Review Article

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Recent Advancements in Intracanal Medicaments used in Paediatric Dentistry: A Comprehensive Review

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Abstract:

This review aimed to examine the recent literature concerning conventional intracanal medicaments, and summarize important recent developments. Literature research was performed focusing on articles on safe and effective intracanal medicaments in Google Scholar using the MeSH terms "herbal drugs as intracanal medicaments", "intracanal medicaments for pediatric patients" and "safe intracanal medicaments". A total of 63 studies were included in this review, following inclusion and exclusion criteria. Our literature search revealed that drugs derived from natural sources have become promising alternatives for intracanal medicaments due to their safety profile and potential therapeutic advantages. Furthermore, herbal remedies are frequently well-tolerated by paediatric patients, reducing the likelihood of adverse events. The advantages of herbal drugs in paediatric dentistry extend beyond their antimicrobial efficacy. They offer a holistic approach by harnessing the healing properties of nature, potentially minimizing the need for synthetic chemicals and antibiotics. Recent advancements in intracanal medicaments for paediatric dentistry encompass a spectrum of options, ranging from conventional to herbal-based formulations. While conventional medicaments continue to play a vital role, herbal drugs offer promising alternatives with potential benefits in efficacy, safety, and patient acceptance.

Keywords: herbal drugs as intracanal medicaments, natural products in paediatric dentistry, newer intracanal medicaments

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Introduction

Dental caries is a prevalent concern in the pediatric population, primarily due to dietary habits, inadequate oral hygiene and some other factors such as developmental disorders and drug usage. It begins with the demineralization of the tooth enamel by acids produced by bacteria in dental plaque, which can progress to the point where it affects the dental pulp—the innermost part of the tooth containing nerves, blood vessels, and connective tissue. Depending on the extent of the infection, pulp therapy such as pulpotomy, pulpectomy or root canal therapy (RCT) can be performed to save the tooth, alleviate pain, or treat the infection[1].

The initial foundation for achieving success in endodontic treatments was based on the triad of thorough disinfection, debridement and obturation of the root canal system, with equal importance given to each component. Presently, the success of root canal treatment depends on general principles, irrespective of the specific factors that contribute to its effectiveness.

This encompasses the process of diagnosing and planning treatment, understanding the structure and form of the affected area, adhering to the conventional practices of removing decayed tissue, ensuring thorough disinfection, and filling the root canal, as well as restoring the coronal part of the tooth[2].

The goal of paediatric endodontics is to maintain the integrity of primary teeth that have suffered pulp tissue damage due to caries, dental trauma, or other causes until they are naturally replaced by permanent teeth. A RCT is necessary when the pulp has become irreversibly infected or necrotic. The procedure is highly dependent on technique, as it can be quite challenging to instrument the complex canals of primary molars that have curved roots and are naturally programmed for resorption. Furthermore, the existence of accessory canals poses challenges in the process of biomechanical preparation, and achieving complete elimination of necrotic pulp tissue is highly challenging. Due to the challenging nature of achieving thorough mechanical preparation of wide canal walls, it is advised to divide the treatment into two separate appointments, with the application of an antiseptic dressing in-between visits. There is a likelihood of intra-canal bacteria multiplying between the appointments when treatment cannot be completed in a single appointment, that is why intracanal medication is recommended for this purpose[3].

Walton asserted that intra-canal medicaments have historically been closely associated with endodontics. They are widely recognised as a vital element of the treatment and act as an indispensable factor for the efficacy of RCT. However, the justification for using intra-canal medicaments in modern endodontics is somewhat different. Using an intra-canal medication can be advantageous in minimising the regrowth of bacteria and potentially improving the suppression of bacteria by completely eliminating the bacteria. Interappointment antimicrobial medication functions by impeding the growth of bacteria and eradicating any remaining bacteria, while also reducing the entry of pathogens through a damaged dental restoration[4]. Typically, when treating teeth with a living pulp, intracanal medication is unnecessary. The issue of the function of intracanal medicaments becomes increasingly pertinent and intricate when dealing with cases involving pulp tissue death and inflammation of the tissues surrounding the tooth's root tip.

