Pulp Therapy (IPT) is recognized for its ability to manage deep carious lesions conservatively, particularly in primary teeth. A variety of materials have been utilized in IPT to maintain pulp vitality, provide a sufficient seal to the underlying dentin, and prevent any symptoms or signs after treatment. For a long time, calcium hydroxide has been recommended as the best material for IPT. To overcome the drawbacks of calcium hydroxide, a range of biocompatible materials like Resin modified glass ionomer (RMGI) with 2% chlorhexidine (CHX), Mineral trioxide aggregate (MTA), Biodentine, Propolis, TheraCal-LC, SDF, and Activa-Bioactive liner with good success rates in IPT of primary molars were listed. This review synthesizes recent advances in IPT medicaments from 2000 to 2024, evaluating their biological mechanisms, material properties, and clinical effectiveness. Modern alternatives to traditional calcium hydroxide, including bioactive, antimicrobial, and self-sealing materials, are assessed to support evidence-based decision-making in pediatric dental practice.

Keywords: Deep dental caries, indirect pulp treatment, biocompatible materials, remineralization, primary teeth.

Introduction
Dental caries, is one of the most common chronic disorders affecting children worldwide that demineralizes and destroys tooth tissue. The degree varies from early, clinically detectable alterations in enamel brought on by demineralization to widespread cavitation. The most prevalent condition affecting primary teeth is extensive tooth decay; 42% of children aged 2-11 have dental caries in their primary teeth, with an average of 1.6 decayed teeth per child (NHANES 2010; Selwitz 2007). According to the CDC (2011), high prevalence of untreated carious lesions are seen in children, particularly in the primary dentition, which increases the likelihood of permanent tooth decay.
Historically, pulpotomy was considered the gold standard for managing deep carious lesions in primary molars due to its ability to remove affected tooth structure together with the infected pulp.[1] Indirect pulp therapy(IPT), has emerged as a conservative option for primary teeth that preserves pulp vitality and allows for normal exfoliation time.[1] Indirect pulp treatment involves selectively removing infected dentin while leaving behind affected dentin to be sealed and remineralized by a biocompatible material. This will maintain the pulp vitality by stimulating the tertiary dentin formation and avoiding pulp exposure [2]. Later, a restoration is used to seal the cavity to prevent the microleakage [1]. Properties required for an ideal indirect pulp capping material include maintaining pulp vitality, stimulate formation of reparative dentin, preventing secondary caries by fluoride release, should be bactericidal or bacteriostatic, adhere to dentin and restorative material, radiopaque and provide bacterial seal [3]. For many years, calcium hydroxide had been proposed to be the best material for IPT due to its high ability to form tertiary dentine [4]. But the major drawback is its poor bonding ability to dentine which makes it unable to avoid microleakage in the longer term resulting in secondary Infections [5]. This drew the attention to find materials that can overcome the limitations of

calcium hydroxide while still exhibiting comparable clinical efficacy [6]. This review aims to critically appraise recent advancements in medicaments employed in IPT for primary teeth, focusing on their mechanisms of action, clinical efficacy, and biological rationale, based on evidence from peer-reviewed literature published between 2000 and 2024.

Methods

Using the keywords ‘Recent advances’, ‘Indirect pulp treatment’, ‘MTA’, ‘Biodentine’, ‘Theracal-LC’, ‘CHX’, ‘Resin - modified glass ionomer’, ‘Calcium hydroxide’. PubMed/Medline, ScienceDirect and Scopus electronic databases were searched for scientific papers which had been published in English between 2000 and 2024. In total, 72 studies were retrieved through initial screening. After title and abstract evaluation, 35 articles met the inclusion criteria and were selected for full-text review. The inclusion criteria required studies to report clinical outcomes or scientific evaluations of medicaments used for IPT in primary molars. Exclusion criteria comprised articles not focused on primary teeth, studies not available in full-text, and those with inadequate methodology.

Discussion

The primary objectives of pulp therapy in pediatric dentistry are to maintain the affected tooth in a healthy state within the dental arch, thereby preserving the arch space and enabling normal function in mastication and esthetics and also prevention of harmful effects on the developing succedaneous tooth and the periapical tissue [3].

Indirect pulp treatment is a procedure that leaves the deepest caries adjacent to the pulp undisturbed in an effort to avoid a pulp exposure. This caries-affected dentin is covered with a biocompatible material to produce a biological seal. (AAPD)

Objectives of indirect pulp treatment (IPT) [7]

As described by Eidelman in 1965, the principal objectives of IPT are:

- Arrest of the carious process
- Promotion of dentin sclerosis
- Stimulation of tertiary dentinogenesis
- Remineralization of caries-affected dentin

Indications of IPT [7]

- Mild, localized pain provoked by eating
- Absence of spontaneous or nocturnal pain
- Deep carious lesions approximating, but not invading, the pulp in vital primary or young permanent teeth
- Absence of tooth mobility
- Minimal pulp inflammation with a definite layer of caries-affected dentin after caries excavation
- Intact lamina dura and periodontal ligament (PDL) on radiographic examination
- No periapical or furcal radiolucency

Contraindications of IPT [7]

