Investigation of different sodium hypochlorite volumes, concentrations and times of irrigation in endodontic therapy: a systematic review

Abstract

Although the sodium hypochlorite (NaOCl) solution has been part of the endodontic arsenal for more than one century, current investigations have been unable to determine which NaOCl volume and concentration or which time of application are able to dissolve organic matter without weakening the dental structure during the phase of biomechanical preparation of the root canal. Thus, the objective of the present study was to conduct a systematic literature review with no restriction of publication year or language in order to resolve these questions. The search strategy included the following databases: PubMed, LILACS, Web of Science and ClinicalTrials.gov, and only in vivo human clinical trials were included in the final review. After the removal of duplicates, the systematic literature review yielded 3,717 articles. Of these, 3,685 were excluded after applying the exclusion criteria (ex vivo studies, animal studies, cell-culture studies, narrative review, and studies with no available full texts). A total of 32 full-text articles were assessed for eligibility. After evaluating the full text, all articles were excluded for different reasons. No studies fulfilled our inclusion criteria. This review was unable to answer what time of irrigation, concentration or volume of NaOCl solution can be of maximum effectiveness in endodontic treatment without producing significant changes in the mechanical properties of dentin. Thus, future human clinical studies are needed in order to resolve these questions.

Descriptors: Endodontics; Sodium Hypochlorite; Review.

INTRODUCTION

Chemical and mechanical preparation is used for root canal cleaning, expansion and modeling. These steps essentially involve filing of dentinal walls with the aid of endodontic instruments1 plus the action of irrigating chemical substances on the components of the root canal system2 for residue removal and for an antimicrobial action3,4. An important challenge is the choice of the chemical substance to be used since, so far, none of them has proved to have ideal qualities needed for the disinfection of root canals5. However, sodium hypochlorite (NaOCl) is the auxiliary substance

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usually chosen by clinicians and endodontists because of its ability to neutralize the content of toxic-necrotic material and to dissolve organic matter in the root canals\(^9\). The recommended NaOCl concentrations range from 0.5 to 6\%, but there is no consensus about NaOCl concentration or volume or time of irrigation in clinical practice\(^9\).

The properties of NaOCl for the dissolution and degradation of organic matter are directly proportional to its concentration and volume which, when elevated, may be toxic and favor dentin fragility after endodontic treatment\(^{10}\). Although many studies have assessed the development of this fragility such as root fractures related to excessive expansion of the root canals, pressure transmission to canal walls during shaping and obturation, presence of a post or an isthmus, and occlusal overload by masticatory forces\(^{11,12}\), few investigations have concentrated on the use of NaOCl and its possible deleterious action on root dentin\(^{13}\).

For these reasons, clinicians and endodontists are concerned about the ideal concentration and volume of NaOCl and the time needed for its action during the biomechanical preparation of root canals in order to dissolve and disinfect organic matter without weakening the dental root. On the basis of the above considerations, the objective of the present study was to conduct a systematic literature review aiming at the resolution of these questions.

**MATERIAL AND METHOD**

- **Information sources and search strategy**
  This study followed the PRISMA guidelines for systematic reviews\(^13\) and the PICO strategy (Patient, Intervention, Comparison and Outcome) was used to formulate an adequate research question. Table 1 presents the four components of this strategy for the present study. The review protocol was registered with PROSPERO (registration No. CRD 42017054317).

  A systematic review with no restriction of publication year or language was carried out. The search strategy included the following databases: PubMed (National Library of Medicine), LILACS (via BVS, Latin America), Web of Science (Thomson Reuters), and ClinicalTrials.gov and the reference list of selected articles. The search was undertaken in September 2017. The following search criteria were applied to the PubMed, BVS and Web of Science databases: (NaOCl OR sodium hypochlorite) AND (endo* OR root canal). For the ClinicalTrials.gov database, the term sodium hypochlorite was applied in the search field “other terms”.

- **Eligibility criteria and study selection**
  Articles had to be in vivo human clinical trials to be included in the final review. The exclusion criteria were ex vivo studies, animal studies, cell-culture studies, narrative review, and studies with no available full texts.

