A critical analysis of the sanitization strategies on root canal cleaning

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ABSTRACT

Objective: To assess the efficacy of irrigant solutions used in endodontic treatment in terms of cleanliness, smear layer removal and tissue dissolving potency by means of a systematic review of longitudinal studies. Method: Articles were identified in electronic bibliographies accessible via MEDLINE. Searches were run on the PubMed Database (http://www.ncbi.nlm.nih.gov/PubMed) for articles published from 1966 to January 10, 2012, using combinations of the following keywords: (Endodontic or root canal) and (Smear layer or clean* or tissue dissolution or organic dissolution) and (irrigants or NaOCl or sodium hypochlorite or Milton Solution or Dakin solution or Labarraque solution or chlorinated soda or chlorine or chloride or hypoclean or hypochlor or niclor or Chlor-xtra or chlorhexidine or chx or cloreximid or peridex or periogard or EDTA or Acid or citric or acetic or peracetic or malic or vinegar or citrate or Hydrogen peroxide or H_2O_2 or Iodine or iodide or povidone or povidine or PVP or Ozone or ozonated or MTAD or Tetraclean or Endoptc or Rc prep or Morinda citrifolia or Aquatine or hydroxyethylcellulose or cat's claw or propolis). Studies were assessed for inclusion and exclusion criteria by two independent examiners. Results: The search returned 817 articles. Four (04) studies met the preestablished inclusion criteria and not the exclusion criteria. Teeth were assessed histologically at points 1, 2 and 3 mm from the root apex. Sodium hypochlorite at 5.25% and 6% was the only irrigating solution for which there is scientific evidence of root wall cleaning activity. Conclusions: Addition of ultrasound improved the cleaning potency of irrigant solutions. Isthmus regions had the lowest percentages of area free from debris.

Keywords: Sodium Hypochlorite, Smear Layer, Review.

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Análise crítica das estratégias de sanificação na limpeza do canal radicular

RESUMO

Objetivo: Avaliar, em estudos longitudinais, a eficácia das soluções irrigantes utilizadas no tratamento endodôntico sobre a limpeza, remoção da smear layer e poder de dissolução tecidual, através de revisão sistemática. Método: Empregaram-se fontes de catalogação bibliográfica identificadas eletronicamente pelo portal MEDLINE (http://www.ncbi.nlm.nih.gov/PubMed), a partir de 1966 até 10 de janeiro de 2012. Na estratégia de busca empregou-se a combinação dos unitermos: (Endodontic or root canal) and (Smear layer or clean* or tissue dissolution or organic dissolution) and (irrigants or NaOCl or sodium hypochlorite or Milton Solution or Dakin solution or Labarraque solution or chlorinated soda or chlorine or chloride or hypoclean or hypochlor or niclor or Chlor-xtra or chlorhexidine or chx or cloreximid or peridex or periogard or EDTA or Acid or citric or acetic or peracetic or malic or vinegar or citrate or Hydrogen peroxide or h2o2 or Iodine or iodide or povidone or povidine or PVP or Ozone or ozonated or MTAD or Tetraclean or Endoptc or Rc prep or Morinda citrifolia or Aquatine or hydroxyethylcellulose or cat's claw or propolis). Os estudos foram selecionados por dois revisores, independentes, que determinaram os critérios de inclusão e exclusão. Resultados: A busca apresentou 817 artigos relacionados. Quatro (04) estudos satisfizeram os critérios de inclusão e exclusão preestabelecidos. A avaliação histológica foi realizada a 1, 2 e 3 mm do ápice radicular. O hipoclorito de sódio a 5,25% e 6% foi a única solução irrigante a apresentar evidências científicas de ação de limpeza sobre as paredes dos canais radiculares. Conclusão: A utilização do ultrassom melhorou o potencial de limpeza das soluções irrigantes. As regiões de istmo apresentaram menor percentual de áreas livres de detritos.