- Acute pulpal inflammation characterized by sharp, spontaneous, or nocturnal pain
- Tooth mobility or discoloration
- Negative response to pulp vitality testing
- Clinical or radiographic evidence of frank pulp exposure
- Disruption or loss of lamina dura integrity
- Presence of periapical radiolucency
- Widened PDL space

Types of Indirect pulp capping techniques

1. Two stage / stepwise caries removal technique
2. One stage indirect pulp capping technique

1. Two stage / stepwise caries removal technique

This approach involves two clinical visits. The initial visit focuses on removing all peripheral necrotic and infected dentin while leaving the deeper caries-affected dentin near the pulp not excavated to prevent pulp exposure [8]. A temporary restoration is then placed, often using calcium hydroxide and a self-setting or resin-modified glass ionomer [9]. The goal of stepwise excavation is to enable more tertiary dentin formation and allow the affected dentin to remineralize [8]. After 8-12 weeks, the tooth is re-entered, the softened dentin is further excavated, and a final restoration is placed over hard dentin.The goal of placing a final restoration is to prevent microleakage and seal the pulp [9].

2. One step / Partial caries removal technique

This method is also known as partial or incomplete which involves selective removal of infected dentin in a single appointment while leaving behind the deeper caries to prevent pulp exposure. The remaining caries-affected dentin is sealed, and a definitive restoration is placed immediately [10]. This eliminates the need for re-entry and allows for remineralization of the residual dentin by altering the microbial equilibrium.

Classification of Indirect Pulp Treatment Medicaments Based on the Mechanism of Action:

1. Indirect pulp treatment medicaments with remineralizing potential

i) Calcium hydroxide
ii) Calcium phosphate
iii) MTA
iv) Biodentine
v) Thercal LC
vi) Activa bioactive
vii) Propolis
viii) Neoputty

2. Indirect pulp treatment medicaments with antimicrobial properties

i) Chlorhexidine gluconate
ii) Silver diamine fluoride
iii) 3 MIX MP
iv) Lasers

3. Indirect pulp treatment medicaments with self- sealing properties

i) Glass ionomer cement
ii) Self-etching system
iii) Resin modified glass ionomer cement

Overview of indirect pulp treatment medicaments used in primary teeth

1. Indirect pulp treatment medicaments with remineralizing potential

i) Calcium Hydroxide

Calcium hydroxide has long been considered as the "Gold Standard" material for indirect pulp treatment (IPT), particularly in primary dentition. Since its introduction by Hermann in 1921, it has been extensively used for pulp capping procedures due to its reliable clinical outcomes, often maintaining pulp vitality for up to ten years. Despite its widespread acceptance, calcium hydroxide is limited by a number of disadvantages including its inability to form a proper seal, poor bonding to dentin, and the development of tunnel defects in the reparative dentin formed beneath it [11].

Advantages

- Regarded as the gold standard in direct pulp capping
- Strong antibacterial activity
- Stimulates mineralized tissue formation
- Low cytotoxicity [12]

Disadvantages:

- Highly soluble in oral fluids
- Subject to dissolution over time
- Extensive dentin formation obliterating the pulp chamber
- Lack of adhesion
- Vulnerable to acid dissolution
- Formation of tunnel defects in dentin [12]

ii) **Calcium Phosphate:** Calcium phosphate-based materials are recognized for their excellent biocompatibility and nontoxic properties. Tricalcium phosphate and hydroxyapatite are the two most commonly used bioactive synthetic materials in Calcium phosphate cements. They offer self-curing capabilities, consisting of powder and liquid.

According to Al-Sanabani *et al.* [13], Calcium phosphate developed by Brown and Chow in the 1980s, has the potential to be utilized in direct or indirect pulp capping procedures for dentin regeneration. Calcium phosphate outperforms pure calcium hydroxide due to its biocompatibility, compressive strength, and self-curing ability [14]. A study compared the ability of dentin bridge formation in pigs' primary teeth using calcium hydroxide and calcium phosphate. It was reported that, in comparison to calcium hydroxide, calcium phosphate can form dentin bridge that is more regular, thicker and faster. Calcium phosphate has a superior capacity of dentinal bridge formation, improved compressive strength, and good biocompatibility than calcium hydroxide [15].

iii) **Mineral Trioxide Aggregate (MTA):** Mineral trioxide aggregate (MTA) was initially developed in 1993 by Mahmoud Torabinejad of Loma Linda University and received approval from the U.S. Food and Drug Administration in 1988. Originally, MTA was used for root-end filling and sealing root perforations [27]. MTA was later widely utilized in the Pediatric dentistry. Additionally, MTA is a Portland cement that is formed through the interaction of calcium oxide and silicon dioxide, which produces tricalcium silicate, dicalcium silicate, tetracalcium aluminoferrite, and tricalcium aluminate. Bismuth oxide is added to the material to help with radiographic differentiation. Furthermore, compared to other materials like IRM and super EBA, MTA is less cytotoxic biocompatible, and non-mutagenic. In IPT, MTA can promote the formation of collagen from cells in contrast to calcium hydroxide, resulting in a superior quality dentinal bridge formation. MTA also exhibits antibacterial action against Enterococcus faecalis (E. faecalis), Streptococcus mutans (S. mutans), and Streptococcus sanguis (S. sanguis) [29].

