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Review Article

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Root Canal Irrigants in Pediatric Dentistry: A Literature Review & Update

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Abstract

Successful root canal treatment is dependent on the removal of microorganisms from the pulp and other anatomical irregularities of the root canal system. However, complete elimination of bacterial contaminants as well as necrotic debris require adjunctive use of root canal irrigants along with mechanical instrumentation. Irrigants can augment mechanical debridement byflushing out debris, dissolving tissue, and disinfecting the root canal system. Chemical debridement is especially needed for primary teeth with complex internal anatomy and zones inaccessible to debridement, such as accessory canals, ramifications, and dentinal tubules that might be missed by instrumentation. None of the available irrigating solutions alone provides all the ideal requirements. Studies have shown that a combination of two or more irrigating solutions in a specific sequence will help to achieve optimal irrigation. This review article mainly highlights the mechanism of action, safety and biocompatibility of currently used irrigation solutions and also the other materials that can be used

as a potent irrigants, their advantages and limitations infuture.

Keywords:Root canal irrigants, primary tooth, smear layer, dentin permeability, antimicrobialproperties.

Introduction

The success of endodontic therapy in primary teeth strongly depends on achieving an adequate level of disinfection within their root canals[5]. Mechanical instrumentation alone is unlikely to be sufficient in attaining such disinfection, considering the root resorption process and the complex anatomy of the root canal system, characteristic of primary molars, and the risk of damage to the permanent germ[6 7]. Evidence has shown that the mechanical instrumentation technique with files is limited because it tends to leave significant portions of the infected canal walls untouched; thus, an important number of viable pathogenic microorganisms persist, lodged together with dentin debris and necrotic pulp-tissue remnants inside the dentin tubules, canal ramifications, and resorption craters[8]. Therefore, it is necessary to significantly reduce or to eradicate, to the extent possible, the microorganisms and their by-products present to the pulp canals byemploying clinically effective and biocompatible irrigants, which also aid in dissolving organic debris[9]. Irrigation currently represents the best method in paediatricpulpectomy for the lubrication and flushing away of loose necrotic and contaminated materials during instrumentation[10].

RATIONALE FOR USING ROOT CANAL IRRIGANTS

While various chemical and physical irritants can cause irritation and even necrosis of the pulp, the most common causes for pulpal inflammation (pulpitis) are bacteria and/or their products entering the pulp through a deep caries lesion or a leaking filling, e.g. an inflammatory reaction in the pulp starts long before bacteria invade the pulp tissue. The inflammatory reaction is first initiated by bacterial antigens interacting with the local immune system**.** Although no exact data are available, it is likely that the majority of bacteria inmost primary

Sr No.	Category	Agents	Ingredients	Major Advantage(s)
1	Antiseptic and/or Disinfectant	Sodium Hypochlorite	0.5-5.25% available chlorine	Tissue dissolution and antimicrobial Antimicrobial
2	Antiseptic and/or Disinfectant	Chlorhexidine Gluconate	0.1-2.0% Chlorhexidine Gluconate	
3	Oxidizing agents	Hydrogen Peroxide	3% Hydrogen Peroxide	Effervescence with NaOCl (beneficial effect in the canal questionable)
4	Oxidizing agents	Urea Peroxide (Endo-PTC)	10% Urea Peroxide, 15% Tween 80 and 75% Carbowax	Good wetting ability, excellent lubricant
5	Oxidizing agents	Urea Peroxide (Gly-Oxide)	10% Carbamide peroxide in glycerol	Good wetting ability, excellent lubricant

6	Chelating agent	Ethylenediamine	10–17% recommended	Softens dentine and removes (partially)

root canal infections are located in the main root canal, while a minority of the cells would have invaded further into the dentinal tubules and lateral canals In root canal treatment, cleaning is the removal of all contents of root canal system before and during shaping. Irrigation is presently the best method for lubrication, destruction of microbes, the removal of tissue remnants, and dentin debris during instrumentation. The simple act of irrigation allows the flushes away loose, necrotic, contaminated materials before that they are inadvertently pushed deeper into the canal and apical tissues, compromising the periapical tissue and permanent bud. In this context, the use of cleansers in the irrigation process is essential.[1]

IDEAL REQUISITES OF A ROOT CANAL IRRIGANT

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

- Broad antimicrobialspectrum
- High efficacy against anaerobic and facultative microorganisms organized inbiofilms
- Ability to dissolve necrotic pulp tissueremnants
- Abilityto inactivateendotoxin.
- Ability to prevent the formation of a smear layer during instrumentation or to dissolve the latter once it hasformed.
- Systemically nontoxic whenthey come in contact with vital tissues, noncausticto periodontal tissues, and with little potential to cause an anaphylacticreaction.