The main purpose of intra-canal medicaments is to prevent the occurrence of secondary infection and provide a bactericidal effect. It is necessary to attempt to eliminate micro-organisms that survive after obturation; otherwise, they will multiply in the root canals. Chemo-mechanical preparations are ineffective in eliminating the micro-organisms that remain in the dentinal tubules. Improper application of antiseptic intra-canal medicaments

between visits can lead to the proliferation of remaining micro-organisms, resulting in the same number of micro-organisms as in the initial stage of treatment. Thus, it is imperative to use effective intracanal medications between treatments[5].

Cardinal features of an intracanal medicament[6]

In addition to functioning as a potent disinfectant against germs and fungi, it should also disinfect surfaces. It must not cause irritation to the tissues surrounding the apex of the tooth.

It should maintain stability in the solution. It is expected to exhibit a long-lasting antimicrobial effect.

It must exhibit activity when exposed to blood, serum, and protein derivatives from tissues.

It is desirable for it to exhibit a low surface tension. It should not impede the restoration of periapical tissues.

It should not cause discoloration of the tooth's structure. It should not elicit a cellular immune response.

The objective is to inhibit coronal microleakage and ensure that it does not permeate the temporary restoration.

Rationales of using intra-canal medicaments

Elimination of the pathogens: The primary reason of intra-canal medicament administration is to eliminate the living bacteria and to eradicate all micro-organisms present in the root canal.

To render the contents of the canal inactive: This is achieved by the application of chemicals to preserve or neutralize the tissue or debris that is present in the pulp cavity.

To mitigate post treatment discomfort: Endodontic treatment aims to reduce inflammatory responses, using intracanal medicaments with antibacterial properties to decrease pain and inflammation, though direct application may cause pain in sensory nerves.

Augmenting anaesthesia: Some agents can help reduce pain in inflamed pulp, allowing easy removal between appointments with slight anesthetic issues.

Managing the ongoing periapical infection: Pain and swelling after treatment or draining a canal indicate an active periapical lesion. Intracanal medications are used to restore balance and reduce difficult situations[7].

Medical and surgical indications of intra-canal medicaments

To desiccate the consistently damp root canal, commonly referred to as weeping canals.

To eradicate any residual micro-organisms in the pulp cavity.

To render the contents of the root canal chemically inactive.

To eliminate tissue debris.

To serve as a protective barrier against leakage from an interappointment dressing in cases with symptoms.

However, concerns over potential drawbacks of intracanal medicaments such as cytotoxicity and antibiotic resistance, have led to the exploration of alternative options. The main objective of this literature review is to search for different treatment outcomes so as to minimize discomfort, especially from the conventional intracanal medicaments, and to explore the plethora of natural products for paediatric patients in dentistry.

Literature research was performed regarding safe and effective intracanal medicaments in Google Scholar and PubMed/MEDLINE articles dated from October 2023 to March 2024 using the MeSH terms "herbal drugs as intracanal medicaments", "intracanal medicaments for pediatric patients" and "safe intracanal medicaments". A total of 63 studies were eventually included in this review following the application of our inclusion and exclusion criteria.

Herbal drugs have been used more or less forever as promising alternatives due to their known high safety profiles and potential therapeutic benefits. Various herbal extracts, including propolis, neem, and aloe vera, have

demonstrated antimicrobial properties and the ability to stimulate dentinogenesis and pulp repair. Moreover, herbal medicaments are generally well-tolerated by pediatric patients, reducing the likelihood of adverse reactions.

The advantages of herbal drugs in pediatric dentistry extend beyond their antimicrobial efficacy. They offer a holistic approach by harnessing the healing properties of nature, minimizing the need for synthetic chemicals and antibiotics. Additionally, herbal medicaments may contribute to patient education and acceptance of natural remedies, aligning with the growing preference for alternative and complementary therapies. Details of various studies regarding the uses of several natural products are enumerated in Table 1.