Advantages

- Potent antimicrobial action
- High biocompatibility
- Excellent marginal seal and adaptation
- Promotes osteogenesis and healing

Disadvantages

- Discoloration
- Prolonged setting time
- Expensive

An article published by George *et al.* (2015) assessed forty primary molars. The sample was split into two groups: Twenty teeth received MTA treatment, and another twenty received calcium hydroxide treatment. Six months after treatment, the patients were followed up. They found that MTA deposited more dentinal bridge and performed better than calcium hydroxide as a pulp capping material in primary molars [6].

Biodentine

Biodentine is a contemporary calcium silicate-based material designed to serve as a dentin substitute. Its mechanical properties closely resemble natural dentin. Biodentine comes in a capsule with an ideal liquid and powder ratio. The composition of Biodentine include tricalcium silicate, dicalcium silicate, calcium carbonate, zirconium oxide, iron oxide, and calcium chloride [30]. Additionally, Biodentine is a biocompatible material that stimulates odontoblastic differentiation in a very short period which results in tertiary dentin formation. Therefore, Biodentine is regarded as a suitable IPT material. It also demonstrates superior antibacterial properties compared to MTA, particularly against *S. mutans* and *E. faecalis*. Additionally, after one month of administration, Biodentine's compressive strength can reach upto 300 MPA which is comparable to that of natural dentine, which is about 297 MPA. Additionally, when compared to MTA, Biodentine has a lower radiopacity, low solubility, and superior adaptation and seal [31].

Advantages

- Capable of inducing odontogenic differentiation and reparative dentin formation
- Biocompatibility
- Antibacterial activity
- Enhanced marginal adaptation
- High bond strength

Disadvantages

- **Expensive**

  In 2017, a study assessing the effect of Biodentine on IPT of primary molars was published in the Pediatric Dentistry Journal. In this study, 60 patients each had two teeth treated in a split-mouth manner, with Biodentine serving as the IPT material on one side and calcium hydroxide on the other. At the 12-month follow-up, the researchers discovered that the success rates of the two groups did not differ statistically significantly.[11] Biodentine is more affordable than MTA, which makes it more widely available.

TheraCal-LC

TheraCal-LC is a novel light-cured resin-modified calcium silicate-filled base/ liner that is recommended for direct and indirect pulp treatments [32]. The composition of TheraCal-LC includes Portland cement, polyethylene glycol dimethacrylate polymerizable methacrylate monomers, and barium zirconate. Additionally, TheraCal-LC has a high calcium releasing ability. Calcium ions stimulate the formation of hard tissues and triggers pulpal tissues to proliferate and differentiate. Furthermore, TheraCal-LC is more stable, durable, less soluble, and it has excellent physical qualities [3]. The antibacterial activity of TheraCal-LC against S. mutans was found to be similar to that of calcium hydroxide. However, it has less effect on S. sanguinis and S. salivarius. The compressive strength of TheraCal-LC is the highest among MTA and Biodentine [33]. Application of thin layer of TheraCal-LC is recommended, to prevent change in the shade of final restoration, as it is opaque whitish in color [32].

Advantages

- Improved mechanical stability
- Excellent sealing ability
- High calcium release
- Facilitates dentin bridge formation
- Low solubility

Disadvantages

Opaque white color

Furthermore, a 2019 study that used calcium hydroxide, MTA, and TheraCal-LC investigated the efficacy of IPT. The sample of 153 second primary molars was observed for 24 months. Although the MTA group had a higher success rate, they did not find any statistically significant differences in the IPT success rates of the three groups [34].

Activa Bio-Active

Launched in 2014 by Pulpdent, ACTIVA BioACTIVE BASE/LINER is a biointeractive material combining the benefits of glass ionomers and composites. It demonstrates enhanced release and recharge of calcium, phosphate, and fluoride compared to glass ionomer (GI), as well as the strength, physical properties, and aesthetics of composites [44]. It is indicated for use in IPT where there is no pulpal exposure and allows for immediate final restoration, offering a practical alternative to MTA and Biodentine due to its shorter setting time.

Propolis

Propolis is a resinous substance collected by honeybees from the tree buds. The Greek word "propolis," which means "in front of" or "at the entrance to," and "polis," which means "community" or "city," refer to a material used to protect hives [52]. Propolis is composed of 30% essential oils, 55% resin, 5% pollen, and 10% other highly potent biochemical ingredients such minerals, ethanol (alcohol), vitamins A, B-complex, E, and bioflavonoids [53]. Propolis contains minerals including copper, iron, and zinc in trace levels, as well as bioflavonoids, arginine, vitamin C, pro-vitamin A, and B-complex, which aid in the production of dentin bridges. Propolis has all of the aforementioned properties that aid in wound healing. It also functions as an effective antibacterial agent by disrupting bacterial cell wall [54]. Similar to Esmeraldo *et al.*and Sabir *et al.*, this study found that an alcoholic extract of propolis induced collagen bridges and dentin formation after 28 days. Propolis has antibacterial, anti-inflammatory, antioxidant, and immunomodulatory qualities that aid in the healing of dental pulp, collagen synthesis, and subsequent regeneration [55].