TABLE 1: Root canals cleansers, which have been studied, for use in endodontic treatment.[2]

		Tetra Acetic Acid		smear layer
7	Chelating agent	EDTAC	EDTA with Cetrimide/Cetavlon	Good wetting ability for EDTAC preparations
8	Chelating agent	RC-Prep	EDTA and Urea Peroxide in a base of carbowax	Excellent lubricant
9	Organic Acid	Citric acid	10-50% recommended	Removes smear layer
10	Organic Acid	Polyacrylic acid	5-20% recommended	Removes smear layer
11	Organic Acid	Tannic acid	25% solution	Removes smear layer

EFFICACY OF CLEANSERS

In root canal treatment, cleaning is the removal all contents of root canal system before and during

shaping. Irrigation is presently the best method for lubrication, destruction of microbes, the removal of tissue remnants, and dentin debris during instrumentation. The simple act of irrigation allows the flushes away loose, necrotic, contaminated materials before that they are inadvertently pushed deeper into the canal and apical tissues, compromising the periapical tissue and permanent bud. In this context, the use of cleansers in the irrigation process is essential[12]. Many researchers have studied the effect of several cleansers on the permeability of the dentine using methods that involve bacteria or radioisotopes, with

different methodologies. Those cleansers have been used with the objective of eliminating pulpal remains and residues. In addition, they increase the dentin permeability (removing the smear layer), facilitate the instrumentation and promote the cleaning and disinfection of the root canals[13-21]. In addition, they should be soluble in water and biocompatible to the periapical tissues[22].

VARIOUS ROOT CANAL IRRIGATING SOLUTIONS

1. NORMAL SALINE[4]
   - 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. 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.
2. SODIUM HYPOCHLORITE(NaOCl)[1]
   - Henry Drysdale Dakin and the surgeon Alexis Carrel popularized the use of buffered 0.5% sodium hypochlorite solution for the irrigation of infected wounds.
   - Sodium hypochlorite 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.
   - The most effective irrigation regimen is reported to be 5.25% at 40 minutes. Irrigation using 1.3% and 2.5% sodium hypochlorite for this same time interval is ineffective in removing *E faecalis* from infected dentin.
   - Altering the pH, temperature and use of ultrasonic agitation increases the efficacy of sodium hypochlorite. Pure hypochlorite solutions, as are used in endodontics, have a pH of 12.
   - Bloomfield and Miles confirmed that hypochlorites possess greater antimicrobial activity

at a lower pH.

- Rising temperature by 25 °C increases efficacy by a factor of 100.
- The dissolution power of 1% sodium hypochlorite at 45 °C is equivalent to that of a 5.25% solution at 20°C.
- Sonic irrigant activation and ultrasonic irrigation with a nickel-titanium tip increases the effectiveness of 5% sodium hypochlorite in the apical third of the root canal.
- A study evaluating effects of sodium hypochlorite on nickel-titanium lightspeed instruments concluded that no significant corrosion of nickel-titanium files in these solutions was detected. Sodium hypochlorite 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.
- The antimicrobial effect of 2.5% sodium hypochlorite used in combination with 0.2% chlorhexidine was greater than that of either agent used separately. But a carcinogenic product parachloroanaline (PCA) is produced by the reaction between sodium hypochlorite and chlorhexidine and the possibility of its leakage into the surrounding tissues is a concern.
- Though sodium hypochlorite 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.

3. CHLORHEXIDINE GLUCONATE[2]

- Chlorhexidine Gluconate, currently used in endodontic therapy, seems to act by adsorbing onto the cell wall of the microorganisms and causing leakage of the intracellular components. At low concentrations, small molecular weight substances will leak out, especially potassium and phosphorus, resulting in a bacteriostatic effect. At high concentrations, chlorhexidine gluconate has a bactericidal effect due to the precipitation and/or coagulation of the cellular cytoplasm, probably caused by cross-linking proteins.
- Vahdaty et al. evaluated in vitro the antibacterial efficiency of 2% and 0.2% chlorhexidine, comparing them with sodium hypochlorite in the same concentrations. These cleansers were used in the infected dentin tubules. The results indicated that both substances reduced the number of bacteria in the superficial layers of the

dentintubules.

- Heling and Chandler and White et al. suggested that chlorhexidine can be an excellent antimicrobial endodontic irrigating agent if used alone, or as an auxiliary to sodium hypochlorite during the instrumentation. ChlorhexidineGluconate showed quick residual antimicrobial activity in these *in vitro*studies.
- Gomes et al. evaluated the antimicrobial activity of the two formulations of ChlorhexidineGluconate (liquid and gel) in three concentrations (0.2%, 1.0% and 2%), and of sodium hypochlorite (0.5%, 1.0%, 2.5%, 4.0%). The results showed that chlorhexidine in liquid form eliminated bacterial cells more quickly than the chlorhexidine gel. Even though all tested cleansers possessed antimicrobial activity, the time required to eliminate the studied microorganisms depended on the concentration and of the type of cleansersused.
- Ferraz et al. evaluated 2% chlorhexidinegluconate gel as an endodontic irrigating agent according to its capacity to disinfect root canals contaminated with *Enterococcus faecalis.* Furthermore, they tested chlorhexidine gel cleaning capacity when compared with 5.25% sodium hypochlorite and 2% chlorhexidinegluconate solution. The results demonstrated that the chlorhexidine gel produced cleaning of the surface of the root canal and presented antimicrobial capacity comparable with the other appraised solutions. It could be concluded that chlorhexidine gel has satisfactory potential to be used as an endodontic irrigating agent. Most of the studies have been undertaken on permanent teeth in vitro, demonstrating the properties of the cleanser used for the instrumentation of those canals. This literature review found only two studies regarding primary teeth and root dentin permeability.
- Bengtson et al. concluded that urea peroxide/Dakin's liquid showed the highest dye penetration index of primary root dentin permeability. Primo verified that 1% sodium hypochlorite associated with 10% citric acid was the most effective association to remove the smear layer of anterior primary teeth, followed by the associations urea peroxide/Dakin´s liquid and 4% sodium hypochlorite /3% hydrogen peroxide. All of these solutions produced an increase in the primary dentin permeability. Therefore, other researches should be undertaken to indicate an effective substance for the chemical-mechanic preparation of primary teeth, as well as to verify the physiochemical properties