Table 1 Showing details of natural and newer intracanal medicaments

Herbal drug	Biological source	Application in dentistry	Reference
Curcumin (Turmeric)	*Curcuma longa*	Intracanal medicament in root canal treatment, periodontal problems, mouthwash, local drug delivery system, subgingival irrigant, pit and fissure sealant, precancerous lesion	46
Propolis	*Bee glue*	Periodontal disease, mouthwash, irrigant, intracanal medicament, pulp capping agent, oral ulcers, precancerous lesion	47
Neem	*Azadirachta indica*	Toothpaste, mouth wash, intracanal medicament, root canal irrigant, periodontal disease, epidermal dysfunction	48
Burdock	*Arctium lappa*	Intracanal dressing, root canal irrigant, biofilm reduction, precancerous lesion	49
Eucalyptus oil	*Eucalyptus globulus*	Gingivitis, mouthwash, irrigant, intracanal dressing, toothpaste, lozenges, cold sores, toothpaste, as an anxiolytic, oral candidiasis	50
Castor seed oil	*Ricinus cvommunis*	Storage medium for avulsed tooth, dressing medicament in pulpectomy & pulpotomy, endodontic sealer	51
Guacatonga plant	*Casearia cylvestris*	Dental plaque treatment, intracanal dressing medicament in root canal therapy, oral ulcers	52
Indian mulberry leaves	*Morinda citrifolia*	Mouth rinse, intracanal medicament, toothpaste, endodontic irrigant, disinfecting impressions	43
Latex of papaya leaves and fruits (Papain)	*Carica papaya*	Gingivitis, toothpaste, mouthwash, intracanal medicament, probiotics, caries removing agent, remineralizing agent	53
Tulsi oil	*Ocimum sanctum*	Obturating material, intracanal medicament, Mouthwash, toothpaste, gingivitis	54
Garlic	*Allium sativum*	As an irrigant and intracanal medicament, pulpotomy, mouthwash, periodontal disease	55
Lemon solution	*Lemon*	Intracanal medicament	50
Aloe vera leaf	*Aloe vera*	Mouthwash, intracanal medicament, root canal irrigant	48
Licorice oil	*Glycyrrhiza glabra*	Chewing gums, dentifrice, gels, lollipops, intracanal medicament, as an irrigant	56
Triphala (Amalaki, Bibhitaki & Haritaki)	*Emblica officinalis, Terminalia bellerica & Terminalia chebula*	Mouth rinse, intracanal medicament, periodontal problems, chelating agent, root canal irrigant	43
Fennel seed	*Foeniculum vulgare*	Dental plaque and salivary pH reduction, intracanal medicament, toothpaste, mouthwash	57

Commonly used intracanal medicaments in pediatric dentistry

Calcium hydroxide $Ca(OH)_2$: The introduction of $Ca(OH)_2$ in dentistry came as, pulp capping material, and it was used in clinical settings for controlling bacteria, decomposing organic residues, managing inflammation, preventing root resorption, restoring tooth structure, and acting as a temporary filling material between appointments. One study reported that the high pH of this substance exhibited antimicrobial properties by deactivating the surface enzymes of microorganisms[8]. Another study reported that *Enterococcus faecalis (E. faecalis)* i.e a gram-positive bacterium which is reported to be a significant pathogen in endodontic infections, was resistant to $Ca(OH)_2$ and could withstand exposure to $Ca(OH)_2$ for approximately ten days[9]. $Ca(OH)_2$ has a minimal impact on facultative anaerobes and Candida species but is effective on obligate anaerobes[10].

Formocresol: Formocresol, a potent antibacterial agent, was initially used by Buckley in 1906. This substance is efficient in combating both aerobic and anaerobic microorganisms within the root canal. It is suitable for emergency endodontic procedures and pain management. However, it exhibits mutagenic and carcinogenic characteristics at elevated levels. In endodontics, a diluted form of Buckley's formocresol formula is used by placing cotton pellets in the tooth's pulp chamber to allow the vapours to spread throughout the entire canal preparation[11]. The use of this substance as a pulpotomy agent is controversial due to its potential for sensitization, toxicity, mutagenic or carcinogenic effects, and the risk of causing harm to the surrounding oral and para-oral tissues if used carelessly[12].