Neo PUTTY

NeoPUTTY^{R}, introduced by NuSmile in 2020, is a pre-mixed, bioactive bioceramic material derived from MTA. It offers enhanced handling, shorter setting time, and superior dimensional stability. Its calcium-releasing properties promote hydroxyapatite formation, aiding in the healing and regeneration of pulpal tissues [40].
According to Gullen *et al.*, NeoPUTTY^{R} can be used in vital pulp therapies because of its calcium releasing property [41].
An invivo study comparing NeoPUTTY^{R} and Biodentine found both materials equally effective for IPT in primary teeth [43]. Its ready-to-use nature, non-tacky consistency, and resistance to washout make it especially suitable for pediatric patients, including those who are less cooperative.In addition, NeoPUTTY^{R} has longer working time than Biodentine™ and doesn't set until it is inserted into the cavity [42].

2. Indirect pulp capping agents with antimicrobial properties

i) Chlorhexidine Gluconate combined with Resin-modified Glass Ionomer or with Calcium Hydroxide

Chlorhexidine gluconate (CHX) is a broad-spectrum antimicrobial agent synthesized by combining chlorhexidine with gluconic acid. It is both bacteriostatic and bactericidal against a wide range of oral microorganisms including S. mutans, S. aureus,E. faecalis, P. intermedia, C. albican. Additionally, CHX is positively charged which causes cell death by disrupting the osmolarity of bacterial cell wall [35].
In the past, CHX was used as an intracanal medicament, as a dental mouthwash and as an ingredient in dentifrices, gels, varnishes. Recently, it has been incorporated into indirect pulp therapy (IPT) protocols in primary molars—particularly in combination with calcium hydroxide or RMGIC—to enhance antibacterial efficacy [36].

Advantages

- Biocompatible
- Effective disinfection of caries-affected dentin
- Antimicrobial activity
- Ability to bond to enamel and dentin
- High mechanical strength
- Uptake and releases fluoride [1]

Disadvantages

- Chlorhexidine with RMGIC has Cytotoxic effect
- Reduced wear resistance

Furthermore, research was done to evaluate the effect of performing IPT on primary molars using 2% CHX in combination with RMGI. Although previous research utilizing RMGI alone in IPT produced satisfactory results, the purpose of adding 2% CHX was to raise the disinfection level. Since RMGI is the preferred liner for primary teeth, using CHX in conjunction with it can increase success rates while maintaining the benefits of the latter [36].
A study published by the American Academy of Pediatric Dentistry evaluated IPT success in primary molars using 2% CHX combined with RMGIC. The findings suggested that this combination enhances bacterial elimination without compromising the sealing benefits of RMGIC, thereby improving the overall success rate of the treatment [36].

ii) Silver Diamine Fluoride (SDF)

In the 20th century, the use of SDF was pioneered by Nishino and Yamaga. SDF is gaining popularity in a variety of dental applications, and it has has garnered renewed interest as a non-invasive agent for arresting and preventing dental caries. SDF exerts its therapeutic effects by increasing the pH of the biofilm, antibacterial action, and decreasing dentin demineralization. In addition to its simplicity of use and its ability to be used in patients who are uncooperative or with special healthcare needs (SHCN), makes it a very appealing choice for dentists [37].

Advantages

- Easy to apply
- Minimally invasive
- Effective in arresting carious lesions
- Side effects: Patients may experience white lesions in the mucosa and a mild increase in erythema upon contact with the gingiva, however this mild discomfort may be outweighed by the material's ability to arrest the caries.

The black staining of tooth cavities is the most obvious adverse effect of SDF. Along with tooth discoloration and irritation of the soft tissues of the mouth, pulpal irritation is also regarded as a side effect of SDF.

According to a systematic review by Baghlaf *et al*. (2023), SDF performed similar to CH as indirect pulp treatment material in terms of clinical and radiographic success [38].

A study comparing the effectiveness of different IPT materials on primary teeth found that SDF established an adequate biological seal, arrested further caries progression, and showed no adverse pulp reactions after six months of follow-up. The materials were inserted into teeth and restored using RM-GIC. After 6 months, Dycal group had the highest reparative dentin with an average of 0.15 mm, followed by the MTA group with 0.11 and the SDF group with 0.07 [39].

iii) Photo activated disinfection by lasers

Photo-Activated Disinfection (PAD) represents a novel, minimally invasive strategy for managing deep carious lesions. It has been suggested that disinfection is a more successful and conservative option than completely eliminating dental caries.It employs a photosensitizing dye activated by a low-power LED light source, which targets and eliminates specific periodontal and cariogenic pathogens. This targeted action minimizes the need for extensive dentin removal and reduces thermal impact on the pulp—temperature increase remains under 3°C, making it safe for vital tissues. Applying PAD to caries management can improve treatment results by ensuring quick healing, and eliminating bacteria that are still present in soft dentin. Clinical and radiographic success rates of $Ca(OH)_2$ and PAD when treated indirectly were comparable for treating deep carious lesions of young permanet teeth [43].

