Influence of cleansers and irrigation methods on primary and permanent root dentin permeability: a literature review

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Abstract
This paper review is key issue to known that the adequate endodontic techniques accomplished on primary and permanent teeth regarding the root dentin permeability. Therefore, it was discussed the efficacy of some cleansers and the influence of two irrigation systems used during endodontic preparation of primary and permanent teeth (manual or ultrasonic activation). The literature was searched for original papers relating cleansers characteristics, cleansers effect of root dentin permeability and the influence of manual irrigation or ultrasonic activation systems regarding primary and permanent endodontic therapy. The articles were selected using Bireme and Medline databases. Manual tracing of references cited in key papers otherwise was not elicited. It can be concluded that regarding cleansers and irrigation systems, there are not enough papers focusing primary teeth to establish patterns of change in the root dentin permeability. However, among the solutions used to treat permanent teeth, all solutions and associations studied increased the root dentin permeability. There was no difference in the root dentin permeability for permanent teeth when compared manual and ultrasonic preparation.

Key-Words:
dentin permeability, irrigating solutions, irrigation systems, primary teeth, permanent teeth

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Introduction

The high rate of tooth-decay derives from bad eating habits. This concept in association with deficient oral hygiene has had great influence on the premature loss of primary teeth. The aim of primary teeth treatment with large caries lesions enveloping pulp is to maintain the teeth in the arch, and to reestablish the healthy condition of the tissues affected by the pulp infection, preserving the normal development of the permanent successor teeth.

Considering the fast development of caries in primary teeth, and consequently the pulp damage due to the pulpar tissue contamination by bacteria and their derived toxins, the endodontic treatment can be necessary. This therapy promotes the removal of necrotic pulpal tissues remains, and the disinfection of the root canals and dentin tubules. In this context, the cleansers are very important to the success of the endodontic therapy. Besides promoting the cleansing of the root canals and having antimicrobial properties, the cleansers allow instrumentation and keep the residues in suspension, minimizing the extrusion of pulpal and dentine remains through the apical foramen.

The choice of a cleanser in the pulpal therapy of primary teeth should take into account the differences among the dentin substrata, and not be irritating to the periapical tissues. It is important to avoid harming the germ of the permanent successor tooth because the physiologic root resorption of the root canals and apical tissues, compromising the periapical tissue before that they are inadvertently pushed deeper into the flushes away loose, necrotic, contaminated materials remaining in the 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.

The use of rotating instruments and endodontic files leads to the formation of a microscopic layer of residues coming from the scoured dentin during the endodontic treatment. The smear layer observed under a Scanning Electron Microscopy (SEM) in permanent teeth comes as a uniform, dense layer of an amorphous structure that completely obliterates the entrance to the dentin tubules and drastically reduces the dentin permeability.

Under clinical conditions, especially during the treatment of infected teeth, viable bacteria and their products can be incorporated into the smear layer, forming a deposit of irritants. Therefore, its complete elimination would allow the most effective removal of irritants from root canals, besides promoting an increase in the dentin permeability and the contact surface between the dentin and the filling paste. This contributes greatly to the success of the endodontic therapy.

Hobson verified that ¾ of the root dentin of necrotic primary teeth are infected. This fact confirms the importance of instrumentation and irrigation endodontic to eliminate the root canal infection, to increase the root dentin permeability and to maintain the asepsis of the canals.

The aims of this review article was to discuss the efficacy of some cleansers, as well as the influence of two irrigation systems used during endodontic preparation of primary and permanent teeth (manual or ultrasonic vibration) with regard to root dentin permeability.

Reviewing Methodology

The authors searched for papers using Bireme and Medline databases from 1960 to 2005. The search was supplemented by manual searching of reference lists from each relevant paper identified.

The main search terms were “root dentin permeability”, “cleansers”, “irrigation solutions”, “endodontic treatment”, and “irrigation methods”. A total of 203 records were originally identified filters, and then used to allow only for subject papers to be connected, which resulting in 65 articles. These were printed as abstracts or full-text articles if the abstract was missing. Only original papers were considered. Interim reports, abstracts, letters, reviews, and chapters in textbooks were discarded. Articles in Swedish, Danish, Norwegian, Japanese, German, and French were not accepted.