Palavras-chave: Hipoclorito de Sódio, Camada de Esfregaço, Revisão.

INTRODUCTION

Removal of remaining vital and/or necrotic pulp tissue, microorganisms and toxins from the root canal improves the results of root canal treatment. The cleaning and shaping process include steps that can challenge professionals and may obstruct the procedure, such as root canal length, diameter and degree of curvature (1,2). The aim of root canal preparation is to remove debris, dentine shavings, remnants of vital or necrotic pulp tissue and bacterial components adhering to the root canal wall (3-5). Removal of these remaining tissues is most effective in the coronary and middle thirds (6), but studies of cleaning effectiveness have shown that instrumentation alone is not always sufficient to completely eliminate debris, especially not in the apical region of curved root canals (7). To achieve complete elimination, ultrasonic activation of the irrigation solution has been proposed as one strategy that can aid in removing organic and inorganic debris from the root canal walls (8). An endodontic file activated by ultrasonic vibration may improve root canal cleaning (1). Furthermore, using the device in combination with hand-rotary instrumentation has been shown to help reduce bacteria (9).

In view of the pathogenicity of the microorganisms that are responsible for apical periodontitis, there is a clear need to find substances that can improve root canal preparation, with the objectives of effective emptying and microbial control. The process of cleaning root canal structures is based on emptying and enlargement during the chemical-mechanical action of endodontic irrigants and instruments. Sodium hypochlorite is an irrigating solution that is has been widely studied and is used by most professionals. This substance has several properties, including antimicrobial activity, the ability to dissolve tissues, cleaning ability and tolerance by tissues at appropriate concentrations (10-21). Another antimicrobial agent that has been investigated is chlorhexidine, which has been tested and found suitable for application to a range of pathogenic endodontic microorganisms (22-27). Chelating agents such as EDTA have been used as auxiliary substances in combination with irrigants, in order to demineralize dentin and assist in removing the inorganic component of the smear layer (28).

The diversity of irrigating solutions, different concentrations and techniques proposed for the same procedures have been justified in the literature in terms of which treatment options are most appropriate for root canal cleaning. Studies based on scientific evidence exhibit a tendency to emphasize studies in humans beings with the aim of answering clinical questions by a longitudinal analysis of published critical articles. The purpose of this study was therefore to establish the influence of sanitization strategies used in root canal cleaning by means of a systematic review of longitudinal studies.

MATERIAL AND METHODS

This investigation consisted of an analysis of longitudinal studies employing quantitative systematic review methodology. Articles were identified in electronic bibliographies accessible via MEDLINE. Searches were run on the PubMed Database (http://www.ncbi.nlm.nih.gov/PubMed) for articles published from 1966 to January 10 2012 using various combinations of the following keywords: endodontic, root canal, smear layer, clean, tissue dissolution, organic dissolution, irrigants, NaOCl, sodium hypochlorite, Milton solution, Dakin solution, Labarraque solution, chlorinated soda, chlorine, chloride, hypoclean, hypochlor, niclor, Chlor-xtra, chlorhexidine, chx, cloreximid, peridex, periogard, EDTA, acid, citric, acetic, peracetic, malic, vinegar, citrate, hydrogen peroxide, H_2O_2, Iodine, iodide, povidone, povidine, PVP, ozone, ozonated, MTAD, tetraclean, endoptc, Rc prep, morinda citrifolia, aquatine, hydroxyethylcellulose, cat's claw and propolis. Articles were selected for the systematic review if they described prospective studies investigating the cleaning efficacy of irrigating solutions used in root canal preparation and their capacity to remove the smear layer and dissolve tissues. The titles and abstracts of the articles identified by the electronic search were evaluated by two independent reviewers on the basis of criteria listed in Table 1. Full text articles were then read and selected or rejected by the reviewer according to the same criteria. Once papers meeting the inclusion criteria had been selected, the studies were analyzed further and those employing methodology that was not compatible with the objectives of the review were excluded. The criteria for the exclusion of articles are also detailed in Table 1.

