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Intracanal irrigants in pediatric endodontics: A review

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Abstract
Bacteria are the major cause of pulpal and periapical diseases. Complexity of the root canal system and formation of smear layer during instrumentation of root canal are the major obstacles for complete elimination of bacteria during cleaning and shaping of root canal systems. The bacterial population of infected root canals can be significantly reduced by using saline irrigation; however, irrigants that have antibacterial effects have clearly superior effectiveness in bacterial elimination when compared with saline solution. The irrigants that are most commonly used include saline, sodium hypochlorite, chlorhexidine, EDTA and MTAD. None of the irrigants has optimal properties to be termed an ideal irrigant. Different irrigating solutions reported in literature have been reviewed here.

Keywords: Root canal irrigants, primary tooth, smear layer

Introduction
Primary teeth are also as important as permanent teeth for the harmonious development of occlusion, maintenance of arch length, mastication and speech. Endodontic therapy helps to preserve and maintain function of severely carious primary teeth. Successful root canal therapy relies on the combination of proper instrumentation, irrigation and obturation of the root canal. Intracanal irrigants can augment mechanical debridement by flushing out debris, dissolving tissue and disinfecting the root canal system [1]. Irrigants play a major role in pediatric endodontics because of the bizarre internal geometry and features like internal connections and horizontal anastomoses seen in primary teeth [2].

Microorganisms present within an asymptomatic root canal differs from those within a clinically symptomatic root canal. The most prevalent bacterial species in infected root canals of primary teeth have been found to be *Enterococcus faecalis, Porphyromonas gingivalis* and *Treponema denticola* [3].

The ideal requisites of a root canal irrigant as given by Zehnder are: [4]

1. Broad antimicrobial spectrum
2. High efficacy against anaerobic and facultative microorganisms organized in biofilms
3. Ability to dissolve necrotic pulp tissue remnants
4. Ability to inactivate endotoxin
5. Ability to prevent the formation of a smear layer during instrumentation or to dissolve the latter once it has formed.
6. Systemically nontoxic when they come in contact with vital tissues, noncaustic to periodontal tissues, and with little potential to cause an anaphylactic reaction.

Since no single irrigant has these optimal properties, studies have reported the use of two or more solutions in a specific sequence or in combinations for better results.

Normal Saline
Normal saline is isotonic to the body fluids. It is universally accepted as the most common irrigating solution in all endodontic and surgical procedures. It is also found to have no side effects, even if pushed into the periapical tissues [5]. However, saline should not be the only solution to be used as an irrigant, it is preferably used in combination with or used in between irrigations with other solutions like sodium hypochlorite [6].

Sodium Hypochlorite
Henry Drysdale Dakin and the surgeon Alexis Carrel popularized the use of buffered 0.5% NaOCl solution for the irrigation of infected wounds [7].

NaOCl is a weak alkali that acts on the albumin (remains of pulpal tissue, foods and microorganisms), denaturing them and turning them soluble in water. It acts on microbial cells disrupting their vital functions leading to cell death [8].

The most effective irrigation regimen is reported to be 5.25% at 40 minutes [9]. Irrigation using 1.3% and 2.5% NaOCl for this same time interval is ineffective in removing *E faecalis* from infected dentin [10].

Altering the pH, temperature and use of ultrasonic agitation increases the efficacy of NaOCl. Pure hypochlorite solutions, as are used in endodontics, have a pH of 12 [11].

Bloomfield and Miles confirmed that hypochlorites possess greater antimicrobial activity at a lower pH [12].

Rising temperature by 25 °C increases efficacy by a factor of 100 [13].

The dissolution power of 1% NaOCl at 45 °C is equivalent to that of a 5.25% solution at 20 °C [14].

Sonic irrigant activation and ultrasonic irrigation with a nickel-titanium tip increases the effectiveness of 5% NaOCl in the apical third of the root canal [15].

A study evaluating effects of sodium hypochlorite on nickel-titanium lightspeed instruments concluded that no significant corrosion of NiTi files in these solutions was detected. NaOCl irrigation leads to decreased bond strength between dentin and resin cements. Certain reversal agents like ascorbic acid or sodium ascorbate reverse this reduction in bond strength completely [16].

The antimicrobial effect of 2.5% NaOCl used in combination with 0.2% chlorhexidine (CHX) was greater than that of either agent used separately. But a carcinogenic product parachloroanaline (PCA) is produced by the reaction between NaOCl and CHX and the possibility of its leakage into the surrounding tissues is a concern [17].

Though NaOCl is widely used as an irrigant in endodontics, it has an unpleasant taste and odour, removes the smear layer only partially, does not consistently disinfect the root canal, is toxic to the periradicular tissues and damages the permanent tooth follicle, peripheral tissues and oral mucosa [18].

Hydrogen peroxide

Hydrogen peroxide is widely used in disinfection and sterilization [19]. It is being used in dentistry in concentrations varying from 1% to 30%. H_2O_2 creates effervescence which facilitates debris removal, acts as an oxidizing agent and is capable of denaturing bacterial proteins and DNA. But in higher concentrations, it is not well tolerated and has the potential of causing cervical resorption [20].

