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Review

What Natural Materials Are Used to Treat Primary Tooth Pulp? A Literature Review

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Abstract

Among the various medicaments used for pulp treatment, natural materials have gained attention due to their potent antibacterial activity and fewer complications compared to standard chemical agents. This study aims to analyze the existing literature on the effectiveness of herbal medicines in comparison to conventional pulp therapy agents in primary teeth. A comprehensive search was conducted across three databases—PubMed, Web of Science, and Scopus— and google scholar to identify relevant studies. Only articles that met the predefined inclusion criteria were selected for review. A total of 33 clinical trials were included in this review, evaluating the clinical and radiographic outcomes of herbal pulp therapy agents in primary teeth. Among the natural substances investigated, propolis and aloe vera appear to be suitable candidates for pulp capping. Additionally, garlic extract and green tea show promise as effective cleaning agents within the root canal.

Keywords: Herbal medicine; Irrigation; Medicament; Primary teeth; Pulp therapy

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Introduction

Dental caries in early childhood is a serious public health concern [1,2]. Primary teeth are equally important for functions such as mastication, maintaining dental arch stability, speech development, and aesthetics [3]. Therefore, early intervention is critical to prevent early loss of primary teeth [4]. Pulp treatment for primary teeth includes two main approaches based on the caries depth and the condition of the pulp: vital pulp therapy (VPT) or non-vital pulp therapy (NPT) [5, 6]. When the pulp remains recoverable, VPT is indicated, offering three techniques: indirect pulp capping (IPC), direct pulp capping (DPC), and partial or cervical pulpotomy [7,8]. The primary goal of VPT is to restore normal tissue structure at the dentin-pulp interface [6]. IPC is a successful technique in primary teeth, with success rates reported between 93% and 96% [9]. However, DPC is not recommended for primary teeth due to its high failure rate [9]. When the carious lesion has progressed to pulp necrosis, NPT procedures like pulpectomy are performed, which involve the removal of pulpal tissue [5].

Several materials have been introduced for VPT. Mineral trioxide aggregate (MTA) is a successful pulp capping agent, but its high cost may limit its use in many clinical settings [10]. Additionally, the use of calcium hydroxide ($Ca(OH)_2$) in DPC for primary teeth remains controversial due to its low success rate based on histopathologic data [11]. Formocresol (FC), long considered the gold standard for pulpotomy, is now under scrutiny due to concerns about its potential for immune sensitization and carcinogenesis [12]. Other pulpotomy agents, such as $Ca(OH)_2$ and ferric sulfate (FS), also have notable drawbacks, including internal resorption and calcific metamorphosis. Pulpectomy materials can be applied in three key ways: as irrigants, medicaments, or obturating materials. Sodium hypochlorite (NaOCl) is a widely used root canal irrigant due to its ability to dissolve tissue and its strong antibacterial effect. However, it has several drawbacks, including cytotoxicity, particularly when it contacts the periapical area. Additionally, accidental exposure to NaOCl can cause injuries to the eyes, skin, and mucous membranes, and it may trigger allergic reactions. NaOCl also poses risks to permanent tooth follicles, surrounding tissues, and the oral mucosa [13,14]. Zinc oxide eugenol (ZOE) remains the most commonly used obturating substance. However, ZOE has drawbacks, including delayed resorption when extruded beyond the apex and concerns over its toxicity [15]. To address these issues, researchers have explored alternative obturating materials, such as herbal derivatives, which have shown promising results as substitutes for conventional ZOE [15].

Materials used in primary pulp treatments often contain chemicals that can pose potential risks. The main drawbacks of various antimicrobials and pulp therapeutic agents used in dentistry have long been immune suppression, allergic reactions, hypersensitivity, and microbial resistance to these medications. Moreover, some agents have mutagenic and cytotoxic properties [16]. Moreover, while conventional medications are generally effective in treating bacterial infections, there is a growing issue of antibiotic resistance [17]. In endodontics, cytotoxic effects of many commercial intracanal medicaments and their limited ability to eliminate bacteria from dentinal tubules led to an increased focus on biological materials for pulp treatments that are cost-effective and may offer better long-term prognosis [10,18]. Several herbal agents, such as propolis*, Nigella sativa* L., *Curcuma longa* L., turmeric powder, *Thymus vulgaris* L., honey, *Allium sativum* L. oil, *Aloe vera*, and acemannan, have shown promising potential as alternatives to traditional agents [3,19,20]. They have several properties, including anti-inflammatory, antimicrobial, antiseptics, antioxidants, antibacterials, antivirals, antifungals, and analgesics [1,19,21]. Therefore, this narrative review aims to introduce the potential herbal agents in pulp therapy for primary teeth.

Materials and Methods

The keywords "Root Canal Medicament," "Herbal Medicine," "Primary Teeth," and "Pulp Capping" and "Pulpectomy Agents" were searched in English-language articles up to January 2023 across google scholar search engine, and PubMed, Web of Science, and Scopus databases. The PRISMA flowchart shows the stages of selecting studies and the reason for exclusion from the study (Figure 2). The inclusion criteria of this study included all clinical and laboratory studies in which at least one herbal substance was investigated for pulp therapy of primary teeth or its laboratory effect on living pulp cells. The relevant articles were then reviewed and categorized into different pulp therapy techniques: IPC, DPC, partial pulpotomy, cervical pulpotomy, and pulpectomy. In vitro studies, therapies involving permanent teeth, and non-English language studies were excluded.

Results

The studies included in this narrative review evaluated various herbal medicinal products, such as *Allium sativum, Elaeagnus angustifolia* L.*,* Ankaferd blood stopper, and propolis, as pulp therapy agents, comparing them to standard treatments. These studies assessed clinical and radiographic parameters such as tenderness to percussion, postoperative pain, presence of sinus tracts and mobility, periodontal ligament widening, external or internal root resorption, furcal or periapical radiolucencies, and pulp canal obliteration in relation to different herbal agents and standard pulp dressing medicaments. Table 1 represents the characteristics and outcomes of natural agents used in pulp therapy.