TABLE 1 – Description of the inclusion and exclusion criteria used for the systematic review

Inclusion criteria
In vivo studies
Use of methodologies for assessing the effectiveness of endodontic irrigation agents
Use of methodologies to evaluate the cleanliness of root canals
Exclusion criteria
Studies conducted in animals
Case Reports
Using the technique for cleaning canals without instrumentation
Work in deciduous teeth
Studies not written in English
Articles with no abstract

The most important methodological features considered during study selection were sample size; initial pulp status (vital or necrotic pulp); types and concentrations of irrigating solutions used during preparation; surgical techniques for cleaning canals and the criteria used to assess cleanliness after canal preparation. Percentage cleanliness of canal lumen and isthmus were calculated from the results reported in the selected articles. Means and standard deviations were calculated for points 1, 2 and 3 mm short of the apical foramen. The *t* test for independent samples was used to compare cleaned areas (area free from debris) after cleaning with or without ultrasound as an irrigation aid. ANOVA with Tukey's *post hoc* test was used to determine the significance of differences at varying distances from the apical foramen (1, 2 or 3 mm). The significance level adopted was 5% and statistical analysis was conducted using the Statistical Package for the Social Sciences, version 20 (SPSS, Chicago, IL).

RESULTS

The search for articles on the subject of the systematic review returned a total of 817 studies. Fifty-four of these articles met the inclusion criteria. Detailed analysis revealed characteristics consistent with the exclusion criteria in 50 studies. Just four articles met the inclusion criteria without meeting the exclusion criteria, all of which were derived from the systematic review methodology (29-32) (Table 2). Haidet et al. (29) instrumented 60 molars using the step-back technique and # 25 or 30 K-files. An experimental group also received 3 min of ultrasonic (Cavi-Endo) instrumentation with 5.25% sodium hypochlorite at a constant flow rate of 30 mL/min. Archer et al. (30) prepared 42 mandibular molar root canals with vital pulp using a step-back technique and # 25 or 30 K-files. At each change of instrument, intermittent irrigation was performed using 2 mL of 5.25% sodium hypochlorite. An experimental group also received 3 min of instrumentation with an ultrasonic unit (Osada ENAC OE-7). Gutarts et al. (31) modeled 36 mesial roots of molars with vital pulp using K-files up to # 20, followed by a crown-down technique with nickel-titanium ProFile GT # 35.12 . At the end of preparation, each root canal was flushed with 15 ml of 6% sodium hypochlorite at a constant 15 mL/min. One of the experimental groups also received 1 min of MiniEndo ultrasonic instrumentation. Burleson et al. (32) evaluated 48 mesial roots of mandibular molars with an initial diagnosis of apical periodontitis. Teeth were instrumented with a #20K-file, followed by the crown-down technique with a nickel-titanium ProFile GT # 35.12. Canals were irrigated with 30 mL of 6% sodium hypochlorite with an accurate and constant flow of 15 mL/min, controlled by an Aladdin mechanical pump. One of the experimental groups also received 1 minute of MiniEndo ultrasonic instrumentation.

TABLE 2 – Summary of methods used and results obtained by studies analyzed.

