

Use of ultrasound and laser in root canal decontamination: literature review

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ABSTRACT

The greatest challenge to successful endodontic treatment is the elimination of microbiota. Mechanical instrumentation as well as auxiliary chemical substances are used to eliminate this microbiota. In addition to irrigating solutions, other complementary techniques such as passive ultrasonic irrigation (PUI) and laser are used to optimize elimination of microorganisms. Thus, the present study aimed at a bibliographic survey of different types of agitation of irrigating solutions in endodontic treatment. PUI has been suggested as a mean

to improve canal debridement. Laser has been used for presenting therapeutic advantages to treatment. All techniques considered to better clean root canals showed some improvement. The most commonly used technique is ultrasonic agitation due to being an efficient and practical procedure. It could be concluded that efficiency of microbial decrease is better achieved when a higher concentration of irrigating solution is used, irrespective of the chosen final agitation.

Keywords: Ultrasound. Lasers. Dental infections control.

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Introduction

Since the 1960's, it is established in the literature that the greatest challenge in Endodontics is total microorganism removal from root canals.¹

The use of sodium hypochlorite is effective in reducing microorganisms. Its concentration also influences antimicrobial action and deeper penetration into dentin tubules. The higher the concentration, the more effective.^{2,3}

The use of EDTA for final irrigation has also been proved very effective to supplement root canals cleaning.⁴

In addition to conventional irrigation, new means used to enhance root canal cleaning are being employed, such as agitation of irrigating solution with ultrasound and laser light.^{5,6}

Passive ultrasonic irrigation (PUI) has been suggested as a mean to improve root canal debridement, disinfection and further improvement in fillings.⁷ Besides debridement, ultrasound presents good mechanical effects, with removal of most smear layer, when compared to other preparation methods.^{8,9}

Laser has been used due to presenting adjuvant advantages in endodontic treatment, such as selectivity to dental tissues and precision during treatment, as well as considerable reduction in oral pathogens in the surgical field, better hemostasis, and a decrease in pain sensation for the patient.¹⁰ Low-level lasers have been studied *in vitro* and show that the use of laser associated with sodium hypochlorite has higher ability to dissolve organic material, thus enabling elimination of most microorganisms present inside root canal.⁶

Thereby, the present study aimed at carrying out a bibliographic survey of different types of agitation of endodontic irrigating solutions, in order to evaluate their participation in root canal system decontamination.

Literature review

Siqueira et al¹¹ assessed the microbiota of primary endodontic infections using the technique of checkerboard DNA-DNA hybridization for 42 bacterial species. Samples were collected from 26 single-root teeth with asymptomatic periapical lesions. The number of species found per canal ranged from 1 to 17 (mean = 4.7). The most prevalent species were: *Tanarella forsythia* (42% of cases), *Haemophilus aphrophilus* (19%), *Porphyromonas gingivalis* (19%), *Corynebacterium matruchotii* (15%), *Treponema denticola* (15%) *Capnocytophaga gingivalis* (12%), and *Streptococcus intermedius* (12%). The red complex bacteria (*T. forsythia*, *P. gingivalis* and *T. denticola*), which are often associated with severe periodontal disease, were found in two cases.

A study was carried out with 50 single-root teeth with apical periodontitis prepared with the aid of Bio-RaCe rotary instruments (FKG Dental, La Chaux-de-Fonds, Switzerland) and irrigated with 2.5% sodium hypochlorite (NaOCl) (n = 25) or 2% chlorhexidine (CHX) (n = 25). To compare the effectiveness of irrigation, the DNA of clinical samples was extracted, and the reduction in levels of total bacteria and streptococci was assessed. All samples were positive for the presence of bacteria. After chemo-mechanical preparation using 2.5% NaOCl or 2% CHX, 44% and 40% of root canals still had detectable bacteria, respectively. The authors concluded that even with bio-mechanical preparation and irrigation, bacteria persisted in root canals.¹²

Being aware of the persistence of microorganisms within root canal system, even with the use of antibacterial irrigating solutions, complementary means such as ultrasound and lasers are being used to complement the cleaning of root canals.⁵ Ultrasound was first used in the 1940's and 1950's. Basically, the technique consisted of converting electrical into mechanical energy in the form of vibration. Through a small tip vibrating at approximately 29,000 hertz (Hz), aluminum oxide abrasive flowed, thus rapidly cutting the tooth structure.¹³