Propolis

Propolis is a resinous compound sourced from plants and collected by honeybees. It has been shown to promote wound healing and can be effectively used in

Table 1. Summary of studies performed for herbal extract used for pulp therapy of primary teeth

Treatment		Author	Year	Study design	Herbal agent vs. other agents	Substance characteristics	Follow up	Outcome		Further information
								Clinical success rate	Radiographic success rate	
Direct pulp capping	1	Gala-García [21]	2008	Animal study	1. Aloe vera 2. CH	Anti-inflammatory, antimicrobial, and cellular regeneration	30 days	Histological analysis	Aloe vera in direct contact with the exposed pulp has acceptable biocompatibility and can lead to tertiary bridge formation.	
	2	Jittapiromsak [22]	2010	Animal study	1. Acemannan (1,2,4,8 mg/ml) 2. CH	Wound-healing inducer	28 days	Histological analysis	Acemannan promotes dentin formation by stimulating primary human dental pulp cell proliferation differentiation, extracellular matrix formation, and mineralization.	
	3	Songsiripradubboon [23]	2016	RCT	1. Acemannan (0.4 mg acemannan sponge) 2. CH		6 months	A:100% C:100%	A:72.73% C:70.0 %	The histopathological results indicated that the acemannan-treated group had significantly better histopathological responses
	4	Sabir [24]	2017	RCT	1. Propolis flavonoids 2. Zinc oxide-based filler 3. Non-flavonoids		1 week 2 week 4 week	Histological examination	Propolis flavonoids in rats may delay dental pulp inflammation and stimulate reparative dentin.	
	5	Esmeraldo [25]	2013	RCT	1. Propolis 2. Iodoform paste, 3. Propolis+iodoform 4. CH		1 day 3 days 7 days	Histological examination	Calcium hydroxide paste induced the lowest intensity of inflammatory response in the root canal pulp tissue	
	6	Mohanty [26]	2020	RCT	Propolis (1.5g of standardized propolis extract powder in mixture with 70 % ethanol solution)	Wound healing, anti-inflammatory, antibacterial, tissue regeneration capabilities	3 months			
	7	Ahangari [27]	2020	RCT	Propolis	Formation dentinal bridge	45 days			
Partial pulpotomy	8	Purohit [28]	2017	In vivo	Turmeric Powder	Anti-inflammatory Bicompatiblity Therapeutic properties	3 weeks 2 weeks 4 weeks 6 weeks	100 100 100 93.34	100 100 100 100	At the end of month six, only one patient (93.34%) reported pain. None of the patients reported tenderness, mobility, and sinus/fistula after 6 months (100%)
Cervical pulpotomy	9	Abirami [29]	2020	RCT	1. Allium sativum Oil 2. Aloe barbadensis Gel 3. FC	Antibacterial activity, wound-healing	6-12 months			No statistical significance difference

	10	Cantekin [30]	2014	Clinical Study	1. ABS 2. FS	Hemostatic	3 months 6 months 9 months 12 months	ABS:100% FS: 100% ABS:100% FS: 100% ABS:90.9% FS:93.9% ABS:84.8% FS:90.9%	ABS: 100% FS: 100% ABS: 100% FS: 100% ABS: 90.9% FS: 93.9% ABS:84.8% FS:87.8%	No significant difference ($p > 0.05$) was noted at each of the four follow-up periods.
	11	Alolofi [31]	2016	RCT	1. Propolis ethanolic extract 2. Thymus vulgaris ethanolic 3. FC	Antimicrobial Antimicrobial, anti-inflammatory	1 month 6 months 12 months	P: 94.7% T: 94.4% F: 100% P: 88.2% T: 94.1% F: 94.4% P: 88.2% T: 94.1% F: 88.2%	P: f 94.7% T: 94.4% F: 95.0% P: 81.2% T: 87.5% F: 81.2% P: 73.3% T: 87.5% F: 73.3%	No statistical significance difference detected
	12	Kahvand [32]	2019	RCT	1. Allium sativum oil 2. FC	Antimicrobial and antioxidant	3 months 6 months	A:100% F:100% A:100% F:100%	A:82.2% F:80% A:88.9% F:84.4%	Not statistically significant ($p = 0.46$)
	13	Shukry [33]	2014	RCT	1.Allium sativum oil 2. FC	Antimicrobial	6 months			No significant difference
	14	Gonna[34]	2019	RCT	1. Acemannan(0.4% solutions) 2. FC	Anti-inflammatory, antibacterial, antifungal, antiviral, moisturizing and pain-relieving properties	12 months	A: 96.5% F: 89.6%	A: 93.1% F: 86.2%	No significant difference
	15	Omar OM [35]	2012	Animal study	1. Nigella sativa oil (100% pure) 2. FC (cotton pad with 20% buckley's formocresol (1:5 dilution))	Anti-inflammatory, antibacterial	4 weeks	Histological, histochemical and immuno-histochemical staining	NS group showed mild to moderate on inflammation. While the FC group showed moderate to severe inflammation	
	16	Yaman[36]	2012	RCT	1. ABS 2. FC (cotton pad with 20% buckley's formocresol (1:5 dilution))	Hemostatic	3 months 6 months 12 months	A:100% F:100% A:96.7% F:100% A:100% F:100%	A:100% F:100% A:96.7% F:96.7% A:89.3% F:92.9%	No significant difference
	17	Kalra [37]	2017	RCT	1. Aloe barbadensis 2. MTA	Anti-inflammatory, antibacterial, antifungal, antiviral	1 month 3 months	A:25% M:96.4% A: 57.1% M:	A: 25% M:96.4% A: 0% M:	Significant difference