of treatment solutions, providing greater sanitation and appropriate preparation of the rootcanals.

4. ETHYLENEDIAMINE TETRAACETIC ACID(EDTA)$^{2-}$

- Ethylenediamine Tetra Acetic Acid is a chelating substance capable of removing calcium ions of the dentin, giving rise to demineralization and as a consequence, increasing the dentin permeability of the root canals. Ethylenediamine Tetra Acetic Acid is used in concentrations from 10 to 17% and in association with other drugs. The efficiency of chelating agents generally depends on many factors, such as root canal length, penetration depth of the material, hardness of the dentin, application time, pH, andconcentration. Nakashima and Teratoobserved that the permeability of root canal disinfectants increased to similar degrees in the 3% and the 15% ethylenediamine tetra acetic acid groups. Comparing dentin properties, they propose that 3% ethylenediamine tetra acetic acid is more useful for clinical applications.
- Zuolo et al. found that the most effective combination to increase root dentin permeability was ethylenediamine tetra acetic acid associated with Cetavlon(EDTAC).
- Tao et al. verified that ethylenediamine tetra acetic acid did not modify the root dentin permeability. They suggest that the absence of changes in the root dentin permeability with a conventional endodontic preparation was due to the fact that, even though endodontic preparation reduces dentin thickness, it also created a smear layer that compensated to the extent that there was no overall change in permeability. A new chelating agent (Glyde File Prep) containing ethylenediamine tetra acetic acid has been proposed for permanentteeth.
- Grandini et al. evaluated the smear layer, debris, and tubule orifices of root canal walls after being instrumented and irrigated by Glyde File Prep, using a scanning electron microscope. The results of this study confirm that irrigation with sodium hypochlorite alone was not able to remove totally the smear layer, because its action is mainly directed to the organic debris. To obtain the total removal of the smear layer, that is, both organic and inorganic components, the combined use of sodium hypochlorite and ethylenediamine tetra acetic acid is recommended. The chelating agent prepares the canal wall surfaces so that cleansers and medications are effective with their antibacterial action. One of the most effective drugs for removing the smear layer is RC-Prep

(ethylenediamine tetra acetic acid /Urea Peroxide). It is a potent bactericidal agent and increases the dentin permeability significantly.

- Others substances (organic acids) have been used to remove the smear layer, such as 6 - 10% citric acid, 20% polyacrylic acid, and tannic acid. Salamaand Abdelmegid found that irrigation with 6% citric acid for 15 or 30 seconds was effective in removing all smear layer components of the primary root canals. However, further researches are needed to investigate the biocompatibility of acids and to test combinations of solutions. Moreover, these acids could have a harmful effect on the periapical tissues of both permanent and primary teeth.

5. UREA PEROXIDE[2]

- Another widely used solution to aid instrumentation is Urea Peroxide (Endo-PTC or Gly-Oxide). The peroxides are oxidizing agents that react chemically, liberating great amounts of nascent oxygen that explains their bactericidal action. The effervescence, due to the liberation of oxygen, contributes to the removal of pulp tissue remains and dentin particles during the chemical-mechanic preparation.
- In Brazil, the trade name of Urea Peroxide is Endo-PTC (10% Urea Peroxide, 15% Tween 80 and 75% Carbowax).
- International literature points out that Urea Peroxide is marked as Gly-Oxide commercial brand. It is anhydrous glycerol based, without any added detergent.
- Moura and Paiva using Endo-PTC as an auxiliary chemical substance, observed less dye penetration with instrumentation increasing, mainly in the apical area. The Urea Peroxide has several desirable characteristics for the irrigation of root canals in primary teeth. It presents detergent and haemostatic properties, besides not being irritating to the periapical tissues and non allergenic.
- Stewart et al. and Rome et al. observed that the bactericidal activity of the Urea Peroxide (Gly- Oxide) was superior to 3% Hydrogen Peroxide in the preparation of infected root canals. The association of Urea Peroxide/sodium hypochlorite maintains the previously described properties.
- According to Rome et al., the use of Urea Peroxide is the first choice cleanser in small curved canals. Its properties of lubrication without demineralization the dentin walls avoid the risks of root perforation, common in primary teeth. The association of Urea

Peroxide with sodium hypochlorite promotes significant more increase in the dentin permeability index to dye and drugs than when used separately. In spite of promoting increase in the dentin permeability, the association of Urea Peroxide/sodium hypochlorite showed less effectiveness in removing the smear layer. In contrast, it is known that the smear layer reduces dentin permeability, and prevents the penetration of root canal disinfectants into the deep area of the root canal wall.

