

A Review of Root Canal Irrigants in Endodontic Practice - Part 1

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Abstract

Irrigation plays a pivotal role in the success of endodontic treatment in eradicating microbes and tissue material from the root canal system. There are currently a variety of differing protocols with regards to the irrigant selection and this review article covers the irrigants currently used and covers the associated evidence base for their usage. Sodium Hypochlorite is widely used as the most common irrigant in endodontics because of the tissue dissolving capability and also hypochlorite having an effective antimicrobial action. The action of Chlorhexidine has been reviewed as an alternative irrigant as it has a longer antimicrobial action due to its substantivity. However, the limitation of tissue solvent activity have meant its use is more common in retreatment cases. Chelating agents such as EDTA are now routinely used for removal of the smear layer and this article considers the literature on this and also to compare the combined regimens of endodontic irrigants with MTAD. Some alternative contemporary irrigants are also highlighted and discussed.

Keywords: *Root Canal Irrigants; Endodontic Irrigants; Sodium Hypochlorite; Chlorhexidine; EDTA; MTAD*

Introduction

Endodontic disease is one which is caused and facilitated by microbial action (Kakehashi, Stanley, Fitzgerald, 1965). The management of such disease is primarily through removal of necrotic pulp tissue and disinfection of microbes. This is done via mechanical instrumentation and irrigation of the canal system [1]. As to the question of which of these two aspects is more important, it was initially the work of Shilder in 1967 [2] who emphasised the necessity of a good irrigation protocol.

There are papers highlighting limitation of instrumentation and the wider role of irrigants in endodontic treatment. Rodig, *et al.* [3] assessed the effectiveness of instrumentation in oval shaped root canals. Cross sections were taken of roots and photographed before and after treatment. The results showed that aspects of the canal remained un-instrumented due to the inherent limitation of files being of circular in cross-section. Furthermore, Peters, Schonenberger and Labib [4] utilised computed tomography to investigate the limitations of instrumentation. The surface area and volume of the canal structure of extracted teeth was imaged and then a comparison was made after preparation with different file systems. Beyond the walls of the root canal system, the issue of microbial infection of dentinal tubules needs to be considered with regards to limitation of instrumentation. Al-Nazhan, *et al.* [5] demonstrated in a study using extracted teeth significant penetration of microbes into the dentinal tubules. These papers highlight the chemo-therapeutic effect of irrigation being essential in effective cleansing of root canals in endodontic treatment.

As stated by Cohen [6] micro-organisms in the root canal space rely on necrotic pulp tissue, proteins from tissue fluid and components of saliva as a nutrient source. As mechanical instrumentation is limited in managing to clean the canals fully the role of all contemporary irrigants is to facilitate the eradication of these nutrients also [7].

Haapasalo, *et al.* [8] discussed roles of different irrigants in endodontic treatment. These are as a washing effect and usually also involving antimicrobial action, to dissolve tissue and also reducing friction whilst using instruments, improving cutting efficiency and cooling the working area. Zehnder [9] detailed further that the irrigant should be effective against anaerobic and facultative microbes and also to inactivate endotoxins.

Bystrom [10] had shown that saline solution is not sufficient as an irrigant in endodontic treatment. They had also used Sodium hypochlorite (NaOCl) at 0.5%. Since then a variety of different irrigants as well as sodium hypochlorite have been utilised and with varying protocols and concentrations.

A systematic review was carried out by Fedorowicz, *et al.* [11] which compared different irrigants in published literature. From the 11 papers included in the review, comparisons were made between Sodium hypochlorite, Chlorhexidine, Ethylenediaminetetraacetic acid (EDTA) and Mixture Tetracycline Citric Acid and Detergent (MTAD). The paper showed that the success of endodontic treatment involved irrigants but was unable to find any significant differences in irrigant efficacy. The authors highlighted the issues related to bias in a lot of papers, from 1429 found only 11 met the criteria to be included in the systematic review. They suggested more robust randomised controlled trials to be carried out to identify an irrigant ideal for endodontics. These were the very same conclusions as discussed by Zender in 2006 [9]. This shows that either there has been a lack of definitive research in this area, or that clinicians must use a variety of different irrigants considering their individual roles in treatment.