Glutaraldehyde: The product is offered in a 2% glutaraldehyde concentration. The oil is colourless, has low solubility in water, and shows a slightly acidic reaction. Graven initially suggested using glutaraldehyde as a 2% concentration intra-canal medicament due to its strong disinfectant and fixative properties[13]. Glutaraldehyde does not trigger an immunologic response, unlike formaldehyde. Glutaraldehyde has bacteriostatic properties, which means it hinders the growth and reproduction of bacteria. The toxicity level is lower than that of formaldehyde. Its high molecular weight prevents it from penetrating periapical tissues, unlike formaldehyde. Direct application of a 2% glutaraldehyde solution to root stumps in a primary tooth is more effective than mixing a drop of the solution with ZOE paste. Its small molecular size prevents it from reaching the apical foramen, causing minimal disturbance to the systemic circulation.

Chlorhexidine gluconate: Chlorhexidine (CHX) gluconate is available in various formulations, such as mouthwash with concentrations of 0.12% and 0.2%, proven to decrease the amount of *Streptococcus mutans (S.mutans)* within 24 hours. The product is offered in gel form containing 1% of the active ingredient, as well as in varnishes with concentrations of 1%, 10%, 20%, and 35%. It is minimally toxic and very efficient against *E. faecalis*, a prevalent pathogen in root canal treatments. Two percent CHX gel and a mixture of CHX and $Ca(OH)_2$ are used in intracanal medicaments. These substances are effective against both aerobic and anaerobic bacteria[14,15].

Ledermix paste: Schroeder and Tridon (1960) developed the compound, that is a combination of a glucocorticoid and the antibiotic demeclocycline, a broad-spectrum antibiotic. Triamcinolone acetonide (1%) is the active ingredient present in the Ledermix paste. It is a non-hardening paste material that is soluble in water, utilized as a medication in root canals, or as a pulp capping agent, either applied directly or indirectly. It acts as an anti-inflammatory agent. Ledermix paste releases triamcinolone, a glucocorticoid inside of root canal, and that can reach the bloodstream through diffusion across lateral canals, dentinal tubules and the apical foramen[16]. A total of thirty percent

of the release of triamcinolone takes place at the first 24 hours, with the remaining seventy percent released over a 14-week period. It has been also reported that patients treated with Ledermix had superior healing and a more preserved root structure in comparison to a group treated with gutta-percha and sealer[17].

Ozonised oil: Ozone has been increasingly used in dentistry due to its antimicrobial properties and potential benefits in various dental treatments. Ozone can be applied in various forms, like ozonated water, ozonated oil, and ozone gas. It aids in tissue cleaning and encourages the growth of new blood vessels[18]. An investigation showed that low concentrations of ozone effectively eradicated *Escherichia coli* cells, plus the vegetative cells and spores of *Bacillus cereus* and *Bacillus megaterium*[19]. Siqueira et al. studied the antibacterial effects of ozonized oil and the use of $Ca(OH)_2$ pastes on different kinds of bacteria commonly found in peri-radicular diseases. Ozone can be utilised as an intracanal medicament by dissolving it in oil for lubrication and disinfection purposes. The success rate for peri-radicular lesions and their antibacterial activity is very high when used as an intracanal medication.

Octenidine: Octenidine (OCT) hydrochloride is an antimicrobial compound classified as a bipyridine. The Sterling-Winthrop Research Institute created it. It acts as an antimicrobial agent in mouthwashes to inhibit the development of dental plaque. It improves the wound healing process. This compound shows potent efficacy against bacteria, fungi, and viruses even at concentrations as low as 0.1% or lower. Topical administration of this substance does not cause any systemic toxicity. Muller et al. conducted a study that determined OCT's antimicrobial effectiveness was not reduced by the presence of organic matter. Makkar et al's research demonstrated that a 0.1% concentration of OCT effectively reduced the colony-forming units of *E. faecalis* following a 3-minute exposure. OCT demonstrated greater effectiveness than CHX against both planktonic and biofilm microorganisms due to its anti-adhesive characteristic[20]. OCT hinders bacterial co-aggregation and prevents biofilm formation. OCT lacks tissue solubility. This limits the use of OCT.