Chlorhexidine Gluconate (CHX)

Chlorhexidine 2% is also commonly used as root canal irrigant, but it completely lacks tissue dissolving capability [21]. CHX antimicrobial activity is pH dependent, with the optimal range being 5.5–0.7. 2% CHX is significantly effective against root canal pathogens like *Actinomyces israelii and Enterococcus faecalis* [22, 23].

Two studies evaluating the antimicrobial activity of two forms of CHX (gel and liquid) of three different concentrations (0.2%, 1%, and 2%) found that the 2% gel and 2% liquid formulations of CHX eliminated *Staphylococcus aureus* and *Candida albicans* in about 15 seconds, whereas the gel formulation killed *E faecalis* within 1 minute. All the tested irrigants eliminated *Porphyromonas endodontalis*, *Porphyromonas gingivalis* and *Prevotella intermedia* in 15 seconds [24, 25].

At low concentrations, small molecular weight substances like potassium and phosphorus leak out resulting in a bacteriostatic effect of chlorhexidine gluconate. At high concentrations, there is a bactericidal effect due to the precipitation and/or coagulation of the cellular cytoplasm, probably caused by cross-linking proteins [26].

Reaction of CHX and EDTA forms a precipitate that is more than 90% CHX and EDTA and only less than 1% of the decomposition product, p-chloroaniline. The clinical significance of this precipitate is largely unknown [27].

CHX has little or no effect in disrupting biofilm [28].

White *et al*. reported the substantivity of 2% CHX solution to last about 72 hours [29]. Khademi *et al*. stated that a 5 minute application of 2% CHX solution induced substantivity for up to 4 weeks [30]. Rosenthal *et al* found that after a 10minute application the substantivity was up to 12 weeks [31]. Antimicrobial substantivity depends on the number of chlorhexidine molecules available for interaction with dentine [21].

Because of its broad-spectrum anticollagenolytic activity, CHX can significantly improve the resin–dentine bond stability [1].

In the clinically used concentrations, CHX has optimal biocompatibility. But in bactericidal concentrations it is lethal to canine embryonic fibroblasts while non-cytotoxic concentrations aids survival of bacteria [32].

Khademi *et al* contradicts the use of CHX as a final irrigant in endodontic procedures stating its limited effect on gram negative bacteria compared to its effect on gram positive bacteria [33].

EDTA (**Ethylenediamine tetraacetic acid**)

Most commonly used as 17% neutralized solution, EDTA is a chelating agent used for the removal of the inorganic portion of the smear layer. Continuous rinse with 5 ml of 17% EDTA, as a final rinse for 3 min efficiently removes the smear layer from root canal walls [34].

EDTA reacts with the calcium ions in dentine and forms soluble calcium chelates. Hence, exposure for longer duration can cause excessive removal of both peritubular and intratubular dentin [35].

It was reported that EDTA when used as a root canal irrigant in primary teeth, it removed the smear layer but adversely affected the dentinal tubules [36].

The similar type of damage was also noted in permanent teeth studies [35].

MTAD (Mixture of tetracycline isomer, acid and detergent**)**

Torabinejad *et al*. developed an irrigant with combined chelating and antibacterial properties. MTAD is a mixture of 3% doxycycline, 4.25% citric acid, and detergent (Tween-80) [37].

In this formulation, the citric acid may serve to remove the smear layer, allowing doxycycline to enter the dentinal tubules and exert an antibacterial effect. The most recommended protocol for clinical use of MTAD advises an initial irrigation for 20 minute with 1.3% NaOCl, followed by a 5-minute final rinse with MTAD [38]. MTAD has exhibited superior antimicrobial efficacy with significant reduction of *E.faecalis, P.intermedia* and *T.forsynthenis* and also eliminated bacteria from the root canals infected with whole saliva [39].

MTAD has been shown to be less cytotoxic compared to intracanal irrigants like EDTA and hydrogen peroxide [40].

Citric acid
Citric acid in concentrations ranging from 1% to 50% has been used for smear layer removal [41].
Though citric acid is found to be more biocompatible than other irrigants like EDTA it was found to be ineffective in eradication of biofilms of *E faecalis* after 1, 5, and 10 min of exposure [42, 43].

Maleic acid
Maleic acid is a mild organic acid used as an irrigant. Final irrigation with 7% maleic acid for 1 minute was more efficient than 17% EDTA in the removal of smear layer from the apical third of the root canal system [44].

HEBP (1-hydroxyethylidene- 1, 1-bisphosphonate)
Also known as etidronic acid or etidronate. It is a potential alternative to EDTA or citric acid because this shows no short-term reactivity with NaOCl [45].

Silver diamine fluoride
A 3.8% w/v silver diamine fluoride solution has been used for intracanal irrigation. $Ag(NH_3)_2F$ has potential for use as an antimicrobial root canal irrigant or interappointment medicament to reduce bacterial loads. 60 minutes exposure to $Ag(NH_3)_2F$ completely killed *E faecalis*, but silver particles occluded dentinal tubular orifices after removal of the smear layer [46].