6. MIXTURE OF TETRACYCLINE ISOMER, ACID, AND DETERGENT(MTAD)[3]

- Biopuremtad has been introduced to dentistry as a final irrigant for smear layer removal. Mtad has been proved to be effective in eliminating resistant microorganisms and providing sustained antimicrobial activity. Minimal erosion of intra-radicular dentin has been reported after final canal irrigation with mtad.
- Torabinejad *et al*. developed a irrigant with combined chelating and antibacterial properties. Mtad (a mixture of tetracycline isomer, acid, and detergent, biopure, tulsadentsply, tulsa ok, usa) is a new product in the quest for a better root canal irrigant, with a phas low as 2.15. In their study, the above authors used this new irrigant, focusing on the removal of smear layer, extracted single-rooted teeth were prepared by using passive stepback and rotary 0.04 taper niti files. Distilled water or 5.25% sodium hypochlorite was used for irrigation followed by 5ml irrigation with one of the following: sterile distilled water, 5.25% sodium hypochlorite, 17% ethylenediamine tetra acetic acid, or mixture of tetracycline isomer, acid, and detergent. The results indicated that mtad is an effective solution for the removal of the smear layer and does not significantly change the structure of the dentinal tubules, when canals are first irrigated with sodium hypochlorite, followed by a final rinse of mixture of tetracycline isomer, acid, and detergent. Mixture of tetracycline isomer, acid, and detergent is an irrigant solution with ingredients capable of disinfecting the dentin, removing the smear layer, opening the dentinal tubules and allowing the antibacterial agents to penetrate the entire root canal system.
- In another study, the same group investigated the effect of various concentrations of sodium hypochlorite as an intracanal irrigant before irrigation with mixture of tetracycline isomer, acid, and detergent as a final rinse on the smear layer. The results showed that mtad removed most of the smear layer when used alone; however, remnants of the

organic component of the smear layer could be detected on the root canal walls. There were no significant differences between the ability of 1.3%, 2.6%, and 5.25% sodium hypochlorite as root canal irrigants and mtad as a final rinse to remove the smearlayer.

7. CITRIC ACID[3]

- Citric acid can also be used for irrigation of the root canal to remove the smear layer. Concentrations ranging from 1% to 50% have been used. The use of 10% citric acid as final irrigation has shown good results in smear layer removal and proven to be more biocompatible than 17% EDTA-T and 17% ethylenediamine tetra aceticacid.
- Gutmann et al showed that 10% citric acid was more effective in removing the smear layer from apical root-end cavities thanultrasound.
- Yamaguchi et al compared the chelating and antibacterial properties of citric acid andethylenediamine tetra acetic acid. Powdered dentine–resin mixture was found to be more soluble in a 0.5, 1, and 2M citric acid solutions than in a 0.5M ethylenediamine tetra acetic acid solution. Citric acid solution showed antibacterial effects on all 12 root canal bacteriatested.
- Di Lenarda et al and Scelza et al reported a minor or no difference in smear layer removal with citric acid and 15% ethylenediamine tetra acetic acid. The use of 25% citric acid was found to be ineffective in eradication of biofilms of *E faecalis* after 1, 5, and 10 minsofexposure.
- Machado-Silveiro et al measured the demineralization capability of 1% and 10% citric acid, 10% sodium citrate and 17% ethylenediamine tetra acetic acid during immersions of 5, 10 and 15 min on root canal dentine. Ten percent citric acid was more effective than 1% citric acid, which was more effective than ethylenediamine tetra aceticacid.
- Hariharan et al conducted an in vitro study to determine the efficacy of 5.25% sodium hypochlorite, 5.25 sodium hypochlorite + 10% ethylenediamine tetra acetic acid, 6% citric acid and 2% chlorhexidine and saline (control) in removing the smear layer in primary teeth root canals after hand instrumentation. They showed the superior efficacy of 6% citric acid than the other tested irrigantson removing the smear layer in primary teeth. Both ethylenediamine tetra acetic acid and citric acid can effectively remove the smear layer created during canal instrumentation. Although citric acid may also have an antibacterial effect, this has not been compared with other root canal disinfecting agents

in in vitro or in vivostudies.

8. OZONATED WATER[4]

- Ozone is a chemical compound consisting ofthree oxygen atoms (O3-triatomic oxygen), which has higher energetic form than normal atmospheric oxygen. Ozone is capable of oxidizing any biological entity due to its powerful bactericidal properties where even at low concentration, (0.1 ppm), it is capable of inactivating bacterial cells including their spores. Although it is a powerful antimicrobial agent, less attention has been paid to its antibacterial activity on bacterial biofilm and hence in root canalinfection.
- Studies have found that when the specimen was irrigated with sonication killing ability of ozonated water and 2.5% sodium hypochlorite was almost comparable. However, it was found that effecton

  *E. faecalis*was more with sodium hypochlorite than ozonated water in broth culture and in biofilm. Hence concluded that there is need for further studies and modifications in ozonated water before it could be used as a root canal irrigant.