Sodium Hypochlorite

Grossman and Meiman [12] were one of the first to mention the use of sodium hypochlorite (NaOCl) as an endodontic irrigant in their investigations in dissolving pulp tissue and this role of hypochlorite is one of the most important aspects. Mohammadi [13] reviewed papers on NaOCl and discussed the fact that no other irrigant has been shown to be more effective at the time of writing. Despite there being literature which will be discussed later that has shown comparative action to NaOCl, only when proven to be more effective will any irrigant supersede such a widely utilised irrigant. The features of NaOCl described as well as tissue solubility include an anti-bacterial and anti-fungal role and also haemostatic ability. The potential hazards were also included such as toxicity and the potential adverse scenario of inadvertent injection of hypochlorite beyond the apex into periapical tissues. Despite being a comprehensive update paper with most well-known papers on irrigants been cited, there appears to be no discussion on appraisal of the papers chosen. However, the conclusions do appear to concur with Zehnder [9] which is the most commonly cited review on endodontic irrigants.

Spratt, *et al.* [14] evaluated the antimicrobial action of different irrigants on biofilms of root canal isolates. They showed sodium hypochlorite as the most effective in comparison to Chlorhexidine and Iodine. Biofilm eradication was also considered by Dunavant, *et al.* [15], specifically against *enterococcus faecalis*. The authors found concentrations of 6% and 1% were both effective. Time was mentioned as not being a factor in effectiveness. This was also mentioned by Sena [16] who cited 30 seconds as the time needed for 5.25% hypochlorite to be effective.

The paper by Turkun and Cengiz [17] showed 5% sodium hypochlorite being the most potent. However, a comparison was only made with 0.5% against which 5% was significantly better and the sample size was very small at 40 extracted teeth. The paper also highlighted the combination of a pre-treatment of calcium hydroxide as a pre-treatment for example as a dressing that is placed in an emergency appointment prior to comprehensive endodontic treatment. This appeared to work well with lower concentrations of NaOCl having increased effectiveness.

Violich [18] discussed how a smear layer is created on the walls of a root canal during treatment due to the scraping action of endodontic files. It is comprised of fragments of mineralised collagen matrix. Although there remains debate regarding the removal of the smear layer in literature, when desired by a clinician it was shown by Violich [18] and also Zehnder [9] that sodium hypochlorite is ineffective for this use.

Chlorhexidine Digluconate

Mohammadi and Abbott [19] reviewed papers dating back to 1981. The anti-bacterial properties were highlighted. They first showed chlorhexidine to be a suitable irrigant after comparison to sterile saline and also more effective as an anti-microbial than calcium hydroxide or iodine potassium iodide. Chlorhexidine was also mentioned as being more effective than NaOCl in eradicating *Enterococcus Faecalis*. This contrasted previous work by Siqueira, *et al.* [20] and Ayhan, *et al.* [21].

Chlorhexidine was also shown to be an effective anti-fungal medicament although the efficacy was reported as lower than NaOCl. The reported cytotoxicity of CHX is regarded to be negligible at the concentrations used to irrigate in endodontic treatments from reviewed papers. Yesiloy, *et al.* [22] showed least adverse reactions when compared with common irrigants. With regards to disadvantages the main identified feature was that chlorhexidine has no tissue solvent ability which is imperative in successful endodontic treatment as already discussed with limitations of instrumentation alone.

Mohammadi and Abbott [19] also discuss the substantivity of chlorhexidine. This refers to the fact that it is effective after the irrigation time in its anti-microbial action. This was also discussed by Mahendra, *et al.* [23]. Mahendra, *et al.* [23] found comparing different concentrations 2% chlorhexidine was the superior to 1 or 0.1% however a small sample size was noted. The paper also mentioned how the CHX gel could be useful in its action as a lubricant.