						6 months	A: 75% M:100%	A:0% M:100%	
						9 months	A: 66.6 M:100%	A:0% M:100%	
						12 months	A: 100 M:100%	A: 0% M:100%	
18	Ozorio [38]	2012	Animal study	1. Propolis 2. CH combination of pastes Control		7 days 21 days 42 days	Histological examination	According to these findings, calcium hydroxide and standardized propolis extract favored the formation	
19	Kusum [39]	2015	RCT	1. Propolis (1.5 g propolis 100% in mixture with 1.75 mL of polyethylene glycol thickness of 2-3 mm) 2. MTA (2-3 mm) 3. Biodentine (2-3 mm)	Pulpal healing and repair No cytotoxic effects on pulp cells or PDL	3 months	P:100% M:100% B:100%	P:96% M:100% B:96%	Teeth treated with MTA and Biodentine showed more favorable clinical and radiographic success
						6 months	P:100% M:100% B:100%	P:72% M:92% B:88%	
						9 months	P:84% M:100% B:100%	P:72% M:92% B:80%	
20	Hugar [40]	2017	RCT	1. Propolis 2. Turmeric extract gel 3. CH 4. FC	Propolis: antiseptic, antibacterial, antimycotic, astringent, spasmolytic, anti-inflammatory, anesthetic, antioxidant, antitumoural, antifungal, anti-ulcer, anticancer, and immunomodulatory effects. Turmeric: Antioxidant, anti-inflammatory, and antimicrobial properties	1 month	P:100% T:100% C:100% F:100%	P:100% T:100% C:100% F:100%	A comparable clinical and radiographic success rate was seen with all experimental groups as compared to the control (formocresol) group
						3 months	P:100% T:100% C:100% F:100%	P:100% T:100% C:100% F:100%	
						6 months	P:100% T:100% C: 80% F:100%	P: 93.3% T: 86.7% C: 73.3% F:100%	
21	Ozmen [41]	2017	RCT	1. ABS 2. FC 3.FS	Hemostatic	Ranging from 6 to 24 months		A: 87% FC: 87% FS:100%	A: 87% FC: 80% FS: 87%	No significant differences
22	Kumari [42]	2017	RCT	1. Honey (1 drop) 2. FC	Antibacterial activity Wound-healing Antimicrobial Anti-inflammatory Pain management Scarring minimalizing Tissue growth stimulation from wound margins Debrided and deodorized wound autolysation	1 month 3 months 6 months 9 months 12 months	Honey:100 FC:100 Honey:100 FC:100 Honey:100 FC:100 Honey:100 FC:100 Honey:100 FC:100	Honey:100 FC:100 Honey:100 FC:100 Honey:100 FC:100 Honey: 95.6% FC: 95.4% Honey: 91.3% FC: 90.9%	Not significant p<0.05	

						Nutrient for regenerating tissues	18 months	Honey:100 FC:100	Honey: 91.3% FC: 86.3%
							24 months	Honey:100 FC:100	Honey: 86.9% FC: 77.2%
	23	Subramanyam [43]	2020	Double blind RCT	1. Aloe vera 2. FC (Buckley's 1:5 diluted FC)	Wound healing, Anti-inflammatory Antiviral Antimicrobial Antifungal Antioxidant Analgesic Immune modulator Pulpal regenerative	3 months	Aloe vera:96.9 Fc:100	Aloe vera: 96.9 Fc:100
							6 months	Aloe vera:96.6 Fc:96.6	Aloe vera:96.6 Fc:96.6
	24	El sayed [44]	2019	RCT	1. ABS 2. FC	Hemostatic	1 month	ABS:100 FC:100	
							3 months	ABS:100 FC:100	ABS:100 FC:100
							6 months	ABS:93.3 FC:96.7	ABS:93.3 FC:96.7
							9 months	ABS:86.7 FC:90	ABS:83.3 FC:86.7
	25	Odabaş [45]	2011	RCT	1. ABS 2. CH	Hemostatic	12 months	C: 90% A: 95%	C: 90% A: 95%
	26	Gupta [46]	2010	In vivo	1.Aloe vera		1 month	clinical	None of the patients reported any clinical outcome and after 2 months histological examination showed positive signs of healing
							2 months	histological	
	27	Koyuturk [47]	2013	Animal study	1. ABS 2. FS 3. FC (1:5 dilution of Buckley's FC)	Hemostatic	7 days 15 days 30 days	Histological examination	No significant differences in hard-tissue formation
	28	Lima [25]	2011	Animal study	1. CLOR 2. Propolis extract (with 12% of active substance) 3. Fibrin sponge 4. Iodoform-based paste		1 day 3 days 7 days 15 days 30 days	Histological examination	CLOR group showed less inflammatory response
	29	Masule (123)	2016	RCT	1. CLOR 2. FC 3. MTA		12 months	CLOR:100% FC:100% MTA:100%	CLOR:76% FC:90.91% MTA:88.23%
	30	Poureslami [48]	2015	RCT	Elaeagnus angustifolia (15 mg powder in mixture with normal saline-thickness of 1 mm) FC (1.5% formocresol	Anti-inflammatory Antioxidant Coagulative Analgesic Antipyretic	10 days		Pain measurement using visual analogue scale. Both groups showed significant reduction in pain but FC group showed more reduction.
Pulpectomy	31	Elheeny [8]	2019	RCT	1. Allium sativum (concentration of 25%)	Irrigant Antibacterial	3 months	A:80% N:87.3%	A:72.7% N:85.5% No statistically significant difference.