  Photon activated disinfection (PAD): Photon activated disinfection is based on the concept where light of the appropriate wavelength is used to preferentially localize the nontoxic photosensitizers to generate singlet oxygen and free radicals that are cytotoxic to cells of the target tissue. Blue dyes, especially toluidine blue and methylene blue used with a 632.8 nm wavelength laser have shown significant result. A study in primary teeth showed a microbial reduction of 98.37% after using photodynamic therapy. Thus in future photon activated disinfection could bea low-cost and nontraumatic alternative to other irrigants to be used in today's treatment of primaryteeth.

9. CARISOLV[4]

- Carisolv contains 0.5% sodium hypochlorite along with amino acids. Thus it was hypothesized that this agent can also be effective in removal of smear layer in root canal when used as anirrigant.
- The mode of action is to degrade the denaturedcollagen.
- A study which compared carisolv with 17% ethylene diaminetetraacetic acid and 5.25% sodium hypochlorite in removing layer on radicular dentin showed that carisolv was ineffective in removal of smear layer. The reason attributed was because it was in gel form which made it difficult to wet and flushthecanals.

- A study was done to compare the efficacy of carisolv, 1% sodium hypochlorite gel, and 1% sodium hypochlorite solution as root canal irrigants in primary teeth showed that carisolv was better compared to sodium hypochlorite gel in cleaning the debris at the apical third and hence concluded that carisolv can be used as an effective root canalirrigant.

10. TETRACLEAN[4]

- Tetraclean is a mixture of an antibiotic, an acid (citric acid), and a detergent (polypropylene glycol). The concentration of citric acid and the type of detergent used varies from that of a mixture of tetracycline isomer, acid, and detergent. The properties of tetraclean are due to its low surface tension which enables better adaptation of the mixtures to the dentinal walls. It removes the smear layer, effective against strictly anaerobic and facultative anaerobic bacteria like *E.faecalis*.

11. ELECTROCHEMICALLYACTIVATED SOLUTIONS[4]

- A mixture of tap water and low concentrated salt solutions forms the electrochemically activated (ECA) which results in synthesis of Anolyte, and Catholyte. The oxydizing substances of anolyte exhibits microbicidal activity against bacteria, viruses, fungi and protozoa and therefore termed Superoxidized Water or Oxidative Potential Water. Due to its various advantages like ease of removal of debris and smear layer even at the apical third as well as its nontoxic properties it can be used as a potent root canalirrigant.
- A study showed that Oxidative Potential Water was as effective as the sodium hypochlorite when used as an irrigant in necrotic pulpectomized primary teeth and is suggested as an alternative for irrigating primaryteeth.

12. SMEAR CLEAR[1]

- Smear Clear is a recently introduced chelating agent that contains 17% ethylenediamine tetra acetic acid solution with two additional proprietarysurfactants.
- 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*.
- All the studies that have evaluated this product have used it for 1 minute as peraccording to the manufacturer'sinstructions.

13. QMIX[1]
    - 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, a polyaminocarboxylic acid calcium-chelating agent ethylene diaminetetraacetic acid, 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 aboveneutral.
14. SILVER DIAMINEFLUORIDE[1]
    - A 3.8% w/v silver diamine fluoride solution has been used for intracanal irrigation. Silver diamine fluoride has potential for use as an antimicrobial root canal irrigantor interappointment medicament to reduce bacterial loads. 60 minutes exposure to silver diamine fluoride completely killed *Efaecalis*, but silver particles occluded dentinal tubular orifices after removal of the smearlayer.
15. HEBP (1-HYDROXYETHYLIDENE- 1, 1-BISPHOSPHONATE)[1]
    - Also known as etidronic acid or etidronate. It is a potential alternative to ethylene diaminetetra acetic acid or citric acid because this shows no short-term reactivity with sodiumhypochlorite.
16. TRICLOSAN AND GANTREZ[1]
    - Triclosan is a broad spectrum antimicrobial agent, which acts against gram-positive and gram- negative bacteria as well as some fungi andviruses.
    - The addition of Gantrez enhanced the bactericidal activity oftriclosan.
    - Triclosan alone and in combination with Gantrez demonstrated bactericidal activity against the five specific endodontic pathogens *P intermedia, F nucleatum, Anaeslundii, P gingivalis,* and *Efaecalis.*
17. ENDOVAC SYSTEM[1]
    - The EndoVac system is a new irrigation system that consists of a delivery/evacuation tip attached to asyringeofirrigantandthe high-speed suctions ource of the dental unit. As the can nulasa replaced in the canal, negative pressure pulls irrigantfrom 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 suctionhose.

18. HERBAL IRRIGANTS[4]

- The use of herbal products in the field of medicine has been practiced since ancient times and has significantly increased over the last few decades.
- In recent endodontics because of the limitations of most of the commercial intracanal medicaments used such as cytotoxicity and their inability to eliminate bacteria from dentinal tubules, trend of recent medicine to use biologic medication extracted from natural plants is drawing a lot of attention.
- The major advantages of using herbal alternatives are easy availability, cost-effectiveness, increased shelf life, low toxicity, and lack of microbial resistance reported.
- Literature has shown that herbs can have a promising role as root canal irrigants.