  Studies were selected by two independent authors (G.C. and A.P.) and kappa scores were calculated. First, titles and abstracts were screened for inclusion. Those whose titles clearly showed that they were in vitro or animal studies were excluded in this first stage. If there was insufficient information in the abstract the full texts were retrieved and read for possible inclusion. Any disagreements regarding the articles included in the final review were resolved by a third investigator (P.M.R.M.J.) with experience in the subject. The Mendeley Desktop Software (1.17.11, Mendeley LTD., London, UK) was used.

- **Risk of bias assessment and data analysis**
  The “Risk of bias tool” of the Cochrane Collaboration was used to assess the risk of bias of the studies included if randomized clinical trials fulfilling the inclusion criteria were found. The Review Manager 5.3 software (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) was used to perform meta-analysis if appropriate.

  **Table 1. PICO strategy used to formulate the research question**

<table>
<thead>
<tr>
<th>Population</th>
<th>Intervention</th>
<th>Comparison</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent vital tooth</td>
<td>Irrigation with sodium hypochlorite at different concentrations</td>
<td>Irrigation with another irrigation solution or with different sodium hypochlorite concentrations</td>
<td>Tooth structure fragility</td>
</tr>
<tr>
<td>Permanent teeth with necrotic pulp</td>
<td>Irrigation with sodium hypochlorite</td>
<td>Volume</td>
<td></td>
</tr>
<tr>
<td>Teeth with periapical lesions</td>
<td>time</td>
<td>Irrigation time</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disinfection of root canal systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dissolution of organic matter</td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

Inter-examiner agreement based on kappa was 0.83. After duplicate removal, the systematic literature review yielded 3,717 articles, 3,685 of which were excluded after applying the exclusion criteria. A total of 32 full-text articles were assessed for eligibility (Table 2). After evaluating the full-text, all articles were excluded for different reasons.

The flowchart of study selection is illustrated in figure 1. Nineteen of them only assessed one NaOCl concentration, six were in vitro, three were reviews, one was an ex vivo study, one was an animal study, one used irrigation with chlorhexidine, and one was a letter to the editor.

Therefore, no studies fulfilled our inclusion criteria. Also figure 2 shows flow chart about controlled clinical investigations involving young adult patients with anterior teeth showing radiographically visible endodontic lesions and two options of NaOCl treatment.
Table 2. Articles excluded after full text evaluation and reasons for exclusion

<table>
<thead>
<tr>
<th>Reference</th>
<th>Reason for exclusion</th>
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<tbody>
<tr>
<td>Byström P, Sundqvist IC (2007)</td>
<td>Not selected</td>
</tr>
<tr>
<td>Banki AA, Marubini E, Anselmo TF (2004)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Gomes et al. (2007)</td>
<td>Not selected</td>
</tr>
<tr>
<td>Park et al. (2006)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Guimarães et al. (2006)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Siqueira et al. (2006)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Nourzadeh et al. (2005)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Mashalkar et al. (2004)</td>
<td>In vitro study</td>
</tr>
<tr>
<td>Mortin et al. (2004)</td>
<td>Only one NaOCl concentration</td>
</tr>
<tr>
<td>Tripathi et al. (2004)</td>
<td>Not selected</td>
</tr>
<tr>
<td>Siqueira et al. (2003)</td>
<td>Not selected</td>
</tr>
<tr>
<td>Ricci et al. (2003)</td>
<td>Not selected</td>
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<tr>
<td>Siqueira et al. (2003)</td>
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<td>Rotta et al. (2003)</td>
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Figure 1: Flow chart showing the results of the search process.

Inclusion criteria
- Young adults
- Asymptomatic apical periodontitis
- Anterior teeth

Outcomes
- Total regression of the lesion radiographically
- Absence of clinical signs and symptoms
- Tooth longevity

Figure 2: Flow chart suggesting controlled clinical investigations involving young adult patients with anterior teeth showing radiographically visible endodontic lesions using two options of NaOCl concentration, volume, and time of irrigation.

Discussion
Sodium hypochlorite was first used by Henry Dakin in 1915 to clean wounds and its use in endodontics was suggested by Coolidge in 1919. In 1922, Walker proposed its use for the irrigation of root canals, with the procedure being later disseminated by Grossman. Today, this is definitely the solution most extensively used...
worldwide for root canal instrumentation. It is an alkaline solution with an approximate pH of 11 to 12 whose germicidal and antibacterial action has been demonstrated by many investigators.