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				2.NaOCL		6 months 12 months	A:76.2% N:87.3% A:76.2% N:89.1%	A:74.5% N:87.3% A:76.4% N:87.3%	Garlic extract has better antibacterial properties when compared with calcium hydroxide
32	Khairwa [49]	2014	RCT	ZOE with Aloe vera	Obturation Anti-inflammatory Antimicrobial	7 days 1 months 3 months 6 months 9 months	100% 100% 100% 100% 95%	100% 100% 100% 100% 73.34%	It can be observed that endodontic treatment using a mixture of zinc oxide powder and aloe vera gel in primary teeth has shown good clinical and radiographic success
33	Jolly [50]	2013	RCT	1. Propolis (dimethyl sulfoxide extract of propolis (4%)) 2. Chlorhexidine (2%) 3. Calcium hydroxide (4%)	Irrigant Antimicrobial	6 months			Chlorhexidine > Propolis > Calcium hydroxide

Abbreviation: Formocresol = FC; Calcium hydroxide = CH; Ankaferd blood stopper = ABS; Ferric sulfate = FS; Mineral trioxide aggregate = MTA; Copaifera langsdorffii oil resin = CLOR; Sodium hypochlorite = NaOCL; Zinc oxide eugenol =ZOE

DPC [27,52,53]. The therapeutic effects of propolis, including its antibacterial, anti-inflammatory, and immunomodulating properties, are mainly attributed to its combination of flavonoids, aromatic acids, and esters [54].

Pulp capping

Mohanti and Ramesh [27] compared the dentin bridge formation between Biodentine, propolis, and MTA when used as DPC agent. After three months, the teeth were extracted and sent for histological evaluation. Propolis showed substantial changes in the morphology, continuity, and thickness of the dentin bridge compared with the other two groups. While all groups successfully created dentin bridges, MTA and Biodentine demonstrated better quality and quantity of dentin bridge formation than propolis. In another study, Ahangari et al. [28] compared the effects of propolis and $Ca(OH)_2$ as DPS agent. After sealing the cavities with glass ionomer, the teeth were histologically analyzed after extraction. The study found significant differences between the two groups in the quality and quantity of dentin bridges. Ca $(OH)_2$ induced osteopontin production; while propolis led to the formation of a continuous dentin bridge with irregular tubular dentin, showing superior tubular dentin formation compared to $Ca(OH)_2$. Parolia et al. [52] also studied the human pulp tissue response to propolis in comparison with MTA and $Ca(OH)_2$. Final restorations were completed using posterior composite resin and glass ionomer cement liner. On days 15 and 45, the teeth were extracted and histologically assessed. There were no significant differences in pulp inflammation and dentin bridge formation among the groups. However, Ca $(OH)_2$ led to more pulp inflammation than propolis and MTA. Dentin bridge formation was more frequent in the propolis and MTA groups.

Cervical pulpotomy

Propolis can interfere with the adhesion of *Streptococcus mutans* to teeth and exhibits antibacterial effects against *Enterococcus faecalis* [55]. Therefore, it can be used as a cariostatic agent, irrigation solution, intracanal medicament, and pulp-capping material [56,57]. It also aids in wound healing by promoting collagen synthesis, making it suitable for use as a mouth rinse, endodontic disinfectant, and wound healing agent [57,58,59]. Alolof et al. [60] evaluated the clinical and radiographic outcomes in teeth treated with propolis, *Thymus vulgaris*, and FC. After 1 month the formocresol (FC) group demonstrated a slightly higher success rate in both clinical and radiographic evaluations. However, after 6 and 12 months, the success rate was comparable among the groups. Kusum et al. [40] assessed the efficacy of propolis as a pulpotomy agent in comparison to MTA and Biodentine. All pulpotomized teeth were evaluated clinically and radiographically. After 6 months, MTA and Biodentine groups showed more favorable clinical and radiographic outcomes than propolis.

Hugar et al. [41] investigated the clinical and radiographic success rates of FC compared with propolis,

turmeric gel, and $Ca(OH)_2$ in primary molars. After 6 months, $Ca(OH)_2$ led to the lowest clinical and radiographic success; while no significant differences were found between the other groups. In an animal study, Ozorio et al. [39] found that 42 days after vital pulpotomy treatment in pigs, a combination of $Ca(OH)_2$ and propolis as pulpotomy medication compared to using them separately favored the formation of the pulp tissue. Also, it showed less inflammation response according to histological examination. These findings suggest that propolis might be promising pulpotomy agent; however, further research is needed.

Pulpectomy (Medicament)

In a clinical study by Victorino et al. [61], the antibacterial efficacy of a propolis-based paste was evaluated as an intracanal medicament. The study found that propolis-based products were more effective against aerobic bacteria than $Ca(OH)_2$. Despite this, Jolly et al. [51] also noted that propolis demonstrates effective antimicrobial activity against both aerobic and anaerobic bacterial colonies under various in vivo conditions.

Aloe vera Mill. (Acemannan)

Aloe vera has anti-inflammatory, antioxidant, pain-relieving, biocompatible, immunomodulating (aiding wound healing), antibacterial (effective against *Streptococcus pyogenes*, *E. faecalis*, and *Pseudomonas aeruginosa*), and antifungal (effective against *Candida albicans* [62]) properties [63-72]. The compounds aloe-emodin and aloin found in *Aloe vera* exhibit strong antibacterial, antiviral, antineoplastic, hepatoprotective, and laxative properties [73]. When applied directly to exposed rat pulp tissue, it demonstrates good biocompatibility and promotes the formation of a tertiary dentin bridge. Its various bioactive components stimulate wound healing, cell proliferation, and angiogenesis [22].

In dentistry, *Aloe vera* is used in various forms, such as mouthwash, toothpaste, and tooth gel [74]. Aloe activator sprays are also beneficial for managing painful third molar eruptions and throat infections [75]. *Aloe vera* extracts show promise as disinfectants in minimally invasive dentistry [76] and as direct pulp capping agents in primary teeth [24].