19. MISWAK[4]

- Miswak is derived from the plant *Salvadorapersica*(known as ÿarakÿ in Arabic) mainly used as a chewing stick, which is used for cleansing the teeth.
- **Wolinsky** and **Sote/**, by isolation of the active ingredient from S. persica, found that the limonoid had a great antimicrobial activity by inhibiting the growth of various Gram-positive and Gram- negative microorganisms by interfering extrapolysaccharides and glycosidase enzymes produced by these microorganisms.
- An *in vitro* study showed that 10 to 20% miswak extract was effective antifungal and antibacterial agent when used as an irrigant in the endodontic treatment of teeth with necrotic pulps against *candida albicans* and *E.fecalis*.
- A study done on primary teeth showed that for root canal irrigation miswak could be a good natural substitute to sodium hypochlorite.

20. MORINDA CITRIFOLIA[4]

- *Morindacitrifolia*commercially known as Noni or India Mulberry, has a broad range of therapeutic effects such as antibacterial anti-inflammatory, antiviral, antitumor, anthelmintic, analgesic, hypotensive, anti-inflammatory and immune enhancing effects might be advantageous. Due to its properties and not likely to cause the severe injuries to patients that might occur through sodium hypochlorite accidents its juice can be used as a potent irrigant in primary teeth. The antimicrobial activity on *E. faecalis* of 2% chlorhexidine gel, propolis, *M. citrifolia* juice and calcium hydroxide has been compared.

- It was concluded that Propolis and *M. citrifolia* were effective against *E. faecalis* in dentin on extracted teeth.

21. TRIPHALA AND GREEN TEA PHENOLS[4]

- Triphala is one of the well known Indian Ayurvedic herbal formulation consisting of dried and powdered fruits of three medicinal plants namely *Terminal iabellirica* (Gaertn) Roxb, *Terminal iach ebula* Retz and *Emblica officinalis* Gaertn. Green tea polyphenols- Numerous human, animal and *in vitro* studies have shown anticariogenic, anti-inflammatory, thermogenic, probiotic and antimicrobial properties.
- An *in vitro* study showed maximum antibacterial activity with sodium hypochlorite and statistically significant antibacterial activity with Triphala, GTPs, a mixture of tetracycline isomer, acid, and detergent and 5% hypochlorite against *E. faecalis* biofilm.

22. GERMAN CHAMOMILE AND TEA TREE OIL[4]

- German chamomile is a medicinal plant known for its anti-inflammatory, analgesic, anti-microbial, antispasmic and sedative properties. Chamomile was found to be effective when used as a mouthwash and many properties such as antiseptic, antifungal agent and a mild solvent.
- An scanning electron microscopic study done on German chamomile extract and tea tree oil as irrigants and showed that efficacy of chamomile to remove smear layer was superior to sodium hypochlorite alone but less than sodium hypochlorite combined with ethylene diaminetetraacetic acid.

23. PROPOLIS[4]

- Propolis, a resinous beehive product is a potent antimicrobial, antioxidant and anti-inflammatory agent. Very few studies have evaluated propolis as a root canal irrigant. Comparative evaluation of antimicrobial activity of miswak, propolis, sodium hypochlorite and saline as root canal irrigants by microbial culturing and quantification in chronically exposed primary teeth was done showed that results of propolis was comparable to those of the negative control.
- An *in vivo* randomized trial was conducted where root canals were irrigated using either 2% chlorhexidine, 4% calcium hydroxide extract of propolis with normal saline as the control irrigant which showed a significant decrease in mean aerobic colony forming

units count in all the groups, however chlorhexidine was superior. Propolis has also shown to be an effective intracanalirrigant in eradicating *E. faecalis*and *C.albicans.*

INFLUENCE OF IRRIGATION METHODS[2]

- A variety of instrumentation and irrigation methods have been used in endodontic treatment. According to literature researched, the instrumentation and the root canals irrigation can be accomplished via manual conventional means (endodontic files and Luer syringes) orvia endodontic ultrasonic-vibration- generator systems. The endodontic preparations might induce changes in the root dentin permeability. When a file is ultrasonically activated and placed passively in a canal, a phenomenon called acoustic streaming is produced, which is one of the surported mechanisms for superior debridement. Biological material that enters the streaming fields would be subjected to large shear stresses and may be disrupted. Ultrasonically prepared teeth showed cleaner canals than the teeth prepared by handinstrumentation.
- Regarding primary teeth, **Seow**concluded that acombination ofmechanical filling followed by ultrasonication produced the best results, with 95% of bacteria removed. The results showed that the ultrasonication might be useful for primary teeth endodontic treatment. However, the present literature search has found studies, which were carried out on teeth whose instrumentation was accomplished with endodontic files and they were irrigated with Luersyringes (sodiumhypochlorite).
- Hata et al. affirmed that the manual irrigation technique in primary teeth was more effective to remove the smearlayer using 15% ethylene diaminetetraacetic acid irrigation associated with 5% sodium hypochlorite during instrumentation. However, the most effective irrigation technique to remove debris was the ultrasonic system, regardless of the cleanserused.
- Cunningham and Martin observed a good rate of smear layer removal from root canals irrigated with 2.5% sodium hypochlorite, using the Endosonicsystem. Nevertheless, there were no significant differences among the manual and ultrasonic instrumentation techniques to reduce the smear layer effectively in permanent teeth, and consequently no permeability alterations were found. The variation of hydraulic conductance measured *in situ* after three endodontic preparations techniques (manual, ultrasonic, and manual with sodium hypochlorite and ethylene diaminetetraacetic acid) showed an inverse