3. Indirect pulp treatment medicaments with self- sealing properties:

i) Glass Ionomer Cement (GIC):

In an effort to address the drawbacks of silicate cements while maintaining their benefits, GIC was developed. This cement combines the biocompatibility and adhesive qualities of polyacrylic acid with the strength, rigidity, and fluoride-releasing abilities of silicate particles. The end product is a combination of silicate and polycarboxylate cement composed of polyacrylic and itaconic acid liquid, as well as calcium fluoroaluminosilicate glass powder [19].

Significantly important are the cement's fluoride-releasing abilities, which prevents carious processes [20]. It has been noted that fluoride promotes the formation of tertiary dentin in IPT.

GIC offers a higher quality bacterial seal and has been shown to retain better than composite resins [3]. This seal stops microbes, endotoxins, and lipopolysaccharides from further microleakage at the dentin and glass ionomer interface, which prevents the progression of pulpal inflammation. The reason for this is that GIC has less polymerization shrinkage than composite resin since it sets more slowly and contains less resin component [3].

The development of light-cured GIC, by the addition of certain ingredients has significantly improved its setting properties over traditional GIC [21]. A moisture-tolerant reaction product produced by the light-cured version of GIC, enables sufficient working time and quick early strength formation [21]. Additionally, because GIC can adhere directly to composite resin, it can be used as the intermediate dental material in the "sandwich" technique used in IPC, where it is placed between the prepared dentinal surface and the overlying restoration, which is frequently a composite restoration. [21] Moreover, GIC provides a lot of calcium ions to the sclerosed dentinal tissue. This process also reduces overall polymerization shrinkage, releases fluoride, and produces a polished exterior surface. The technique does have some drawbacks, as it requires precision when positioning the two materials and lengthens the process, making it more complicated [3].

Histological investigations of IPTs with GIC have revealed hard, remineralized dentin without caries progression [8]. Therefore, GIC-based IPCs are regarded as definitive dental therapy in cases of primary dentition. Studies comparing GIC and calcium hydroxide revealed that GIC deformed less than calcium hydroxide as a base material [23]. Thus, GIC offers a more supportive base in situations when there is a significant loss of dentinal tissue and low remaining dentin thickness [23].

ii) Self -etching system

Good marginal seal is provided by adhesive restorative materials, which is necessary for the success of IPT.[16] According to few studies, applying adhesive restorative system on the infected dentin has no effect on the clinical performance of the restoration.[16] For the bonding agent to be able to interlock steadily around the exposed collagen network, the "ideal" hybrid layer should be large enough.

Collapse of demineralized dentin is prevented by using Self-etching primers. By acting through the smear layer, the acidic monomers incorporate the adjacent dentin into the union process [17]. Theoretically, this stops the excessive loss of dentin matrix and solubilized apatite crystals surrounding the collagen network by allowing the adhesive monomer to effectively penetrate the substrate. The effectiveness of these materials may provide a better interaction with the carious dentin in the indirect pulp treatment when the demineralized zone produced by the self-etching primers is thinner than the conventional system that use phosphoric acid. Over time, an area of collagen fibers without support becomes susceptible to hydrophilic degradation and a corresponding decrease in adhesive strength due to an increase in the thickness of the demineralized zone and subsequent insufficient impregnation of the bonding system in the collagen network [18]. After long term use, primary molars restored with a self-etching primer showed higher bond strength values than those restored with a traditional bonding technique [17]. The results are due to the interaction between the bonding system and the dentin. Since the carious processes have already changed the dentin during indirect pulp treatment, using a self-etching primer would prevent it from becoming over-etched [17].

iii) Resin-Modified Glass Ionomer Cement (RM-GIC)

Resin-Modified Glass Ionomer Cement (RM-GIC) represents a significant advancement in restorative materials used in pediatric dentistry [24]. A commercially available resin-modified GIC called Vitrebond (3M Corporation, St. Paul, MN) is used as a pulp capping liner. RM-GIC is widely recognized for its ability to reduce postoperative sensitivity, release fluoride ions, and have antibacterial qualities [25].

When RM-GIC is inserted into a cavity preparation, their pH ranges from about 4.0 to 5.5 over the first 24 hours. In turn, the glass ionomer releases ions and perhaps the previously trapped bioactive substances by demineralizing the surrounding dentin. The pulpal response to glass ionomer is favourable when there is still a layer of dentin between the pulp and the material. RMGIC offers extended working hours, less moisture intolerance, and the ability to polish in the same sitting [26].