Acemannan, a major polysaccharide extracted from *Aloe barbadensis* gel, is well-known for its wound healing properties, cytocompatibility [77]. This gel is known for its wound healing properties, cytocompatibility [23], and compatibility with various oral mesenchymal cells [78]. In dentistry, acemannan has demonstrated the ability to stimulate the proliferation, mineralization, and differentiation of pulp cells in human teeth [23]. It has shown favorable results in the reparative dentin formation in cases of iatrogenic pulp exposures [23] and promotes dentin regeneration in reversible pulpitis. Pulpotomy treatments have indicated that acemannan stimulates dentin bridge formation, covering the exposure site and promotes the organization of normal pulp tissues [79]. It also influences the immune system by stimulating the synthesis and release of interleukin-1 (IL-1) and tumor necrosis factor (TNF) from macrophages, which trigger immune responses leading to the regression and necrosis of cancerous cells [47].

Pulp capping

Songsiripradubboon et al. [24] investigated the efficacy of acemannan with $Ca(OH)_2$ as a DPC material in mandibular primary molars. The teeth were treated with a glass-ionomer cement base and restored with stainless steel crown. After six months, clinical and radiographic evaluations were conducted, and exfoliated teeth were examined histologically for inflammation, dentin bridge formation, and soft tissue organization. The acemannan-treated group demonstrated significantly better histological outcomes compared to the CH-treated group.

Cervical pulpotomy

Gupta et al. [80] evaluated the clinical and histopathological effects of *Aloe vera* gel as a healing agent in primary molars. After one month, patients were evaluated for clinical symptoms such as pain, mobility, and abscesses. After 2 months, the vitality of the treated teeth was assessed. A histological examination showed positive healing signs, with intact radicular pulp and pulp tissue enclosed by root dentine. The pulp displayed vitality with delicate fibrocellular connective tissue stroma, an intact odontoblastic layer, blood vessels, and few chronic inflammatory cells. No signs of clinical failure were observed after two months.

Subramanyam et al. [81] assessed the clinical and radiographic success rates of FC and *aloe vera* gel as pulpotomy medicaments in primary molars. After 3 months, the radiographic success rate was higher in the *Aloe vera* group, but by 6 months, FC showed a higher success rate. While the radiographic success rates of both groups declined between 3 and 6 months, the *aloe vera* group's decline was steeper. Clinically, FC had a higher success rate at 3 months, but by 6 months, it was equal to *Aloe vera*, whose success rate remained steady. No statistically significant differences were observed. In another study, Abirami et al. [82] compared the clinical and radiographic success rates of FC, *Allium sativum* oil, and *Aloe barbadensis* gel as pulpotomy medicaments. in primary molars. Both *Allium sativum* oil and *Aloe vera* gel demonstrated efficacy comparable to FC, with no significant differences observed between the groups after 6 and 12 months. Karla et al. [83] evaluated the clinical and radiographic success rates of *Aloe barbadensis* plant extract and MTA in primary molars. MTA showed significantly better results compared to aloe vera after 1, 3, 6, 9, and 12 months.

Gonna et al. [35] conducted a histopathological study comparing the effectiveness of acemannan (a herbal dressing) and FC as pulp-dressing agents in primary molars. While the overall success rate of teeth treated with acemannan was higher than those treated with FC, the difference was not statistically significant. However, acemannan demonstrated an advantage over FC by not causing inflammation or necrosis of pulp tissue.

Additionally, it promoted the formation of a partial hard tissue barrier, an intact odontoblastic layer, and small to medium-sized blood vessels following the procedure. Based on these results, acemannan showed better outcomes than formocresol and could serve as a promising alternative in pulpotomy procedures. However, given the conflicting data currently available, further studies with clinical, radiographic, and histological evaluations, longer follow-up periods, and larger sample sizes are required to fully assess aloe vera's efficacy as a pulpotomy agent in primary teeth.

Pulpectomy (Obturating)

Khairwa et al. [50] evaluated the clinical and radiographic success of zinc oxide mixed with *aloe vera* as an obturating material. Their study reported a high success rate, suggesting that this mixture could be a viable substitute for ZOE. Nonetheless, further studies with longer follow-up periods are needed to confirm the effectiveness of this new treatment approach.

Allium sativum L. Oil (Garlic)

Garlic main components, allicin and thiosulfonates, are known for their antimicrobial and antioxidant properties [84,85]. It has been used for managing dental infections as a mouthwash, root canal irrigant, and pulpotomy medicament [86-88].

Cervical pulpotomy

A study found that *Allium sativum* oil had more favorable histopathological effects on pulp tissue compared to FC in permanent teeth [89]. Kahvand et al. [90] compared the efficacy of *Allium sativum* oil and FC in the pulpotomy of primary molars. Clinical assessments at 3- and 6-months post-treatment showed similar outcomes between the two groups. However, the radiographic success rates in the *Allium sativum* oil group were higher at both follow-up intervals compared to FC. In another clinical study, Mohammad and Baroudi [84] reported that after 6 months of treatment, the clinical and radiographic failure rates were lower in teeth treated with *Allium sativum* oil compared to the FC group, though the difference was not statistically significant. Furthermore, Abirami et al. [82] evaluated *Allium sativum* oil as an herbal pulpotomy medicament compared to FC. At 6 and 12 months post-treatment, the clinical and radiographic evaluations showed no significant differences between the success rates of *Allium sativum* oil and FC. These studies suggest that garlic could be a good alternative to FC due to its potential to promote healing in radicular pulp tissue and its biocompatibility. Despite the promising therapeutic properties of *Allium sativum* oil, more research is needed to provide evidence-based recommendations for its use as a pulpotomy medicament.

Pulpectomy (Irrigation)

Elheeny et al. [14] found no statistically significant difference between *Allium sativum* extract and NaOCl as root canal irrigants in a 12-month clinical and radiographic follow-up period.

Curcuma longa L. (Turmeric)

Curcuma longa (turmeric) is known for its biocompatibility and therapeutic properties, including anti-inflammatory, antimicrobial, and antioxidant effects. It has long been used in the Ayurvedic and Chinese systems of medicine to treat a wide range of ailments [29, 91]. Due to its lipoxygenase and cyclooxygenase-2 inhibiting properties, turmeric also acts as a potential anti-inflammatory agent [92]. In dentistry, turmeric has been used as a dentifrice, mouthwash, pit and fissure sealant coloring agent, and in dental plaque detection systems [93,94,95].