Substantivity of chlorhexidine was measured by Leonardo, *et al.* [24] as being present for up to 48 hours. This prolonged antimicrobial action may be significant as NaOCl showed little if any residual action in comparison as per Weber, *et al.* [25] who showed chlorhexidine activity as long as 168 hours later. This paper has a relatively strong evidence base considering it has used a larger sample size than most of the previous trials and compared 2% chlorhexidine with 5.25% NaOCl, which are the most commonly used preparations of the irrigants. The study was carried out in vitro and the authors do cite a limitation of no tissue dissolving ability of chlorhexidine despite a statistically significant result in residual antimicrobial action.

Dametto, *et al.* [26] carried out a study in which chlorhexidine 2% solution, gel and sodium hypochlorite and controls were compared in removal of *Enterococcus Faecalis*. This paper stated that chlorhexidine in its gel form should be considered as an endodontic irrigant as it was more effective. However, the results were not statistically significant. The difficulty in the recommendation is also that although *E. faecalis* has been used in this study, the biofilms involved in infected canals are of multiple species. There have been reported concerns about the ability of chlorhexidine as an antimicrobial against biofilms. Clegg, *et al.* [27] found this was an issue when comparing to NaOCl and MTAD. This was also confirmed by the work of Viana and Gomez [28]. The recommendation of chlorhexidine in a gel form was suggested by Wang, *et al.* [29] who carried out an in-vivo study. The authors did also add that its role as a medicament in between visits is not recommended as it did not show any difference in reduction of bacteria.

Guneser [30] showed the obturation material Mineral Trioxide Aggregate (MTA) lost strength when exposed to 2% Chlorhexidine when compared with NaOCl and saline. Following these findings where it is planned to use MTA it may be advisable to use a different irrigant.

EDTA

The smear layer defined earlier in the essay as per Violic [18] is significant as bacteria may reside in dentinal tubules. The removal of the smear layer has been advocated by papers such as Cobankara, *et al.* [31] and the systematic review and meta-analysis by Shahra-van, *et al.* [32]. The most common irrigant for removing this is Ethylenediaminetetraacetic acid (EDTA). In comparison to other chelating agents such as Citric acid and Polyacrylic acid, EDTA was found to be the most effective [18].

Calt & Serper [33] showed the smear layer was completely removed by EDTA, but it caused erosion of the peritubular and intertubular dentine. This was contrasted by Dogan [34] although the Calt and Serper [33] paper showed this appeared to occur with a 10 minute application and not with 1 minute and a recommendation of no longer than a minute has been recommended to leave this irrigant in a root canal. This was also stated by Crumpton [35] who stated that 1 ml of EDTA for 1 minute is just as effective as 10 ml.

Yoshida, *et al.* [36] carried out a study using a good sample size of 189 teeth and a comparison made with saline. Their results showed a significant difference in antimicrobial efficacy between the two although the two groups did not appear to be equally divided.

MTAD

Mixture Tetracycline Citric Acid and Detergent was introduced as an irrigant that could potentially fulfil the various afore mentioned roles of an irrigant in endodontic treatment [37]. One of the first papers to discuss this was Torebinejad, *et al* [38]. This paper is often cited to show MTAD is effective as an irrigant. However, the specific study looked at the smear layer under a scanning electron microscope and showed no significant difference when compared to the other common irrigants. The authors stated that it is effective for smear layer removal as a final rinse.

Adrizzoni (2009) discussed the antimicrobial activity of tetracycline, the smear layer removal by citric acid and the surfactants allowing better penetration of the medicaments. Both *in vitro* and *ex vivo* studies carried out showed antimicrobial characteristics of MTAD being superior to sodium hypochlorite including against *Enterococcus Faecalis*. The effectiveness against *Enterococcus Faecalis* was also shown by Newberry [39]. One limitation of the Adrizzoni paper is that it does not refer back to the methodology where the teeth used were standardised by initially being cleaned fully with 5.25% NaOCl prior to testing. Further studies may show the two irrigants work well together or one being more effective.