Antibiotics: Triple antibiotic paste (TAP) is a combination of three antibiotics. The synergistic action of the three drugs in the paste creates a powerful antimicrobial agent that is effective against microbes. The most widely and effectively used intracanal antibiotic medicament is the combination of Metronidazole, Ciprofloxacin, and Minocycline. Various studies have reported on the efficacy of this combination in eradicating bacteria in the innermost layer of the root canal. Furthermore, it has been found that the administration of this blend of antibiotics on the affected dentinal wall of the root canal reduces the presence of bacteria, with only a few exceptions where they remain undetectable. However, prolonged use of this antibiotic combination in endodontic treatment may cause crown discoloration. This staining property is reported by the use of "minocycline," a tetracycline antibiotic[21]. TAP is used in baby teeth to disinfect infected root dentin and prevent the growth of resistant microorganisms. The medication penetrates deeply into the dentin, successfully eradicating bacteria. Root canal dressings are effective when used in conjunction with antibiotics. Hence, TAP has broad utility as a medicament within the root canal for pediatric patients. Its intended uses include canals that are consistently damp or secreting fluid, to eliminate tissue debris by breaking down the contents of the root canal, to eliminate excess microorganisms that impede seepage, and to use in cases with many symptoms[22].

Nisin: Nisin (bacteriocin) is a naturally occurring anti-microbial peptide derived from the Streptococcus and Lactococcus species, gram-positive bacteria. One of the studies reported about the use of Nisin as an oral

antimicrobial agent, while Howell et al. developed Nisin as an anti-microbial mouth rinse. A study conducted by Tong et al. found that Nisin had the ability to hinder the growth of cariogenic bacteria, such as *S. mutans*. The biomedical application of this technology has made significant progress, allowing for the prevention of the proliferation of drug-resistant bacterial strains such as methicillin-resistant *Staphylococcus aureus (S. aureus)*, *Enterococci, Streptococcus pneumoniae*, and *Clostridium difficile*. The antimicrobial activity specifically targets Gram-negative pathogens and a wide range of Gram-positive bacteria, including their spores. It is also effective against drug-resistant *E. faecalis* isolates. The potent and extensive efficacy of this treatment minimises the likelihood of bacterial resistance and reduces cellular toxicity at normal anti-microbial concentrations. Nisin also exhibits anti-biofilm properties. The use of Nisin in dentistry has been limited, however, it has been found to be highly effective in eliminating *E. faecalis* from the root canal system[23].

Anti-microbial photodynamic therapy (aPTD): A technique known as photosensitization has been used in medicine for a considerable time. It is also called Photoactivated Disinfection (PAD). Due to its antimicrobial efficacy, it is used in endodontic procedures. PAD is composed of abundant amounts of tolonium chloride, also referred to as toluidine blue and a photoactive agent. A red laser at 635 nm is used to stimulate the photosensitizer molecule. Through a small flexible optical fiber, light is delivered to the root canal with a maximum power of 100 mW, while maintaining the safety of adjacent tissue. In addition to disrupting membranes, deactivating enzymes, and damaging genomic and plasmid DNA, the potent oxidizer also causes immediate death in microbial cells. The use of light activated therapy in dentistry could help combat human infections caused by biofilms[24].

Endox: Endox endodontic systems sterilize root canals by ejecting high-frequency electrical impulses. In order to achieve sterilization through fulguration, Endox endodontic systems claim to eliminate both pulp and bacteria from the entire root canal. The unit was demonstrated to be incapable of eliminating pulp tissue from root canals without mechanical cleaning, according to a recent study. In spite of the fact that the unit can serve as a substitute for conventional cleaning and shaping methods, the authors do not recommend the use of high-frequency electric pulses exclusively as an endodontic treatment[25].