Tetraclean
Tetraclean is a mixture of doxycycline hyclate, an acid and a detergent. It is similar to MTAD but with a reduced amount of doxycycline (50mg/5ml instead of 150mg/5ml for MTAD), with polypropylene glycol (a surfactant), citric acid and cetrimide. A final 5-minute rinse is recommended to eliminate microorganisms and smear layer. Tetraclean caused a high degree of biofilm disgregation in every considered time interval (5, 30, and 60 min at 20 °C) as compared with MTAD [47].

Triclosan and Gantrez
Triclosan is a broad spectrum antimicrobial agent, which acts against gram-positive and gram-negative bacteria as well as some fungi and viruses. The addition of Gantrez enhanced the bactericidal activity of triclosan. Triclosan alone and in combination with Gantrez demonstrated bactericidal activity against the five specific endodontic pathogens *P intermedia, F nucleatum, A naeslundii, P gingivalis,* and *E faecalis* [48].

Smear clear
Smear Clear (SybronEndo, Orange, CA, USA) is a recently introduced chelating agent that contains 17% EDTA solution with two additional proprietary surfactants [49]. Smear Clear contains cetrimide, which is a quaternary ammonium compound and a cationic detergent that is effective against gram positive and gram negative microorganisms, hence it has been found to be effective against *E.fecalis* [50].
All the studies that have evaluated this product have used it for 1 minute as per according to the manufacturer's instructions [49].

Ethanol
95% ethanol has been studied as a final irrigant before obturation in primary teeth [51]. It was used as a drying agent. Zmener *et al* observed less leakage of dye in canals that were dried with 95% ethanol [52].
Stevens *et al* stated that 95% ethyl alcohol used as a final rinse increased sealer penetration and decreased leakage in permanent root canals [53].

EndoVac System
The EndoVac system (Discus Dental, Culver City, Calif.) is a new irrigation system that consists of a delivery/evacuation tip attached to a syringe of irrigant and the high-speed suction source of the dental unit. As the cannulas are placed in the canal, negative pressure pulls irrigant from a fresh supply in the chamber down into the canal to the tip of the cannula, then into the cannula and finally out through the suction hose [54].

Aqueous Ozone
Ozone is one of the new generations of the disinfectant and a powerful oxidizing agent used to eliminate bacteria in root canals [55]. Ozone has shown antimicrobial efficacy against resistant pathogens by neutralizing them or preventing their growth [56]. Even at as low concentrations as 0.1ppm ozone is capable of deactivating bacterial cells including their spores [2].
One of the most advantageous properties of aqueous ozone is its nontoxicity to oral cells. However, the most important disadvantage of aqueous ozone is its unstable concentration in a long time.

QMix
QMix 2 in 1 solution is a newly introduced irrigation solution developed and marketed by Dentsply Tulsa Dental Specialties, Tulsa, OK, USA. It contains a mixture of a bisbiguanide antimicrobial agent chlorhexidine (CHX), a polyaminocarboxylic acid calcium-chelating agent Ethylenediaminetetraacetic acid [ethylenediaminetetraacetic acid (EDTA)], and a surfactant cetrimide mixed in distilled water with acceptable additional salt. It is recommended as final irrigant during root canal procedures. It eradicates bacteria, removes smear layer, and persists in biofilms. It has pH slightly above neutral [57].

Herbal irrigants
Azadiracta indica (Neem) [58, 59, 60, 61], *Curcuma longa* (turmeric) [62, 63, 64], *Myristica fragrans (nutmeg)* [62, 65], *Terminalia chebula* (Myrobolan) [62], *Aloe barbadensis (*Aloe vera*)* [62, 66], *Morinda citrifolia (Noni)* [58], green tea [58, 66], *Spilanthes acmella (anti-toothache plant)* [67], German chamomile [68], propolis [69, 70, 71], miswak [71] are some of the natural products that have been studied as intracanal irrigants.
Triphala is an Indian herbal formulation consisting of dried and powdered fruits of three medicinal plants namely *Terminalia bellerica, Terminalia chebula* and *Emblica officinalis. Triphala* achieved 100% killing of *E faecalis* at 6 minutes [72].
Ethylene glycol bis [b-aminoethylether] N,N,N=,N=-tetraacetic acid (EGTA), EDTA plus Cetavlon (EDTAC), tetracycline-HCl [73], carbolic acid solution and carisolv [74] have also been studied as potential irrigants for endodontic treatment of deciduous teeth.

Conclusion
Successful root canal therapy depends on thorough chemomechanical debridement of root canal. Irrigants can augment mechanical debridement by rinsing out debris, dissolving tissue and disinfecting the root canal system. Significance of chemical debridement increases for teeth with complex internal anatomy such as tortuous canals or other irregularities that might be missed by mechanical

instrumentation. Root canal instrumentation produces a smear layer consisting of organic and inorganic components that cover the root canal surfaces. Irrigation plays an important role in successful debridement and disinfection. Most commonly used root canal irrigants are normal saline and sodium hypochlorite. Physiological saline has no effect on removing dentinal debris and smear layer and sodium hypochlorite is not effective in removing the smear layer and can be harmful to the peripheral tissues. Researches are still under way on to scientifically validate an irrigant solution with ideal characteristics.

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