Partial pulpotomy

Purohit et al. [29] conducted a clinical and radiographic assessment of turmeric powder as a pulpotomy medicament in 15 primary molars, with follow-ups at 3 weeks, 2, 4, and 6 months. The results showed no radiographic failures in any group during the 6-month follow-up. Only one clinical failure was reported, indicating that turmeric performed well as a pulpotomy medicament.

Cervical pulpotomy

Huger et al. [41] evaluated the clinical and radiographic outcomes of turmeric gel as a pulpotomy agent in primary molars. The results, at the end of a 6-month follow-up period, were comparable to those observed in teeth treated with propolis, $Ca(OH)_2$, and FC. Given the limited studies on turmeric as a pulpotomy medicament in primary teeth and its promising outcomes, more long-term clinical, histological, and radiographic evaluations are needed.

Nigella Sativa L. oil

Nigella sativa (black seed) oil, extracted from black cumin, is known for its analgesic, anti-inflammatory, antibacterial, immune-modulating, and wound-healing properties. It also stimulates fibronectin release from keratinocytes to dermal fibroblasts, promoting tissue repair [96,97]. In dentistry, *Nigella sativa* oil has been used to treat periodontal and gingival infections, ulcers, oral mucositis, and dental caries prevention [98].

Cervical pulpotomy

Omar OM et al. [99] investigated the histological effects of *Nigella sativa* oil in pulpotomized teeth of four dogs. Forty teeth were treated with either *Nigella sativa* oil or FC, with each substance applied to premolars in opposing quadrants. After four weeks, the dogs were sacrificed for specimen collection. The *Nigella sativa*-treated group showed less inflammation, a more continuous odontoblastic layer, and fewer abscesses compared to the FC-treated group. This suggested that *Nigella sativa* oil had a greater potential to preserve pulp vitality and promote repair. In contrast, the FC-treated group exhibited more pronounced degenerative changes, chronic inflammation, increased collagen fiber density, and the formation of vacuoles.

Ankaferd Blood Stopper

Ankaferd Blood Stopper (ABS) is a hemostatic solution composed of standardized mixtures of *Vitis vinifera* L., *Glycyrrhiza glabra* L., *Thymus vulgaris, Urtica dioica*, and *Alpinia officinarum* Hance [100]. ABS promotes the formation of a protein network that encapsulates blood cells, causing erythrocyte aggregation without affecting the systemic circulation or coagulation pathways. Additionally, ABS exhibits potent antibacterial properties [101,102]. It has been widely used in medical surgeries, such as tonsillectomy, to control bleeding [103].

Cervical pulpotomy

Several studies have reported the safe use of ABS to control bleeding in dental treatments [37,46]. In an animal study, histological evaluation showed that teeth treated with ABS had the least inflammatory response at 30 days postoperatively compared with those treated with ferric sulfate (FS) and FC [48]. Ozmen et al. [42] compared the clinical and radiographic success rates of FC, FS, and ABS in primary teeth pulpotomies. While no significant differences were found, they suggested that ABS could be a good alternative. Cantekin et al. [31] compared ABS and FS as pulpotomy medicaments in primary molars and assessed the clinical and radiographic success rates at 3, 6, 9, and 12 months. The results were similar up to 6 months, with FS showing slightly higher clinical and radiographic success rates at 9 and 12 months; though, the differences were not statistically significant. El Sayed et al. [45] reported that FC showed better clinical and radiographic outcomes after 9 months compared to ABS. However, histological examination indicated more thrombus formation and pulp hyperemia in FC-treated teeth; while ABS-treated teeth had less inflammation and a regular odontoblastic cell layer arrangement. Yaman et al. [37] evaluated the clinical and radiographic effectiveness of ABS compared to FC in primary molar pulpotomies over 3, 6, and 12 months. Both groups had similar clinical success rates, although the radiographic success rate was slightly lower in the ABS group; though, not significantly different from the FC group. Odabaş et al. [46] demonstrated that ABS could effectively control pulpal bleeding during pulpotomies in primary molars. They found that the ABS group had a slightly higher success rate than the $Ca(OH)_2$ group after 12 months, based on both clinical and radiographic criteria. Due to the promising results in earlier studies, further investigations with larger sample sizes and longer follow-up periods are needed to confirm ABS as a reliable alternative to chemical agents.

Thymus vulgaris L.

Thymus vulgaris (thyme) is well-known for its antitussive, spasmolytic, antioxidant, antimicrobial, hemostatic, and wound healing properties [104]. Thymol, carvacrol, and flavonoids such as apigenin, are the primary compounds responsible for its hemostatic, anti-inflammatory, and antimicrobial effects [46,104-109].

Cervical pulpotomy

Alolof et al. [60] treated primary molars using three different pulpotomy medicaments: propolis extract, *Thymus vulgaris*, and FC. After 1, 6, and 12 months of treatment, the FC group showed a higher success rate at the 1-month follow-up. However, the *Thymus vulgaris* extract group had the highest success rates at the 6- and 12-month follow-ups. Although *Thymus vulgaris* has shown promising outcomes, further studies are necessary to account for the differences in success rates between short-term and long-term follow-ups.

Honey

Honey has been used for centuries to treat various systemic conditions [110]. Its polyphenols have shown effectiveness in combating oral cancer, caries, and periodontal diseases [111]. Honey is also used in oral hygiene products like mouthwashes and toothpaste to prevent caries [112]. Additionally, it has antioxidant, anti-inflammatory, antimicrobial, and wound-healing properties [113]. Its ability to debride and deodorize wounds adds to its therapeutic benefits [110,114,115]. Honey has broad-spectrum antibacterial properties against both Gram-positive and Gram-negative bacteria, as well as aerobic and anaerobic species [116]. Its healing properties are attributed to its antibacterial action, the moisture it provides to the wound environment, and its high viscosity, which forms a protective barrier against infections [117]. Honey's high-protein nutritional content also supports tissue repair [118]. Its acidity helps enhance oxygen supply for tissue regeneration by lowering pH, which facilitates the release of oxygen from hemoglobin. Moreover, honey stimulates cytokine release, including IL-6, TNF-α, and IL-1β, from monocytes, which aids in tissue healing and repair [119].