Natural products

Curcumin: Curcumin is a natural compound obtained from the roots of *Curcuma longa* (Turmeric). It has been recognised for its pleiotropic effects, such as antimicrobial, anti-inflammatory, antioxidant, and anti-cancer. These properties make it relevant in clinical dentistry for the treatment and prevention of various diseases. Concerning its endodontic intracanal medications, in an in vitro study, Curcumin was incorporated into polymeric fibers to evaluate its antimicrobial properties and potential application in root canal disinfection, and the author concluded that photoactivation of curcumin-based medicaments seems to be essential to obtain greater antibiofilm activity[26]. Recent studies have emphasized curcumin's potential as a viable alternative to TAP for infection control. One study reported that a minimum concentration of 2.5 mg/mL was required to produce a therapeutic response[27].

Propolis: Propolis is one of the most superior intra-canal medicaments due to its anti-inflammatory and potent antimicrobial properties. Its effectiveness is comparable to NaCl when compared to saline. It can be utilized as a short-term treatment for pulp and periapical pathologies. Propolis contains active components such as flavonoids,

phenolics, and aromatics, contributing to its diverse biological activities like antimicrobial, anti-inflammatory, antioxidant, anaesthetic, and cytotoxic effects. Propolis demonstrates notable antibacterial effectiveness and can serve as an intracanal medicament[28].

Azadirachta indica: Commonly referred to as Neem, possesses exceptional antimicrobial properties and the oil of neem seeds has been extensively used in dentistry. The key active chemical constituents responsible for the broad spectrum of antimicrobial effects are azadirachtin, nimbolinin, nimbidin, and nimbin. In dentistry neem leaves and their oil has been evaluated for its antibacterial and antifungal properties and it is quite useful in dentistry for curing gingival problems and maintaining oral health in a natural way. Neem-based pastes and oil have also been studied and thoroughly tested for their intracanal medicament and irrigant purposes removal of oral aerobic and anaerobic pathogens existing in the oral cavity. Nimbidin is the primary extract obtained from the seed kernels of neem. This active ingredient exhibits antibacterial properties. In a recent study, neem oil was reported to have potential antimicrobial effects against *S. mutans* and *E. faecalis*, while it was comparably effective against *Candida* species. It can be used as a substitute for $Ca(OH)_2$, an intracanal medicament obtained from a chemical source[29].

***Arctium lappa*:** It is a plant native to Japan that is found all over the world. It has been extensively utilized as a medicine due to its antibacterial, antioxidant, and antifungal properties. The presence of polyacetylenes in this plant is responsible for their antibacterial activity. *Arctium lappa* has shown significant antimicrobial properties against the various root canal microbes[30].

Eucalyptus oil: Eucalyptus oil is an essential oil obtained from the leaves of the Eucalyptus tree. It possesses anti-inflammatory and antimicrobial properties. Its broad antimicrobial spectrum, synergistic effects and biocompatibility suggest its effectiveness as an intracanal medicament[31].

Castor oil: Castor oil is obtained from the seeds of *Ricinus communis*. The plant is rich in ricinoleic acid. *Ricinus communis* can be utilised as a root canal irrigant and intracanal medicament due to its composition of alkaloids (oxindole), glycosides, triterpenes, tannin, phenolic compounds, steroids, and flavonoids, which contribute to its antimicrobial properties. One study reported that *Ricinus communis* paste, along with $Ca(OH)_2$, demonstrated superior antimicrobial efficacy compared to a paste containing $Ca(OH)_2$ and propylene glycol[32]. Additionally, another study found that *Ricinus communis* exhibited complete eradication against *Candida albicans* and significant antimicrobial activity against *E. faecalis*[33].

***Casearia sylvestris**: Casearia sylvestris* is a medicinal plant native to tropical America and Brazil that exhibits antiseptic and antimicrobial properties. It can serve as a viable option for short-term intracanal medication in cases of pulp and periapical inflammation. Also known as 'guacatonga,' this plant is recognised for its antimicrobial, diuretic, anti-ulcer, and healing attributes. It includes a substantial quantity of phospholipase A2 inhibitors. Silva et.al. suggest that *Casearia sylvestris* can be used as a substitute for short-term intracanal medication[34].