From the 65 selected papers, 46 studies were included from the appraisal. The main reasons for exclusion of 19 articles were: papers of reviews and papers that evaluated root dentin permeability associated with laser applications. Out of the 46 papers that were critically assessed, 14 studies were identified from the search and were pointed out due to they related dentin permeability, cleaners and irrigation methods (Table 1).

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.

Many researchers have studied the effect of several cleaners on the permeability of the dentine using methods that involve bacteria or radioisotopes, with different methodologies. Those cleaners 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\textsuperscript{5-16}. In addition, they should be soluble in water and biocompatible to the periapical tissues\textsuperscript{17}.

In view of the fact that there is not a single drug that unites all those properties mentioned, a variety of cleansers and their associations have been used such as Sodium Hypochlorite, Urea Peroxide, Hydrogen Peroxide, Ethylenediamine Tetra Acetic Acid, Organic Acids, and Chlorhexidine Gluconate (Table 2).

### Sodium Hypochlorite

Sodium Hypochlorite (NaOCl) have been used separately or associated with other medicines. NaOCl is a weak alkaline/base that acts on the albumin (remains of pulpal tissue, foods and microorganisms), denaturing them and turning them soluble in water. Like soap, it facilitates the removal of debris from the root canals and, in spite of being a necrosis agent (to act on organic matter) it is little poisonous or irritating to the live tissues\textsuperscript{18}. Dakin’s liquid (0.5% NaOCl neutralized with boric acid) is the most commonly used solution to irrigate primary teeth, because it is less irritating to the periapical tissue. The NaOCl alkali contacting with organic products in decomposition liberates chlorine and nascent oxygen that promote bactericidal action\textsuperscript{18}.

Marshall et al.\textsuperscript{9} observed a small increase of the dentin permeability to radioisotopes when the root canals were irrigated with 5.25% NaOCl. However, the association of this solution with 3% hydrogen peroxide solution significantly increased the dentin permeability. Fogel and Pashley\textsuperscript{19} found that the use of endodontic files created smear layers, which produced modest reductions in the permeability of inner and outer root dentin. Sodium hypochlorite or saline application did not affect the hydraulic conductance of such smear layers.

### Urea Peroxide

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\textsuperscript{20} using Endo-

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**Table 1 - Cleansers, Instrumentation/Irrigation Method, Type of teeth, and Evaluations regarding endodontic treatment**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Cleansers</th>
<th>Method</th>
<th>Teeth</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stewart et al. 2</td>
<td>1969</td>
<td>EDTA+ Gly-Oxide / Gly-Oxide / Aqueous Peroxide / DW</td>
<td>Manual</td>
<td>PT</td>
<td>DP</td>
</tr>
<tr>
<td>Fraser &amp; Laws 29</td>
<td>1976</td>
<td>RC-Prep / Decal / Largal Ultra *</td>
<td>Manual</td>
<td>PT</td>
<td>DP</td>
</tr>
<tr>
<td>Bengtson et al. 35</td>
<td>1983</td>
<td>NaOCl / Endo-PTC / Tergentol / DW</td>
<td>Manual</td>
<td>DT</td>
<td>DP</td>
</tr>
<tr>
<td>Bengtson et al. 36</td>
<td>1985</td>
<td>NaOCl / Endo-PTC / Tergentol / DW</td>
<td>Manual</td>
<td>DT</td>
<td>DP</td>
</tr>
<tr>
<td>Zuolo et al. 26</td>
<td>1987</td>
<td>EDTA / EDTAC / EDTAT** / EDTACP*** / SS</td>
<td>Manual</td>
<td>PT</td>
<td>H M</td>
</tr>
<tr>
<td>Pécora et al. 13</td>
<td>1987</td>
<td>NaOCl / NaOCl + HP / EDTA</td>
<td>Manual</td>
<td>PT</td>
<td>H M</td>
</tr>
<tr>
<td>Moura &amp; Paiva 20</td>
<td>1989</td>
<td>NaOCl / Endo-PTC</td>
<td>Manual</td>
<td>PT</td>
<td>DP</td>
</tr>
<tr>
<td>Pécora et al. 42</td>
<td>1990</td>
<td>NaOCl / DW</td>
<td>Manual/Ultrassom</td>
<td>PT</td>
<td>H M</td>
</tr>
<tr>
<td>Vansan et al. 43</td>
<td>1990</td>
<td>NaOCl / DW / Tergentol</td>
<td>Manual/Ultrassom</td>
<td>PT</td>
<td>H M</td>
</tr>
<tr>
<td>Fogel &amp; Pashley 19</td>
<td>1990</td>
<td>NaOCl / Citric acid / Monopotassium-Monohydrogen oxalate</td>
<td>Manual</td>
<td>PT</td>
<td>H C</td>
</tr>
<tr>
<td>Tao et al. 27</td>
<td>1991</td>
<td>NaOCl / EDTA</td>
<td>Manual</td>
<td>PT</td>
<td>H C</td>
</tr>
<tr>
<td>Guignes et al. 37</td>
<td>1996</td>
<td>NaOCl / EDTA</td>
<td>Manual/Ultrassom</td>
<td>PT</td>
<td>H C / SEM</td>
</tr>
</tbody>
</table>