Boff¹⁴ histologically assessed the passive use of ultrasound in the cleaning of flattened root canal system apical portion. The sample consisted of 20 extracted human mandibular incisors and divided into two distinct groups; after being instrumented with the rotary system Hero 642 (Micro Mega, Besançon, France) up to surgical diameter #45: Group A = final irrigation with 4ml of 2.5% sodium hypochlorite by the conventional technique with the use of syringe; and Group B = final irrigation with 4ml of 2.5% sodium hypochlorite, divided into four samples of 1 ml each activated by passive ultrasound for 15 seconds each, thus generating a total activation time of one minute. Afterwards, the teeth were submitted to mor-

phometric analysis to have the cleaning ability promoted in both groups assessed. Statistical analysis showed significant difference between groups, with passive ultrasound resulting in cleaner root canals.

Paqu  et al¹⁵ used 20 extracted human mandibular molars. Root canals were instrumented with ProTaper rotary system up to F3 file reaching the working length — 1% sodium hypochlorite was used during instrumentation. Subsequently, root canals were irrigated with 5 ml of 17% EDTA. After that, passive ultrasonic irrigation (PUI) was performed using sodium hypochlorite agitated three times for 20 seconds each time. Significant effect of both EDTA and PUI has been demonstrated. However, about half of debris accumulated during instrumentation remained in the root canal system.

Jiang et al¹⁶ reaffirmed what had already been studied by Paque et al.¹⁵ In their study, different types of irrigation associated with agitation (irrigation with conventional syringe, dynamic manual activation with gutta-percha cone, irrigation with continuous ultrasonic agitation and irrigation with negative apical pressure) were used and tested in 20 *ex-vivo* root canals full of debris in the apical portion of one root canal wall. The apical portion was instrumented with nickel-titanium files #40/02 (Dentsply Maillefer, Ballaigues, Switzerland) by means of balanced force technique. During preparation, root canals were rinsed with 2 ml of 2% NaOCl after each instrument change with a 10-ml syringe (Terumo, Leuven, Belgium) and a Navitip #27 gauge needle (Ultradent, USA). Ultrasonic agitation proved significantly better than all other techniques tested in this study ($p < 0.001$), thus concluding that PUI was the most effective technique used to remove dentine remains from apical irregularities.

In a study by Roldi et al,¹⁷ it can be seen that the use of ultrasound associated with 2.5% sodium hypochlorite irrigation is more efficient than irrigation only. However, when NaOCl concentration was increased to 5.25%, ultrasound did not enhance its action. Thus, the authors were able to conclude that irrigating solution concentration is more important than agitation with ultrasound, particularly when it comes to cleaning and death of microorganisms within root canals.

Guerreiro-Tanomaru et al¹⁸ conducted a study comparing groups treated with: G1 = 1% sodium

hypochlorite and PUI; G2 = saline solution with PUI; G3 = only 1% sodium hypochlorite; and G4 = only saline solution. The authors found that microorganisms decreased in groups treated with 1% sodium hypochlorite both with and without agitation. However, complete elimination of microorganisms was not possible.

Zorzin et al¹⁹ assessed 130 extracted human teeth with straight roots instrumented with Flexmaster files #45/04 (VDW, Munich, Germany). Out of those, 120 teeth were filled with calcium hydroxide (CH) and a gutta-percha cone; 10 teeth were filled with one gutta-percha cone for negative control. Teeth were randomly divided into 12 groups ($n = 10$). Gutta-percha was removed and so was CH by irrigation with different volumes (0 ml, 0.5 ml, 1 ml, 2 ml, 4 ml, or 8 ml) or mechanical activation with volume of 2 ml or 4 ml with the aid of a cone (Instr Flex Master #45/04; VDW, Munich, Germany), a canal brush, (Coltene/Whaledent, Langenau, Germany), or passive ultrasonic irrigation (PUI). Irrigation was performed by alternating 40% citric acid and 3% sodium hypochlorite. No irrigation procedure was able to remove CH completely, but PUI and irrigation with volume of 8 ml were the most effective methods.