***Morinda citrifolia**:* It is commonly known as Indian mulberry. It has a large variety of applications due to its analgesic, anti-inflammatory, antioxidant, antibacterial, and antiviral properties. *Morinda citrifolia* shows a significant reduction in the zone produced by the microorganism *E. faecalis*, this property making it suitable for use as an effective intra-canal medicament[35].

Papain: Papain is an enzyme and a natural product derived from the latex of papaya leaves and fruits (*Carica papaya*). Papain is a cysteine protease enzyme that exhibits notable antibacterial and anti-inflammatory characteristics

due to its proteolytic properties. Various studies suggest that it can be utilised as an intra-canal medicament. It also possesses a debris-removing effect. Its ability to dissolve tissue makes it useful as a cariostatic agent. Anuj Bhardwaj et al.'s study found that papain treatment was equieffective in comparison with CHX in terms of antimicrobial effectiveness. By virtue of this, it could be a substitute for CHX[36].

Tulsi: Tulsi is obtained from the leaves of the plant Tulsi *(Ocimum sanctum),* a member of the Labiateae family. Tulsi is regarded as sacred plant in subcontinent such as India, and known as sacred basil. It is renowned for its antimicrobial, antifungal, and antiviral characteristics. The essential oil extract of *Ocimum sanctum* demonstrates strong concentration-dependent antibacterial properties. Using *Ocimum sanctum* as a medicament inside the tooth canal in paediatric dentistry provides a hopeful natural option. The antimicrobial, anti-inflammatory, and analgesic qualities of this substance make it highly suitable for treating infected root canals in primary teeth. Furthermore, its organic source and limited negative impacts make it well-suited for paediatric patients. Additional research is required to determine the ideal concentration and long-term effectiveness of Tulsi in paediatric endodontic procedures, but it shows promise as a valuable addition to paediatric dental care[37].

Garlic: Garlic is obtained from the cloves of *Allium sativum*, and possesses a diverse range of antimicrobial responses, exhibiting both bacteriostatic and bactericidal effects depending on the formulation and concentrations. Its antimicrobial effectiveness stems from its ability to prevent toxin production and the activation of enzymes involved in causing endodontic diseases. It may serve as a substitute intracanal medicament. It has pharmacological properties including antimicrobial, antiplatelet, antithrombotic, and anticancer effects. It has been proven effective against *S. mutans, S. aureus, E. faecalis*, and *Escherichia coli*. Research by Eswara K et al. found that garlic had superior antimicrobial effectiveness in comparison to $Ca(OH)_2$[38]. Another study by Salih et al. found that garlic exhibited greater efficacy against strains of *S. aureus* in comparison to *E. faecalis*[39].

Lemon solution: Is obtained from the plant *Citrus limon,* from the family Rutaceae. The lemon solution is a natural source of citric acid with a mild level of acidity. One study found that a fresh lemon solution had broad antibacterial properties, even against *E. faecalis*, making it suitable for use as an intracanal medicament[40].

Aloe vera: *Aloe vera* is a member of the family Liliaceae. *Aloe vera* gel is obtained from the mucilaginous tissue found in the center of the *Aloe vera* leaves. Anthraquinone glycosides found in total leaf extracts of *Aloe vera* possess potent antibacterial properties. *Aloe vera* has been studied for its antibacterial effectiveness and examined as a medicament for use inside root canals[41]. The leaf extracts contain anthraquinones, which are responsible for their antibacterial properties. The substance also includes various active components such as vitamins, minerals, enzymes, sugars, lignin, saponins, salicylic acids, and amino acids. Alloin and emodin function as analgesics, antibacterials, and antivirals. The effectiveness against *Streptococcus pyogenes* and *E. faecalis* is attributed to the presence of anthrax quinine. In 2016, Kurian et al. conducted a study demonstrating that the minimal inhibitory concentration of *Aloe vera* was more effective than $Ca(OH)_2$ in eradicating *E. faecalis*. The antibacterial properties of *Aloe vera* were found to enhance over time[42]. *Aloe vera* exhibits wide-ranging antibacterial effects against different oral pathogens when compared to other natural extracts.