Table 1: Indirect pulp treatment medicaments with remineralizing potential for primary teeth and their success rate

S. No.	Name of medicament	Main advantages	Main disadvantages	Success rate
1.	Calcium hydroxide (2014)	Antimicrobial activity Calcified barrier formation Fibroblast stimulation[45]	May dissolve after one year Poor sealing properties[45]	94%
2.	Calcium phosphate	Helps in bridge formation with no superficial tissue necrosis Good physical properties [3]	Clinical trials are necessary to evaluate this material	No studies
3.	Mineral trioxide aggregate (2016)	Biocompatible Improved sealing properties Induced osteogenesis Promotes healing[47]	Discoloration Prolonged setting time High cost [47]	100%
4.	Biodentine (2017)	Biocompatible Increased marginal adaptation Can induce formation of reparative dentin[11]	Expensive[11]	98.3%
5.	Theracal LC (2019)	Enhanced physical properties High calcium release Induced formation of dentin bridge[32]	Opaque whitish color[32]	87.8%
6.	ACTIVA- Bioactive liner (2022)	Fluoride uptake and re-release it Decreased incidence of secondary caries Ability to induce hard tissue formation Biocompatibility.[44]	Self-adhesive ability of the material is not elucidated[44]	94%
7.	Propolis (2016)	Comparable tertiary dentin formation Good sealing ability[53]	None reported	80%
8.	Neoputty (2024)	Superior handling properties to trigger the healing process Property of calcium release[42]	None reported	100%

Table 2: Indirect pulp treatment medicaments with antimicrobial properties for primary teeth and their success rate

S. No.	Name of medicament	Main advantages	Main disadvantages	Success rate
1.	Chlorhexidine gluconate with RMGIC or with calcium hydroxide(2013 and 2016)	Disinfection of affected dentin[36]	None reported	CHX with calcium hydroxide:97% CHX with RMGI: 97%
2.	Silver diamine fluoride (2022)	Minimally invasive nature Ability to arrest the progression of caries.	Irritation of oral soft tissue Dental staining	96%
3.	3 Mix MP (2014)	Wide bactericidal spectrum against anaerobes. Non invasive[46]	Antibiotic resistance Tooth staining from Minocycline Internal resorption [46]	78%
4.	Lasers (2020)	Disinfection in soft dentin Reassures rapid healing[43]	None reported	100%

Table 3: Indirect pulp treatment medicaments with self-sealing properties for primary teeth and their success rate

S. No.	IPC agent with self-sealing properties	Main advantages	Main disadvantages	Success rate
1.	Glass ionomer cement (2016)	Excellent bacterial seal Fluoride release Biocompatible	Causes chronic inflammation Lack of dentin bridge formation Poor physical properties	97%
2.	Self-etching system (2002)	Excellent adhesion to hard tissues Effective seal against microleakage.[3]	Cytotoxic effect Absence of calcific bridge formation	93%
3.	Resin modified glass ionomer cement	Biocompatible Fluoride ion release	Initial pH is 4.0-5.5	96%

	(2011)	Antimicrobial effect[48]		

Conclusions

This review highlights several crucial points concerning deep caries management and material selection in primary teeth:

- The American Academy of Pediatric Dentistry (AAPD) endorses indirect pulp treatment (IPT) as the preferred method for deep caries in primary teeth, noting its higher success rate compared to pulpotomy.
- Current studies do not definitively identify the superior material for indirect pulp capping in primary teeth, indicating a need for more comparative research.
- Mineral Trioxide Aggregate (MTA) consistently facilitates the formation of a more robust and higher-quality dentinal bridge than calcium hydroxide.
- Similarly, Biodentine accelerates the formation of reparative dentin when compared to calcium hydroxide.
- TheraCal-LC is characterized by its low solubility, excellent physical properties, and enhanced stability and durability, making it a promising option.
- For non-invasive interventions, Silver Diamine Fluoride (SDF) is highly effective in halting the progression of dental caries, offering significant clinical advantages in pediatric dentistry.
- Additionally, Chlorhexidine is a new material when combined with other materials like calcium hydroxide and RMGI, can yield promising results in IPT.