**Hydrogen Peroxide = HP; Distilled Water = DW; Saline Solution = SS.**

**Permanent Teeth = PT; Primary (Deciduous) Teeth = DT.**

**Dye penetration = DP; Radioisotope = R; Scanning Electron Microscopy = SEM;**

**Histochemical = H; Morphometric = M; Hydraulic Conductance = HC**

*Decal and Largal Ultra are chelating agents used in Australia and France, respectively.
**EDTAT=EDTA + Tergentol (Lauryl-dietylene-glycol-ether sodium sulphate)
*** EDTACP= EDTA + Pyridine-phenyl-chlorine
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.21 and Rome et al.12 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/NaOCl maintains the previously described properties 10. According to Rome et al. 12, the use of Urea Peroxide is the first choice cleanser in small curved canals. Its properties of lubrication without demineralization the dentin walls10 avoid the risks of root perforation, common in primary teeth.

The association of Urea Peroxide with NaOCl promotes significant more increase in the dentin permeability index to dye and drugs21 than when used separately9. In spite of promoting increase in the dentin permeability, the association of Urea Peroxide/NaOCl showed less effectiveness in removing the smear layer22. 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 wall22,23.

Hydrogen Peroxide
Hydrogen Peroxide (H2O2) is an oxidizing agent that acts similarly to Urea Peroxide releasing nascent oxygen and producing effervescence. The H2O2/NaOCl association produces increased dentin permeability in smaller degree than the association Urea Peroxide/NaOCl11. In addition, Urea Peroxide (Gly-Oxide) presented smaller bactericidal activity than H2O2 for irrigation of infected permanent root canals10.

Ethylendiamine Tetra Acetic Acid
Ethylendiamine Tetra Acetic Acid (EDTA) is a chelating substance that has been also used. It is capable of removing calcium ions of the dentin, giving rise to demineralization.
and as a consequence, increasing the dentin permeability of the root canals. EDTA is used in concentrations from 10 to 17% and in association with other drugs\textsuperscript{21}. 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, and concentration. Serper and Calt’s study\textsuperscript{23} compared the effects of EDTA (pH and concentration) on root dentin demineralization, and the results suggest that during prolonged cleaning and shaping of root canals lower concentrations of EDTA (10%) would rather than the neutral pH. It reduces erosive effects of EDTA solutions. In addition, Nakashima and Terata\textsuperscript{25} observed that the permeability of root canal disinfectants increased to similar degrees in the 3% and the 15% EDTA groups. Comparing dentin properties, they propose that 3% EDTA is more useful for clinical applications. Zuolo et al.\textsuperscript{26} found that the most effective combination to increase root dentin permeability was EDTA associated with Cetavlon (EDTAC).

However, Tao et al.\textsuperscript{27} verified that EDTA 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 EDTA has been proposed for permanent teeth. Therefore, Grandini et al.\textsuperscript{28} evaluated the smear layer, debris, and tubule orifices of root canal walls after being instrumented and irrigated by Glyde File Prep, using a SEM. The results of this study confirm that irrigation with NaOCl 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 NaOCl and EDTA 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 (EDTA/Urea Peroxide). It is a potent bactericidal agent and increases the dentin permeability significantly\textsuperscript{21,21}. In contrary, in this literature review only one paper found that Decal (Glover Laboratories, Melbourne, Australia), Largal Ultra (Sevadent, Paris, France), and RC-Prep (Medical Products Laboratories, Philadelphia, USA) significantly reduced the dye penetration into dentin, but that there was no difference among the agents in the degree of reduction of dye penetration\textsuperscript{29}. Others substances (organic acids) have been used to remove the smear layer, such as 6 - 10% citric acid, 20% polyacrylic acid, and tannic acid. Salama and Abdelmegid\textsuperscript{30} 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\textsuperscript{28}.