Kho and Baumgartner [40] had previously investigated a comparison of MTAD and an irrigation protocol of NaOCl and EDTA. Extracted teeth No significant differences were noted between two groups.

Singla Garg and Gupta [37] discussed the antifungal activity of MTAD having good substantivity for up to 28 days. Dissolution of inorganic material was found to be effective and the irrigant was reported to be less cytotoxic and more biocompatible than other common irrigants.

Paul, *et al.* [41] carried out a study to compare different irrigants utilised after 5.25% NaOCl and comparisons were made between EDTA with and without ultrasonic activation and MTAD. The paper had several strengths in using strict criteria for monitoring however only 45 teeth had been utilised in the study. The authors concluded that none of the selected irrigants were ideal in removing the smear layer. The smear layers were noted to be lighter and MTAD appeared to be the most effective in combination with NaOCl however the result was not statistically significant.

Alternative Contemporary Irrigants

Calcium Hydroxide is most commonly used as inter-appointment medicament. Oliveira, *et al.* [42] considered the effects of different irrigants on endotoxins. They noted the ability of calcium hydroxide in this and also the effect of stimulating antibody production by B lymphocytes. In the study sodium hypochlorite and chlorhexidine did not detoxify endotoxin. In contrast to this Schafer and Bossmann [43] looked at combinations of calcium hydroxide and chlorhexidine and reported that 2% chlorhexidine was more effective than calcium hydroxide or when both were used. Similar conclusions were found by Almyroudi, *et al.* [44] and Haenni, *et al.* [45] using the same combinations and it may be accepted at present that the role of calcium hydroxide should be as an inter-appointment medicament.

Sterilox has been suggested as having a role as an irrigant. Rossi-Fedele, *et al.* [46] discussed the use of super oxidised water as an irrigant due to the less cytotoxic effect when compared to an irrigant such as sodium hypochlorite. It was shown by Giles, *et al.* [47] had shown Sterilox being anti-microbial compared to the control and no significant differences when compared to NaOCl or Chlorhexidine. However only 12 teeth were used in this study. Rossi-Fedele, *et al.* [46] showed Sterilox not being as effective as NaOCl and again a small study of 15 roots were used in carrying out the study.

PAD was mentioned by Iqbal [48] which is an irrigation method involving a solution which can bind to bacteria and then treatment with a laser to irradiate bacteria. It offers advantages of low toxicity however the authors suggested there is no robust evidence to support

the use of this system. The issue of lasers being able to penetrate curvatures in canals and also the cost of the system was mentioned as disadvantages.

Kandil, *et al.* [49] found that malic acid could be a potential alternative to EDTA in removing the smear layer. They found at 7% was more effective than sodium hypochlorite with or without EDTA, MTAD and a saline group. However, the study was small and conclusions at present suggest that further investigation is required.

Conclusions

Due to the essential nature of irrigation in endodontic treatment success there always be continued studies into finding the ideal irrigant. Irrigants have a variety of roles during treatment including dissolving tissue, eradicating bacteria and assisting in cleaning the root canal system prior to achieving a sealed off root canal system. As there appears to be a weak base of evidence due to non-uniformity in the way studies are carried out there is contention as to the most appropriate. It was suggested by Zehnder [9] to consider sodium hypochlorite first for tissue dissolving capabilities and then removing the smear layer with EDTA followed by chlorhexidine which has a prolonged antimicrobial action. It must be noted that care must be taken in mixing irrigants also, as mentioned by Basrani, *et al.* [50] who showed that the combination of hypochlorite and chlorhexidine lead to precipitate formation known as para-chloroaniline which is toxic and it has been reported as carcinogenic. Further studies are warranted as although the role of contemporary irrigants is widely reported, there may be opportunities to improve success rates and also reduce adverse effects of using irrigants [51,52].

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