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References

1. American Academy of Pediatric Dentistry. Guideline on pulp therapy for primary and immature permanent teeth. Pediatric Dentistry. 2019;40(6):343-351.
2. Seale N. Indirect pulp therapy: an alternative to pulpotomy in primary teeth. Texas Dental Journal. 2010;127(11):1175-1183.
3. Qureshi A, E S, Nandakumar, Pratapkumar, Sambashivarao. Recent advances in pulp capping materials: an overview. Journal of Clinical and Diagnostic Research. 2014;8(1):316-321.
4. Pathak S, Bansode P, Wavdhane M, *et al*. Advances in pulp capping materials: a review. IOSR Journal of Dental and Medical Sciences. 2017;16(2):31-37.
5. Milosevic A. Calcium hydroxide in restorative dentistry. Journal of Dentistry. 1991;19(1):3-13.
6. George V, Janardhanan S, Varma B, *et al*. Clinical and radiographic evaluation of indirect pulp treatment with MTA and calcium hydroxide in primary teeth (*in vivo* study). Journal of the Indian Society of Pedodontics and Preventive Dentistry. 2015;33(2):104-110.
7. Marwah N. Textbook of Pedodontics. 6th ed. New Delhi: Jaypee Brothers Medical Publishers; year unknown.
8. Bjørndal L, Larsen T, Thylstrup A. A clinical and microbiological study of deep carious lesions during stepwise excavation using long treatment intervals. Caries Research. 1997;31(6):411-417.
9. Bjørndal L, Reit C, Bruun G, Markvart M, Kjældgaard M, Näsman P, *et al*. Treatment of deep caries lesions in adults: randomized clinical trials comparing stepwise vs direct complete excavation, and direct pulp capping vs partial pulpotomy. European Journal of Oral Sciences. 2010;118(3):290-297.
10. Schwendicke F, Dörfer CE, Paris S. Incomplete caries removal: a systematic review and meta-analysis. Journal of Dental Research. 2013;92(4):306-314.
11. 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. Pediatric Dentistry. 2017;39(5):377-382.
12. Baranwal R, Singh BD, Dubey A, *et al*. Calcium hydroxide in dentistry. Chettinad Health City Medical Journal. 2016;5(1):30-33.
13. Al-Sanabani JS, Madfa AA, Al-Sanabani FA. Application of calcium phosphate materials in dentistry. International Journal of Biomaterials. 2013;2013:876132.
14. Yoshimine Y, Maeda K. Histologic evaluation of tetracalcium phosphate-based cement as a direct pulp-capping agent. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1995;79(3):351-358.
15. Shen Q, Sun J, Wu J, Liu C, Chen F. An *in vitro* investigation of the mechanical, chemical, and biological properties of calcium phosphate/calcium silicate/bismutite cement for dental pulp capping. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2010;94(1):141-148.
16. Falster CA, Araujo FB, Straffon LH, Nör JE. Indirect pulp treatment: *in vivo* outcomes of an adhesive resin system vs calcium hydroxide for protection of the dentin-pulp complex. Pediatric Dentistry. 2002;24(3):241-248.
17. Casagrande L, de Hipólito V, de Góes MF, Barata JS, Garcia-Godoy F, de Araújo FB. Bond strength and failure patterns of adhesive restorations in primary teeth aged in the oral environment. American Journal of Dentistry. 2006;19(5):279-282.
18. Nör JE, Feigal RJ, Dennison JB, Edwards CA. Dentin bonding: SEM comparison of the resin-dentin interface in primary and permanent teeth. Journal of Dental Research. 1996;75(6):1396-1403.
19. Kovarik RE, Haubenreich JE, Gore D. Glass ionomer cements: a review of composition, chemistry, and biocompatibility as a dental and medical implant material. Journal of Long-Term Effects of Medical Implants. 2005;15(6):655-672.
20. Billington R, Pearson G, Williams J. Uptake of fluoride ions by the glass component of glass ionomer cement. Journal of Dentistry. 2007;35(5):452-455.
21. Nicholson JW, Czarnecka B. The biocompatibility of resin-modified glass-ionomer cements for dentistry. Dental Materials. 2008;24(12):1702-1708.
22. Croll TP. The sandwich technique. Journal of Esthetic and Restorative Dentistry. 2004;16(4):210-212.
23. Tam L, Pulver E, McComb D, Smith D. Physical properties of calcium hydroxide and glass-ionomer base and lining materials. Dental Materials. 1989;5(3):145-149.
24. Croll TP, Nicholson JW. Glass ionomer cements in pediatric dentistry: review of the literature. Pediatric Dentistry. 2002;24(5):423-429.
25. Tam LE, Chan GP, Yim D. *In vitro* caries inhibition effects by conventional and resin-modified glass ionomer restorations. Operative Dentistry. 1997;22(1):4-14.
26. Fuks AB, Kupietzky A, Guelmann M. Pulp therapy for the primary dentition. Pediatric Dentistry. 2019;41(5):42-44.
27. Srinivasan V, Waterhouse P, Whitworth J. Mineral trioxide aggregate in paediatric dentistry. International Journal of Paediatric Dentistry. 2009;19(1):34-47.