Cervical pulpotomy

Kumari et al. [43] compared the radiographic and clinical success rates of honey and FC as pulpotomy medicaments in mandibular primary molars. Follow-ups were conducted at 6, 9, 12, 18, and 24 months. No clinical failures were observed in either group during the 24-month follow-up. Radiographic failures began to appear after the 9-month follow-up, with honey showing slightly better radiographic outcomes than FC, though the difference was not statistically significant.

Copaifera Langsdorffii Oil Resin (CLOR)

Copaifera langsdorffii var. langsdorffii, a plant-based substance, is a combination of diterpene acids and essential oils. Due to its pharmacological properties—such as anti-inflammatory, antimicrobial, analgesic, antioxidant, and wound-healing effects—CLOR is widely used in medical applications [120,121]. In dentistry, it has been considered for use as a pulpotomy medicament, anticariogenic agent, root canal sealer, and for periodontal treatment [122]

Cervical pulpotomy

In an animal study, Lima et al. [26] histologically eval-

uated the response of rat pulp tissue after pulpotomy. The study used CLOR, green propolis extract, fibrin sponge, and iodoform-based paste as pulpotomy medicaments. After 1 month, the inflammation level in the CLOR group was lower, the pulp necrosis area was smaller, and the mineralized tissue formation was greater than the other materials. In contrast, the fibrin sponge group had the highest levels of inflammation and the least signs of tissue repair. Musale et al. [123] performed a clinical and radiographic evaluation comparing the effectiveness of CLOR, FC, and MTA in the pulpotomy of human primary molars. After 12 months, the clinical success rates for all groups were 100%. The CLOR group had the lowest radiographic success rate. Since no significant differences were observed between the groups, further studies are recommended to confirm the effectiveness of CLOR.

Salvadora persica L. (Miswak)

Miswak is a plant primarily used as a natural toothbrush. Its main constituents include alkaloids such as trimethylamine and salvadorine, as well as a high content of fluoride and chloride. Miswak also contains silica, sulfur, vitamin C, tannins, flavonoids, and sterols [21]. The antimicrobial and cleaning properties of Miswak are attributed to the chemical compounds present in its extracts [124].

Pulpectomy (Irrigation)

Almas et al. [125] showed that *E. faecalis* is sensitive to *Salvadora persica*, and that Miswak can inhibit bacterial adherence to tooth surfaces. Another study also demonstrated a significant reduction in *S. mutans* counts when using Miswak [124]. The antimicrobial effect is believed to be linked to its fluoride content, which interacts with bacterial glycolytic enzymes. According to Al-Azzawi et al. [126], *S. persica* was found to be more effective against *E. faecalis* than green tea, although other studies have reported contrary results [127].

Due to its strong antimicrobial activity and low cytotoxicity, Miswak could potentially replace NaOCl and chlorhexidine (CHX) as a root canal irrigant. It is also safer for use in primary teeth [21].

German Chamomile (*Matricaria chamomilla* L.)

German Chamomile extract has demonstrated antibacterial activity against *E. faecalis* when used as a root canal irrigant in primary teeth [127]. Chamomile has been used medicinally for decades due to its anti-inflammatory, analgesic, antibacterial, antispasmodic, and sedative effects [128].

Pulpectomy (Irrigation)

Several studies have concluded that herbal irrigant solutions, including chamomile, exhibit acceptable antibacterial effects against *E. faecalis* in primary teeth [127,129]. However, given the limited histopathological data, further clinical studies are recommended.

Camellia sinensis (L.) Kuntze (Green tea)

Green tea contains active components with physiological properties suitable for use as an intracanal irrigant [127]. It also possesses antibacterial effects against *E. faecalis* [127,129].

Pulpectomy (Irrigation)

According to Naamatullah et al. [127], there was no statistically significant difference in antibacterial efficacy between NaOCl and green tea. NaOCl showed the highest antibacterial activity against *E. faecalis*, followed by green tea, Miswak, and chamomile.

Elaeagnus angustifolia L. (Eremanthus elaeagnus)

Elaeagnus angustifolia, commonly known as Russian olive, contains potent antioxidants and exhibits anti-inflammatory, analgesic, coagulation, and antipyretic properties [130].

Cervical pulpotomy

Poureslami et al. [1] evaluated the pain levels in patients treated with FC and *Elaeagnus angustifolia* after 10 days and found that both groups experienced significant pain reduction, with a higher reduction in the FC group. However, the study showed a high risk of bias in its quality assessment.

A summary of discussed natural materials shown in figure 1.

Discussion

The growing interest in natural therapeutic agents for primary tooth pulp management is supported by numerous studies demonstrating their antimicrobial, anti-inflammatory, and regenerative properties. Propolis and acemannan have consistently shown the ability to induce dentin bridge formation, maintain pulp vitality, and reduce inflammatory responses, aligning well with the ideals of minimally invasive pediatric endodontic treatments. Equally promising are other substances such as *Allium sativum* oil, *Curcuma longa*, and *Nigella sativa* oil, which exhibit favorable histological and clinical outcomes in pulpotomy procedures. Similarly, Ankaferd Blood Stopper, *Thymus vulgaris*, honey, and *Copaifera langsdorffii* oil resin have been studied for their capacity to control bleeding, minimize inflammation, and foster reparative processes. Moreover, plant-based irrigants including *Salvadora persica*, chamomile, green tea, and *Elaeagnus angustifolia* have shown efficacy against common endodontic pathogens, with some suggesting comparable results to sodium hypochlorite and chlorhexidine solutions.