Glycyrrhiza glabra: Also known as liquorice, it is recognized for its anti-inflammatory, anticarcinogenic, and antiviral properties. Glycyrrhizin is a chemical constituent,

a triterpenoid compound, that is effective against various strains of *S. mutans.* It exhibits higher bio-compatibility than CHX as an intracanal medicament[43].

Triphala: (Haritaki, Bibhitaki, and Amalaki) Triphala, a renowned Ayurvedic blend, has been demonstrated to successfully prevent the formation of biofilm. It is very suitable for use as an intra-canal medicament. It possesses potential antibacterial and anti-inflammatory characteristics. The fruit contains a high concentration of citric acid, which can help remove the smear layer by acting as a chelating agent. A study by Prabhakar et al. found that Triphala displayed antibacterial effectiveness nearly equivalent to $Ca(OH)_2$ and could serve as a substitute for $Ca(OH)_2$ in combating *E. faecalis*[44].

Foeniculum vulgare: This belongs to the Apiaceae family, and its fennel seeds are known for their analgesic, anti-inflammatory, antispasmodic, antioxidant, diuretic, carminative, anti-microbial, and anti-cancer properties. Analysis conducted in a controlled environment indicated its potential application as a medicament within a root canal[45].

In this study, some of the naturally obtained drugs which have been reported to have utility as intracanal medications and in other endodontic treatments are Curcumin, Propolis, *Aloe Vera*, Neem extracts, and Tulsi oil. Their broad mechanisms and pharmacological actions are summarized in Table 2. Recent advancements in intracanal medicament are adumbrated in Figure 1.

Table 2 Pharmacological properties of natural intracanal medicaments[58]

Pharmacological activity	Biological source
Analgesics and anti-inflammatory action	*Curcuma longa, Arctium lappa, Propolis, Azadirachta indica, Casearia sylvestris, Allium sativum, Citrus limonum, Carica papaya, Morinda citrifolia, and Glycyrrhiza glabra, Triphala, Ocimum sanctum, Eucalyptus oil*
Anti-microbial action	*C. sylvestris, M. citrifolia, Propolis, and Glycyrrhiza glabra, Curcumin, Propolis, Aloe vera, Ocimum sanctum, Eucalyptus oil*
Antioxidants	*Curcumin, Grape seed extracts, Quercetin, Morinda citrifolia*
Anti-anxiety	*Arctium lappa*
Anti-fungal	*Ocimum sanctum, Azadirachta indica*
Anti-viral	*Glycyrrhiza glabra, Aloe vera, Ocimum sanctum, Morinda citrifolia*

C. sylvestris=casearia sylvestris

Figure 1 Various sources of intracanal medicaments

Conclusion

Intracanal medicaments play a crucial role in pediatric dentistry by aiding in the disinfection and healing of root canals in primary teeth. Through their antimicrobial properties, they effectively combat bacterial infections, reduce inflammation, and promote the preservation of primary dentition. However, it's essential to recognize the unique considerations of pediatric patients, such as their smaller tooth size and the potential systemic effects of medicaments, necessitating careful selection and administration under professional supervision. Despite the challenges, the judicious use of intracanal medicaments remains a valuable tool in ensuring the long-term oral health and well-being of young dental patients. Continued research and advancements in this area hold promise for further enhancing treatment outcomes and minimizing potential risks, thereby contributing to the overall success of pediatric dental care. Further research and clinical trials are warranted to elucidate the full therapeutic potential of herbal intracanal medicaments and their integration into pediatric endodontic practice.

Authors' contributions

Authors SA and SG designed and performed the study, RO and AS contributed to proofing and the literature search. All authors also contributed to manuscript writing.

Ethical considerations

Since this was a literature review, no ethical clearance was required. However, we followed all ethical guidelines and practices for the study.

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Conflict of interest

There are no conflicts of interest to report.

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