Authors	N	Pulp/ periapical status	Irrigating solution	Preparation technique	Area free from debris (histological evaluation) (%) *			
					Root canal		Isthmus area	
					ultrasound	no ultrasound	ultrasound	no ultrasound
Haidet et al.[29] (1989)	60 mandibular molars.	Vital	5,25% Sodium hypochlorite	Manual (step-back)	1mm-88% 3mm-99%	1mm-99.6% 3mm-100%	1mm-10.4% 3mm-69.2%	1mm-85,7% 3mm-94,1%
Archer et al.[30] (1992)	42 mesial canals of mandibular molars	Vital	5,25% Sodium hypochlorite	Manual (step-back)	1mm-64.2% 2mm-81.2% 3mm-90.1%	1mm-92.3% 2mm-97.3% 3mm-99.9%	1mm-2.2% 2mm-15.3% 3mm-16.3%	1mm-45,6% 2mm-59,8% 3mm-83%
Gutarts et al.[31] (2005)	36 mesial roots of molars	Vital	6% Sodium hypochlorite	Manual / rotary (crown down)	1mm-75.1% 2mm-96.5% 3mm-99.7%	1mm-99% 2mm-100% 3mm-99.8%	1mm-15% 2mm-27.8% 3mm-34.1%	1mm-96,5% 2mm-73,3% 3mm-94,2%
Burleson et al.[32] (2007)	48 mesial roots of mandibular molars	Apical periodontitis	6% Sodium hypochlorite	Manual / rotary (crown down)	1mm-80.1% 2mm-91.6% 3mm-95.1%	1mm-94.7% 2mm-99% 3mm-99.6%	1mm-33.3% 2mm-31.4% 3mm-44.6%	1mm-82,8% 2mm-86,1% 3mm-91,1%
Total Means	-	-	-	-	**1mm-76.85% 2mm-89.76% 3mm-95.9%**	**1mm-96.4% 2mm-98.76% 3mm-99.82%**	**1mm-15.2% 2mm-24.83% 3mm-41.07%**	**1mm-77,65% 2mm-73,06% 3mm-90,6%**

* Cleanliness of the root canal and isthmus was evaluated at points 1, 2 and 3 mm short of the apical tip.

Table 2 summarizes the methods used and results obtained by the four articles selected for the systematic review. Comparison of mean results from the four articles that met the inclusion criteria without falling foul of the exclusion criteria revealed that the canal lumen had the highest percentage cleaned area 3 mm short of the foramen. The worst results were observed 1 mm short of the foramen. There was a statistical difference between the mean percentages of cleaned canal lumen area between points 3 mm and 1 mm short of the foramen, when the ultrasound was not used during irrigation of root canals (Table 3).

TABLE 3 – Percentage of the root canal lumen and isthmus area cleaned at points 1mm, 2mm and 3mm short of the apical foramen. Mean ($\bar{x}$) and standard deviation (S).

Root canal lumen.				
	1mm	**2mm**	**3mm**	**P**
	$\bar{x} \pm s$	$\bar{x} \pm s$	$\bar{x} \pm s$	
ultrasound	76.85 ± 9.97[a]	89.77 ± 7.81	95.98 ± 4.41[b]	0.023
no ultrasound	96.40 ± 3.50	98.77 ± 1.37	99.83 ± 0.17	0.152

Isthmus area				
	1mm	**2mm**	**3mm**	**P**
	$\bar{x} \pm s$	$\bar{x} \pm s$	$\bar{x} \pm s$	
ultrasound	15.23 ± 13.16	24.83 ± 8.45	41.05 ± 22.10	0.139
no ultrasound	77.65 ± 22.16	73.07 ± 13.15	90.60 ± 5.27	0.333

(P: Anova).

A higher percentage of the root canal area at the point 1 mm short of the foramen was cleaned when ultrasound was used (96.4%) then when ultrasound was not used (76.85%) (Table 4).

TABLE 4 – Percentage of canal lumen cleaned with and without ultrasound. Mean ($\bar{x}$) and standard deviation (S).

Root canal lumen			
	no ultrasound	**ultrasound**	**P**
	$\bar{x} \pm s$	$\bar{x} \pm s$	
1mm	76.85 ± 9.97	96.40 ± 3,50	0.01
2mm	89.77 ± 7.81	98.77 ± 1.37	0.121
3mm	95.98 ± 4.41	99.83 ± 0.17	0.132
Isthmus area			
	no ultrasound	**ultrasound**	**P**
	$\bar{x} \pm s$	$\bar{x} \pm s$	
1mm	15.23 ± 13.16	77.65 ± 22.16	0.003
2mm	24.83 ± 8.45	73.07 ± 13.15	0.006
3mm	41.05 ± 22.10	90.60 ± 5.27	0.005

(P: *t* test for independent samples).