relationship between variations in dentin permeability and the presence of smear layer. Dentin thickness was a significant factor influencing radicular permeability as wellas the smear layer. The use of ethylene diaminetetraacetic acid induced a considerable increase in radicular permeability and the use of ultrasonics produced a similar but weakereffect.

- Cameron affirmed that the most effective method to increase the root dentin permeability, considering removal of smear layer, was a manual instrumentation (endodontic files), irrigation with EDTAC (Ethylene diaminetetraacetic acid associated to Cetavlon), followed by the use of ultrasound with EDTAC for 1 minute and ultrasound with 4% sodium hypochlorite for 2minutes.
- Further researches should be carried out to evaluate the best irrigation method for primary teeth, which should provide increase ofroot dentinpermeability.
- Based on literature reviewed, it can be concluded that among the solutions used for permanent teeth, all solutions and associations studied increased the dentinpermeability. There was no difference in thedentin permeability when comparing manual and ultrasonic irrigation. There are not enough papers focusing primary teeth onthis subject to establish the patterns of increased dentin permeability in tooth root canal treatment regarding the irrigating solutions and irrigationsystems.

SEQUENCE OF IRRIGATION[23]

During the last several years endodontics has progressed to the point for treatment to be less traumatic for the patient and less stressful for the dentist. However, if the use of nickel titanium rotary instruments has allowed us to gain time during endodontic treatment, it can also tempt us to neglect one of the main objectives of endodontics, that being the "cleaning" on which Dr. Herbert Schilder has emphasized since he insisted on "cleaning and shaping". It may be more appropriate to say, "shaping for cleaning". The main goal of the root canal treatment is to completely eliminate the different components of the pulpal tissue, calcification and bacteria, the placement of a hermetic seal to prevent infection or re-infection and to promote healing of the surrounding tissues if needed.

Irrigation has an important role during endodontic treatment. We must ask ourselves the question, "Why do we irrigate and what irrigation protocol will provide the cleanest canal?" In this context, let us remember that the shaping is the result ofendodontic instruments while the cleaning results from irrigation. Therefore, we have two types of preparation. The first one is chemical and the

second one is mechanical. Moreover, it has been proven that there is a close correlation between these two types of preparation. In fact, with greater tapered preparations, the quantity and the concentration of the irrigating solution will begreater and will therefore better eliminate the smear layer. The files can clean only parts of the root canal system. They create a reservoir that can hold the different irrigating solutions, which will access and clean portions of the root canal system that the instruments cannotreach.

Here's a sequence for the different irrigating agents in order to achieve the best chemical preparation possible:

VITALTEETH:In this case there's a challenge oftreating the complexity of the different components of the pulp, and eventually the presence of bacteria. Begin the treatment by:

1) An application of sodium hypochlorite and/or an application of urea peroxide. The purpose ofthis mixture:
   a. The collagenic anti-aggregation effect due to the proteolytic and lipidic affinity of urea peroxide.
   b. To destroy the biggest amount of pulp tissue inside the access cavity and provide a better view of the canal orifices by controlling bleeding and preventing any collagenic plugs fromforming.
   c. At this stage the effect of ethylene diaminetetraacetic acid is only important for its antibacterial effect in combination with other antibacterialagents.
2) The second step consists of irrigating with 2ml of sodium hypochlorite 5.25 percent (60°C). The warm sodium hypochlorite is more efficient in destroying the collagen and this will reduce the time needed for the elimination of the organic part. This irrigation will create an effervescent effect between the sodium hypochlorite and urea peroxide. This "elevator effect" will evacuate the organic debris outside the access cavity, disorganize the coronal pulp tissue and help to better detect the canalorifices.
3) A second application and its activation is obtained by using a K file (08-10). This will disorganize the pulpal tissue in both the cervical and middle thirds of the endodontic system.This step has to be preceded by an abundant irrigation with distilled water in order to eliminate the first mixture present in the accesscavity.
4) Once the preparation of the canal has begun, Smear Clear (Sybron Endo, Orange, CA) (17 % ethylene diaminetetraacetic acid, cetrimide and surfactants) must be used.

The ethylene diaminetetraacetic acid is an organic acid which eliminates the mineral part of pulp tissue, the surface tension inhibitor will allow a better contact with the dentin for a higher efficiency of the product.