Nevertheless, despite the promising in vitro and in vivo evidence, the literature remains somewhat heterogeneous. Variations in methodology, sample size, follow-up duration, and outcome assessment make direct comparisons and consensus-building

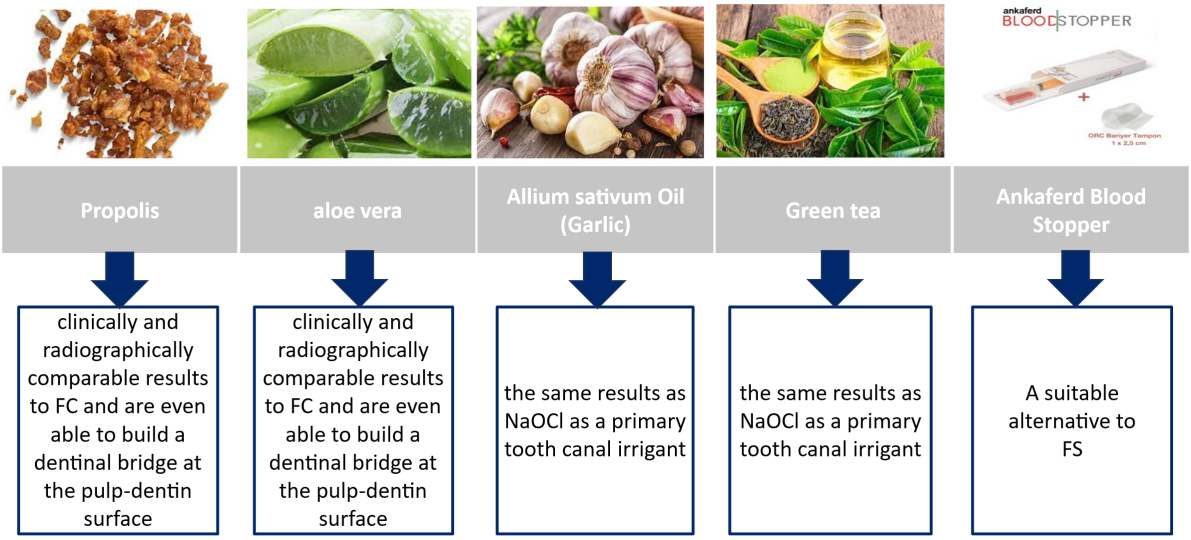

Figure 1. A summary of five effective herbal ingredients (propolis, aloe vera, garlic oil, green tea and Ankaford Blood Stopper) in pulp therapy for primary teeth.

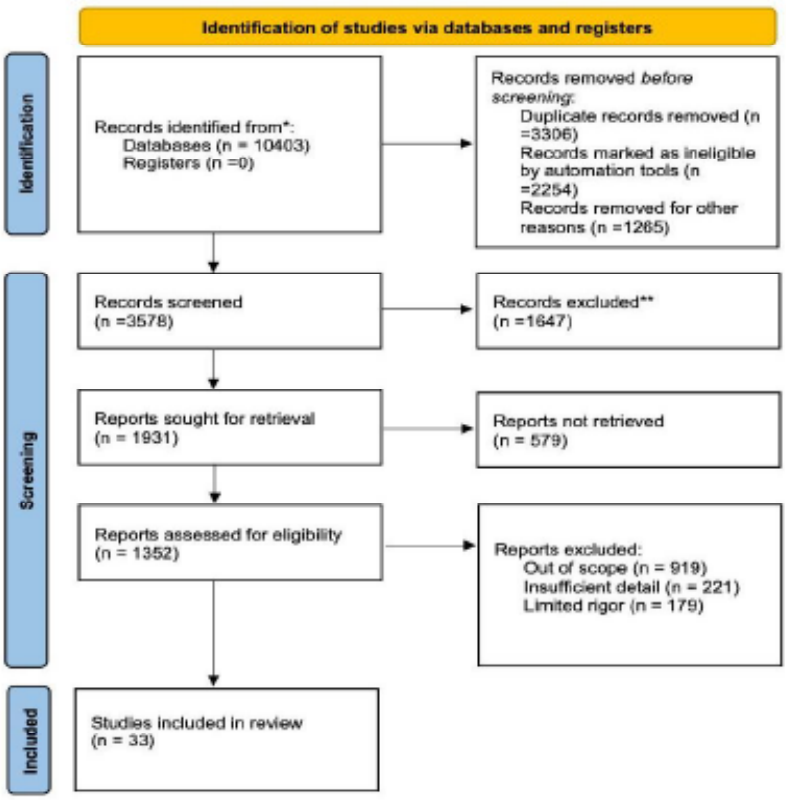

Figure 2. PRISMA Flowchart of study selection.

challenging. Many existing studies also lack robust long-term data, thereby preventing clear conclusions about sustained success or late failures. Consequently, to substantiate the use of these materials as reliable stand-alone or adjunctive therapies, future investigations should employ standardized protocols, larger cohorts, and lengthier follow-up periods. By systematically examining each agent's optimal concentration, delivery method, and synergy with existing materials, the pediatric dentistry field can better determine how to harness these biologically active substances for improved patient outcomes.

Conclusion

Studies to date suggest that natural agents like propolis and aloe vera show clinically and radiographically comparable results to FC, and both have demonstrated the ability to form a dentinal bridge at the pulp-dentin interface. However, some studies have reported contradictory findings. Additionally, garlic extract and green tea have shown comparable efficacy to NaOCl as irrigants in primary tooth canal treatments. While these natural products offer numerous benefits and hold potential for use in pediatric dentistry, the current evidence is insufficient to fully support their widespread adoption. Therefore, further long-term clinical trials are necessary to validate their effectiveness and safety for pulp treatment in primary teeth.

Conflict of Interests

The authors declare no conflict of interest, financial or otherwise.

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