The percentage area cleaned at isthmus regions was higher when ultrasound was used at all apical levels studied (Table 5). Isthmus regions (Table 5) had lower percentages of area cleaned than canal lumens, irrespective of whether ultrasound was used or not.

TABLE 5 – Percentage of the root canal and isthmus regions cleaned. Mean ($\bar{x}$) and standard deviation (S).

	Root canal	Isthmus area	P
Ultrasound			
	$\bar{x} \pm s$	$\bar{x} \pm s$	
1mm	96.40 ± 3.50	77.65 ± 22.16	0.146
2mm	98.77 ± 1.37	73.07 ± 13.15	0.028
3mm	99.83 ± 0.17	90.60 ± 5.27	0.013
No ultrasound			
	Root canal.	**Isthmus area**	**P**
	$\bar{x} \pm s$	$\bar{x} \pm s$	
1mm	76.85 ± 9.97	15.23 ± 13.16	0.000
2mm	89.77 ± 7.81	24.83 ± 8.45	0.001
3mm	95.98 ± 4.41	41.05 ± 22.10	0.003

(P: *t* test for independent samples).

DISCUSSION

Irrigating solutions are important sanitization agents for root canal preparation, since they are able to remove microorganisms and remnant tissues (both organic and inorganic), allowing for elimination of contaminated dentin (33). An effective action is achieved when the irrigant solutions come into close contact with the root canal walls, which is critical in the apical third (34). There is currently no single substance that is known to have all of the characteristics, even if temperature is increased or surfactants added in order to improve their effectiveness (35,36). Sodium hypochlorite is the most commonly used auxiliary solution for endodontic root canal preparation because it offers excellent antimicrobial activity and the ability to dissolve organic materials. However, its powerful organic tissue dissolution activity is not selective. Depending on concentration, sodium hypochlorite is capable of dissolving both remnants of necrotic pulp tissue and also vital periodontal ligament tissues if inadvertent extrusion occurs through the apical foramen. [37] The search therefore continues for a substitute solution that offers bactericidal action on a par with sodium hypochlorite but with better biocompatibility with periapical tissues (38).

The conventional method of syringe irrigation is often not an effective procedure in the apical third (39). Efforts have therefore been made to develop systems capable of improving the effects of endodontic irrigating solutions through agitation and controlled application. The various different systems use rotating brushes, alternating pressure devices, sonic and ultrasonic systems or rotary instrumentation mechanisms with simultaneous canal irrigation. These methods appear to improve canal cleaning in comparison with the conventional irrigation method using syringe and needle (40). Ultrasonic irrigation is the most effective method for removing dentin debris. Sabins et al. (41) evaluated the technique in artificial roots, showing that from thirty seconds to one minute of ultrasonic activation is enough to reduce the amount of debris after endodontic instrumentation. The results of four studies in humans, including a systematic review, showed that the area free from debris was larger when ultrasound was used to improve irrigation results (Table 3).

The complex anatomy of the root canals makes it difficult to completely remove tissue, debris and biofilm from the lumen and isthmus of root canals. Ultrasound is used to assist this process during canal irrigation by promoting an acoustic flow can be defined as fluid moving rapidly in a vortex or circular path around the vibrating instrument. Ultrasonic vibrations also cause cavitation in irrigating solutions, which is a phenomenon defined as the creation of vapor bubbles or the expansion, contraction and/or distortion of pre-existing bubbles in the liquid (42). The result is that combining one minute of ultrasound-activated irrigation with hand-rotary instrumentation significantly increases the percentage of the root canal that is cleaned (32). In general, the literature recommends using ultrasonic irrigation for periods of 30 s to 3 min, but there is no consensus on an exact duration for this application (33,34,43).