### Chlorhexidine Gluconate

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\textsuperscript{31}. Vahdaty et al.\textsuperscript{14} evaluated in vitro the antibacterial efficiency of 2% and 0.2% chlorhexidine, comparing them with NaOCl 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 dentin tubules. Heling and Chandler\textsuperscript{32} and White et al.\textsuperscript{33} suggested that chlorhexidine can be an excellent antimicrobial endodontic irrigating agent if used alone, or as an auxiliary to NaOCl during the instrumentation. Chlorhexidine Gluconate showed quick residual antimicrobial activity in these in vitro studies.

Gomes et al.\textsuperscript{34} evaluated the antimicrobial activity of the two formulations of Chlorhexidine Gluconate (liquid and gel) in three concentrations (0.2%, 1.0% and 2%), and of NaOCl (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 cleansers used. Ferraz et al.\textsuperscript{35} evaluated 2% chlorhexidine gluconate 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% NaOCl and 2% chlorhexidine gluconate 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 (Table 1). Bengtson et al.\textsuperscript{35,36} concluded that Endo-PTC/Dakin’s liquid...
showed the highest dye penetration index of primary root dentin permeability. Primo\textsuperscript{15} verified that 1% NaOCl associated with 10% citric acid was the most effective association to remove the smear layer of anterior primary teeth, followed by the associations Endo-PTC/Dakin’s liquid and 4% NaOCl/3% H\textsubscript{2}O\textsubscript{2}. 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 root canals.

**Influence of Irrigation Methods**

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) or via endodontic ultrasonic-vibration-generator systems. The endodontic preparations might induce changes in the root dentin permeability\textsuperscript{37}. When a file is ultrasonically activated and placed passively in a canal, a phenomenon called acoustic streaming is produced\textsuperscript{38}, which is one of the surported mechanisms for superior debridement\textsuperscript{39}. Biological material that enters the streaming fields would be subjected to large stresses and may be disrupted\textsuperscript{40}. Ultrasonically prepared teeth showed cleaner canals than the teeth prepared by hand instrumentation\textsuperscript{41,42}.

Regarding primary teeth, Seow\textsuperscript{43} concluded that a combination of mechanical 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 Luer syringes (NaOCl).

Hata et al.\textsuperscript{16} affirmed that the manual irrigation technique in primary teeth was more effective to remove the smear layer using 15% EDTA irrigation associated with 5% NaOCl during instrumentation. However, the most effective irrigation technique to remove debris was the ultrasonic system, regardless of the cleanser used. Cunningham and Martin\textsuperscript{41} observed a good rate of smear layer removal from root canals irrigated with 2.5% NaOCl, using the Endosonic system. 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\textsuperscript{44-48}. The variation of hydraulic conductance measured in situ after three endodontic preparations techniques (manual, ultrasonic, and manual with NaOCl and EDTA) showed an inverse relationship between variations in dentin permeability and the presence of smear layer\textsuperscript{37}. Dentin thickness was a significant factor influencing radicular permeability as well as the smear layer. The use of EDTA induced a considerable increase in radicular permeability and the use of ultrasonics produced a similar but weaker effect. Cameron\textsuperscript{49} 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 (EDTA associated to Cetavlon), followed by the use of ultrasound with EDTAC for 1 minute and ultrasound with 4% NaOCl for 2 minutes.

This literature review found no study that demonstrates the close relation among primary teeth, root dentin permeability, and irrigation methods. Further researches should be carried out to evaluate the best irrigation method for primary teeth, which should provide increase of root dentin permeability. Based on literature reviewed, it can be concluded that among the solutions used for permanent teeth, all solutions and associations studied increased the dentin permeability. There was no difference in the dentin permeability when comparing manual and ultrasonic irrigation. There are not enough papers focusing primary teeth on this subject to establish the patterns of increased dentin permeability in tooth root canal treatment regarding the irrigating solutions and irrigation systems.

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