28. Macwan C, Deshpande A. Mineral trioxide aggregate (MTA) in dentistry: a review of literature. Journal of Oral Research and Review. 2014;6(2):71-74.
29. Al-Hezaimi K, Al-Shalan TA, Naghshbandi J, *et al*. Antibacterial effect of two mineral trioxide aggregate (MTA) preparations against Enterococcus faecalis and Streptococcus sanguis *in vitro*. Journal of Endodontics. 2006;32(11):1053-1056.
30. Kaur M, Singh H, Dhillon J, *et al*. MTA versus Biodentine: review of literature with a comparative analysis. Journal of Clinical and Diagnostic Research. 2017;11(8):ZG01-ZG05.
31. Kim J, Song Y, Min K, *et al*. Evaluation of reparative dentin formation of ProRoot MTA, Biodentine and BioAggregate using micro-CT and immunohistochemistry. Restorative Dentistry and Endodontics. 2016;41(1):29-36.
32. Singhal M, Chaudhary C, Anand R, Singh N, Sahni T. Recent advancements of indirect pulp capping in primary teeth: a review. Journal of Advanced Medical and Dental Sciences Research. 2015;3(5):S78-S82.
33. Nielsen M, Casey J, VanderWeele R, *et al*. Mechanical properties of new dental pulp-capping materials. General Dentistry. 2016;64(1):44-48.
34. Gurcan AT, Seymen F. Clinical and radiographic evaluation of indirect pulp capping with three different materials: a 2-year follow-up study. European Journal of Paediatric Dentistry. 2019;20(2):105-110.
35. Markowska K, Anna M, Wolska G. Silver nanoparticles as an alternative strategy against bacterial biofilms: a review. Acta Biochimica Polonica. 2013;60(4):523-530.
36. Rosenberg L, *et al*. Prospective study of indirect pulp treatment in primary molars using resin-modified glass ionomer and 2% chlorhexidine gluconate: a 12-month follow-up. Pediatric Dentistry. 2013;35(1):13-17.
37. Contreras V, Toro MJ, Elías-Boneta AR, Encarnación-Burgos A. Effectiveness of silver diamine fluoride in caries prevention and arrest: a systematic literature review. General Dentistry. 2017;65:22-29.
38. Baghlaf K, Sindi AE, Almughalliq FA, Alarifi NK, Alquthami R, Alzahrani RA, *et al*. Effectiveness of silver diamine fluoride in indirect pulp capping in primary molars: a systematic review and meta-analysis. Heliyon. 2023;9:e19462.
39. Divyashree R. Effectiveness of silver diamine fluoride when used as an indirect pulp therapy (IPT) material - a clinical and radiological assessment. International Journal of Applied Dental Sciences. 2021;7:466-478.
40. Hondares TC. An evaluation of the *in vitro* antibacterial, biocompatibility, and mineralization properties of six calcium silicate-based pulp capping materials [dissertation]. Birmingham: The University of Alabama at Birmingham; 2022.
41. Lozano-Guillen A, Lopez-Garcia S, Rodriguez-Lozano FJ, *et al*. Comparative cytocompatibility of the new calcium silicate-based cement NeoPUTTY versus NeoMTA Plus and MTA on human dental pulp cells: an *in vitro* study. Clinical Oral Investigations. 2022;26(12):7219-7228.
42. Kothari P, Mathur A, Tirupathi S, Chauhan R, Nankar M, Suvarna A. Comparative clinical and radiographic success rate of bioceramic premix vs biosilicate-based medicament as indirect pulp treatment materials in primary molars: a double-blind randomized trial with a follow-up of 12 months. International Journal of Clinical Pediatric Dentistry. 2024;17(7):748-753.
43. Elchaghaby MA, Moheb DM, El Shahawy OI, Abd Alsamad AM, Rashed MA. Clinical and radiographic evaluation of indirect pulp treatment of young permanent molars using photo-activated oral disinfection versus calcium hydroxide: a randomized controlled pilot trial. BDJ Open. 2020;6(1):4.
44. May E, Donly KJ. Fluoride release and re-release from a bioactive restorative material. American Journal of Dentistry. 2017;30:305-308.
45. Baranwal R, Singh BD, Dubey A, *et al*. Calcium hydroxide in dentistry. Chettinad Health City Medical Journal. 2016;5(1):30-33.
46. Trairatvorakul C, Sastararuji T. Indirect pulp treatment vs antibiotic sterilization of deep caries in mandibular primary molars. International Journal of Paediatric Dentistry. 2014;24(1):23-31.
47. Mathur VP, Dhillon JK, Logani A, Kalra G. Evaluation of indirect pulp capping using three different materials: a randomized control trial using cone beam computed tomography. Indian Journal of Dental Research. 2016;27:623-629.
48. Kotsanos N, Arizos S. Evaluation of a resin-modified glass ionomer serving both as indirect pulp therapy and as restorative material for primary molars. European Archives of Paediatric Dentistry. 2011;12:170-175.
49. Venkatesh Babu N, Kavyashree B, Amitha H. Comparative assessment of success rate of indirect pulp treatment with 2% chlorhexidine gluconate disinfecting solution, calcium hydroxide and resin-modified glass ionomer liner in primary teeth - a prospective study. IOSR Journal of Dental and Medical Sciences. 2016;15(2):45-53.
50. Shafi N, Kaur H, Choudhary R, Yeluri R. Dilute silver diamine fluoride (1:10) versus light-cure calcium hydroxide as indirect pulp capping agents in primary molars - a randomized clinical trial. Journal of Clinical Pediatric Dentistry. 2022;46:273-279.
51. İnci MA, Korkut E. Is bioactive glass an effective agent in pulp-capping treatments? A randomized controlled clinical trial with one-year follow-up. Journal of Contemporary Dental Practice. 2022;23(11):1128-1135.
52. Toreti VC, Sato HH, Pastore GM, *et al*. Recent progress of propolis for its biological and chemical compositions and its botanical origin. Evidence-Based Complementary and Alternative Medicine. 2013;2013:697390.
53. Handa A, Hedge N, Mahendra S, *et al*. Propolis and its potential in dentistry: a review. International Journal of Health Sciences Research. 2012;1(2):143-147.
54. Deswal H, Singh Y, Grover HS, *et al*. Healing effects of propolis in medicine and dentistry: a review. Innovative Journal of Ayurvedic Science. 2016;4(1):1-4.
55. Sabir A, Mooduto L, Kaelan C, *et al*. Impact of the use of ethanolic extract of propolis, flavonoid and non-flavonoid propolis for direct pulp capping in collagen type I density. Brazilian Journal of Oral Sciences. 2016;15(4):264-268.

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