It is advised to alternate the use of ethylene diaminetetraacetic acid from the beginning of the preparation in order to eliminate the mineral layer before its thickening and condensing it inside the canal systems which will close the entrances of lateral and accessory canals and dentinaltubules.

Each time a rotary file is working inside the canal, irrigating solution must be present. Ultrasonic activation of the irrigating solution, using a small diameter file, is advised for a more efficient chemical preparation.

The early use of ethylene diaminetetraacetic acid facilitates the flow of the different irrigants in the lateral canals permitting a chemical preparation of all the endodontic system. Ethylene diaminetetraaceticacid also plays an important role in the reduction of inflammatory reaction by inhibiting the affinity of macrophages to the vaso-active peptides of the pulpal tissue. A time frame between four and five minutes must not be exceeded for the presence of the ethylene diaminetetraacetic acid inside thecanal.

Chlorehexidine can be used for a total elimination of the bacteria inside the canal. Distilled wateris used between each irrigating solution in order to prevent an acid/ base reaction, between sodium hypochlorite and ethylene diaminetetraacetic acid, for a more efficient action of the chemicals on the tissues. A copious neutralization of all the chemical agents must be done by the end of the preparation and before the fitting of the guttapercha cones so that the master cone does not push any of the chemicals outside the canal that might cause an inflammation of the surroundingtissues.

NECROTIC TEETH: The main difference between vital teeth and necrotic ones is the absence, not in total, of the pulpal parenchyme and the abundance of bacteria present in the latter. For this reason, the irrigation sequence will be different. Irrigation will be initiated with either sodium hypochlorite (5.25%, 60%C) for its bacterial effect or with chlorohexidine (0.2%) for the elimination of various bacterial types present in the root canals and dentinal tubuli. Then using distilled water to neutralize the effect of these irrigants followed by which we can repeat the same irrigation sequence described previously for vital teeth. The ethylene diaminetetraacetic acid, byeliminating the smear layer and opening the dentinal tubuli will permit an easy flow of sodium hypochlorite or chlorhexidine for a better disinfection of the endodontic system. In both clinical situations (vital and necrotic

teeth) it is necessary to end our sequence by using distilled water in order to eliminate the chemical agents or to neutralize their effects. This will inhibit:

- Their flow towards the periodontal tissues,
- The alteration of the filling material,
- The formation of a precipitating layer due to the crystallization of sodium hypochlorite after drying the canal walls.

PRESENCE OF RESORPTIONS: When there's an internal resorption, the irrigation sequence is the same that was described for vital teeth. But this sequence will be followed by the use of citric acid 50 percent (10 minutes) in order to eliminate the granulation tissue and to obtain smooth dentinal walls. This will ameliorate the adaptation of the filling material. The citric acid is eliminated by sodium hypochlorite
and distilled water. The same sequence is adopted for external apical resorptions but with an activation of the patency.

Discussion

The preservation of primary teeth is one the most important aims of paediatric dentistry. The aim is to maintain the harmonious growth and development of arch length and occlusal balance, with optimal function for swallowing, chewing, speech, and aesthetics[10]. Therefore, pulp therapies should be performed with high levels of quality to ensure a maximally successful clinical result. The combination of chemical and mechanical preparation is the key requisite for the achievement of the best eradication of debris. Irrigation has to be constant and copious to eliminate living/non-living materials. Currently, there is no agreement among paediatric dentists concerning the best intracanal irrigant solution for use against pulp pathogens involved in irreversibly inflamed/infected or non-vital primary teeth; this absence of consensus is probably due to the lack of research based evidence to support the use of any 'best' agent[8].

The time we gain by using rotary Nickel-titanium instruments is compensated by an abundant irrigation for a better cleaning of the endodontic system and this will contribute to the increase success rate of endodontic treatment. Chemical preparation is a double-edged sword; it will help us succeed in the adequate cleaning of the main canal its systems. But it must be followed by a three dimensional obturation to fill all of what has been cleansed and prepared. Perfect absorption of the fluid is essential from the main canal and all of its systems. If this is not accomplished then the adherence between the sealer and the dentin will be compromised. In addition, the presence of the

fluid inside the systems can have a negative hydraulic pressure preventing the obturation material from entering the complexity of the root canal systems for accomplishing a three dimensional obturation.[23]

Conclusion

Successful root canal therapy depends on thorough chemomechanical debridement of root canal. Irrigants can augment mechanical debridement byrinsing 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 canalsurfaces.

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. Certain authors have reported that during instrumentation, canals should be irrigated utilizing copious amounts of sodium hypochlorite, and once the shaping procedure is completed, ethylene diaminetetraacetic acid or citric acid should be employed; these authors also mentioned that chlorhexidine or

mixture of tetracycline isomer, acid, and detergent are strongly recommended as best final irrigant agent prior to canal drying and filling11.

Currently, there is no agreement among paediatric dentists concerning the best intracanal irrigant solution for use against pulp pathogens involved in irreversibly inflamed/infected or non-vital primary teeth; this absence of consensus is probably due to the lack of researchbased evidence to support the use of any 'best' agent11. Researches are still under way on to scientifically validate an irrigant solution with ideal characteristics.

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