Although NaOCl has been part of the endodontic arsenal for more than one century, current investigations have been unable to determine the time of application, the volume or the concentration of this solution that can dissolve organic matter without weakening the dental structure during the phase of biomechanical preparation of the root canal. The present investigation was surprising by showing that no clinical trials on humans for the assessment of the concentrations, volumes and irrigation time with NaOCl solution were detected. And this result obligatorily stimulates the proposal of scientific methods that may resolve these questions.

Suggesting human studies that will provide an answer to this question is a challenge because of different variables. Other factors should be considered in addition to time of irrigation and concentration of the NaOCl solution. Age-related structural changes in dentin may also be detrimental to its mechanical properties since dentin becomes dehydrated and therefore more fragile with age. Gender has also been suggested to influence the number of roots and root canal system configuration in human permanent teeth. Thus, it is another variable that needs to be controlled in future trials.

Different endodontic diagnoses also need to be standardized in future studies since the time of regression of lesions such as periapical granulomas or cysts is longer than that for regression of only inflamed pulp. Another provocative factor is the time of irrigation. Establishing the time necessary for the action of NaOCl during biomechanical preparation of the root canal system, i.e., 5, 10, 15, or 20 minutes as observational intervals, may render it enviable to obtain results due to aspects such as expertise of the clinicians and endodontists, the selection of endodontic systems, the protocols used, and patient collaboration. It should be pointed out, for example, that Nourzadeh et al. obtained an effective protocol using 5.25% NaOCl for 10 minutes. However, that was an in vitro study.

Also, the NaOCl concentrations used vary from values such as 0.5% (Dakin’s fluid), 1% (Milton’s solution), 2.5% (Labarraque’s liquor), and 4 to 6% chlorinated soda. Different NaOCl irrigation protocols may alter the mechanical properties of dentin such as microhardness and modulus of elasticity. NaOCl solutions of 5.25% have been shown to be potently antimicrobial in an in vitro study and in a clinical investigation by Paudel et al. However, this result was obtained without a comparative analysis and using a reduced sample. Siqueira et al. demonstrated the killing efficacy of lower NaOCl concentrations, such as 4.0%, against E. faecalis, and van der Vyver et al. demonstrated it using a 3.5% concentration. However, these were laboratory studies using isolated bacterial species. An effective antimicrobial action of 2.5% NaOCl was detected in human trials, although the results were only compared to 0.2% or 0.12% chlorhexidine and to potassium iodide. In contrast, according to a clinical study conducted by Gomes et al., a 2.5% NaOCl solution was ineffective in the elimination of endotoxins in primary infections of root canals of teeth with pulp necrosis and apical periodontitis.

Regarding the dissolution of organic tissue, there is no consensus about an ideal concentration for an effective action, although The proposed that 3% NaOCl is the ideal concentration able to dissolve necrotic tissues. More recently, van der Vyver et al. stated that the irrigating solution is an ideal solvent of organic matter both for a vital and a necrotic pulp. However, they observed that this solution is intensely irritating for periapical tissues, especially at high concentrations. In our survey we did not detect comparative studies regarding different times and volumes of irrigation. Soares et al. suggested a volume of 15 mL for the reduction of the number of aerobic and anaerobic bacteria per root canal.

The importance of the present investigation may perhaps reside in the feeling of absolute frustration it caused among the authors. The fact that there are no studies able to answer the key question leads us to suggest controlled clinical investigations involving young adult patients with anterior teeth showing radiographically visible endodontic lesions using two options of NaOCl concentration, volume, and time of irrigation, as shown in figure 2. After 12 years, Zehnder’s comment that we are living in the age of evidence-based medicine, and any new concept or technique to be used in the clinic should ideally be assessed in randomized controlled trials is still timely and valid. This, however, represents a major problem in endodontic research.

CONCLUSION

This systematic review was unable to indicate what time of irrigation, concentration or volume of NaOCl solution can be of maximum effectiveness in endodontic treatment without causing significant changes in the mechanical properties of dentin. Thus, future controlled human clinical trials should be encouraged in view of the different factors that may bias and confuse the results.

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CONFLICTS OF INTERESTS
The authors declare no conflicts of interests.

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