The systematic review of the cleaning efficacy of endodontic irrigating solutions identified four studies that met the previously established inclusion criteria and were not ruled out by the exclusion criteria. All four of these studies investigated experimental methods using 5.25% or 6% sodium hypochlorite. When the focus of the investigation was root canal cleanliness, sodium hypochlorite achieved better results at high concentrations (44). Haidet et al. (29) reported that manual preparation combined with ultrasound was the better option after assessing cleanliness at a point 1 mm short of the foramen in the canal (99.6% versus 88%) and the isthmus region (86% versus 10%). Archer et al. (30) found that the manual technique combined with ultrasound achieved better cleaning of the isthmus regions at points 1 and 3 mm short of the foramen (83% at 3 mm against 16.3% for the manual technique at the same level). Gutarts et al. (31) showed that addition of one minute of ultrasound-activated irrigation significantly improved mean root canal cleanliness at the apical levels analyzed. Their results were equal to or superior to results observed in earlier studies (29,30,45-47). It is unlikely that a manual-rotary cleaning technique without ultrasound can completely remove isthmus tissues from teeth with vital pulp. Addition of ultrasonic increased cleanliness percentages at all levels evaluated. The systematic review found that the area free from debris at 1 mm short of the foramen increased from 15.2% to 77.65% when ultrasound was used, while at 3 mm short of the foramen the percentage increased from 41% to 90% (31). Burleson et al. (32) showed that the average percentage root canal cleanliness was higher for a manual-rotary instrumentation group when compared to the results of other studies that used step-back preparation (29,45,46) and similar to results reported by Gutarts et al. (31).

Despite the fact that Attin et al. (48) conducted histological assessments to determine the degree of root canal cleanliness, certain methodological characteristics of their study justified its exclusion from the systematic review: a hydrodynamic, noninstrumental preparation technique was used; the irrigating solution was injected into the canal using a vacuum pump and alternating pressure was created using a piston pump. Attin et al. (48) found that this noninstrumental hydrodynamic technique resulted in retention of a large amount of debris in the apical region compared to manual/rotary instrumentation techniques (29-32,45-47,49,50). This observation has an impact on the effectiveness of noninstrumental cleaning. It is also conceivable that hydrodynamic irrigation caused pulpal and/or periapical irritation, resulting in bleeding into the root canal, as observed in most of the teeth treated in their study. Nevertheless, it is conceivable that in vivo the open apex and the surrounding tissue do not guarantee the maintenance of a closed system, which is important to achieve the turbulence needed for hydrodynamic cleaning of the root canal.

Despite not having been addressed in studies selected for the meta-analysis, chlorhexidine solution is currently under investigation as an irrigating solution. The cationic nature of chlorhexidine allows it to bind to anionic groups on the bacterial surface, interfering with its integrity. A suitable concentration of chlorhexidine alters the permeability of the cytoplasmic membrane; promotes precipitation of proteins, altering the osmotic balance of the cell, interferes in metabolism, growth and cell division, and inhibits the ATPase enzyme and the anaerobic process (22-27). These characteristics confer antimicrobial potency on chlorhexidine, but do not indicate the capacity to break down organic matter required of an irrigant soluti. The methodological rigor of the systematic review highlighted the absence of human studies with scientific evidence of the cleaning potency of chlorhexidine. Use of ultrasound as a supplemental aid in the process of root canal irrigation substantially improved the cleaning potency of endodontic irrigating solutions. Regardless of the irrigation method used, the isthmus regions of the root canals were shown to be areas prone to the accumulation of debris and consequently more difficult to clean.

Furthermore, it is necessary to find new irrigation methods for endodontic use that are able to meet all the requirements of root canal treatment. Irrigating solutions and irrigating methods produce better root canal cleaning results when combined with mechanical procedure that promote better emptying and sanitization of the root canal.

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