In the year of 1903, Dr. Niels Ryberg Finsen received the Nobel Prize in Physiology and Medicine for the use of ultraviolet waves emitted from solar radiation in the treatment of patients with lupus vulgaris. This was the first time light energy was applied for therapeutic purposes, thus opening doors to a new development area of Medical Sciences.²⁰

Weichman and Johnson²¹ used laser for the first time in Endodontics while trying to seal the apical foramen externally. In this case, CO₂ laser (carbon dioxide) was used. Since that date, the demand for laser application in Endodontics has become frequent, which revolutionized some aspects of conventional treatment. Nowadays photodynamic therapy (PDT) is more used in Endodontics, in which case dye is placed inside root canal, thus leading to pigmentation of microorganisms and causing light to be captured only by them.

Foschi et al²⁵ investigated the effects of PDT on species of *Enterococcus faecalis* in root canals of extracted teeth. Teeth were sensitized with methylene blue (6.25 µg/ml) for five minutes. Root canals were irradiated by means of optical fiber with laser emitted

in red, with wavelength of 665 nm and energy of fluency of 60 J/cm². PDT achieved a 77.5% reduction in viability of *E. faecalis*.

Fonseca et al²⁶ assessed the effects of PDT in root canals of human teeth infected with *E. faecalis in vitro*. Root canals were sensitized with toluidine blue at a concentration of 0.0125%. Specimens were irradiated with laser emitting in red, with wavelength of 660 nm, by means of optical fiber with energy of fluency of 400 J/cm² for five minutes and 20 seconds. Results evidenced a microbial reduction of 99.9% in colony forming units.

In an *in vivo* study, Garcez et al²⁷ used 30 anterior teeth of 21 patients with periapical lesions that had been treated with conventional endodontic treatment and antibiotics. Microbiological samples were collected: 1) after access to the root canal; 2) after endodontic treatment; and 3) after PDT. The use of PDT added to conventional endodontic treatment led to a large reduction in microbial load. PDT is an effective treatment for eliminating multi-drug resistant microorganisms.

Pedullà et al²⁸ studied 148 single-rooted extracted teeth prepared with Mtwo files #25/06 (Sweden & Martina, Due Carrare, Italy). Samples were sterilized, and all teeth except ten (negative control group) inoculated with *Enterococcus faecalis* incubated in a CO₂ chamber at 37 °C for 15 days in Eppendorf tubes through triptic soy broth changed every two days. Infected teeth were then randomly divided into four test groups (*n* = 32 for each): erbium:YAG laser for 30 seconds with sterile bidistilled water (Group A); 5% sodium hypochlorite (Group B); non-sterile irrigation with bidistilled water activated by laser for 30 seconds (Group C); 5% NaOCl irrigation for 30 seconds (Group D). Positive control group received no treatment on infected teeth (*n* = 10). Under the conditions of this *ex-vivo* study, there was no significant difference in bacterial reduction between laser and irrigation with NaOCl only.

Garcez et al²⁷ discussed the need to use optical fiber/diffuser to perform PDT associated with endodontic therapy. A total of 50 single-root human teeth were used. Conventional endodontic treatment was performed using the ProTaper sequence (Dentsply Tulsa Dental, USA), teeth were sterilized, and root canals contaminated with *Enterococcus faecalis*. Samples

were divided into five groups: G1 = 10 roots irradiated with laser tip (area of 0.04 cm²); G2 = 10 roots irradiated with a smaller laser tip (area of 0.028 cm²); G3 = 10 teeth with crown irradiated with laser tip with 0.04 cm² of area; G4 followed the same methodology applied to G3, but irradiation was performed with a smaller tip (area of 0.028 cm²); and G5 had 10 teeth with crown irradiated using a 200 mm tip of optical fiber/diffuser coupled to the diode laser. Microbiological samples were collected after root canals had been treated after PDT. Results suggest that the use of PDT used on canals infected with *E. faecalis* with the optical fiber/diffuser is better than when laser light is used to access the addressed cavity.

Garcez et al²⁹ assessed 28 teeth of 22 patients with periapical lesions previously subjected to endodontic treatment. All teeth presented signs and symptoms of apical periodontitis and radiographically visible periapical lesion. Complete mucoperiosteal flap, osteotomy, curettage (of lesion cavities and external root surface), root apex resection, and retrograde preparation with the aid of an ultrasound tip were performed. After the conventional procedure, cavities received a solution in aqueous medium with methylene blue (60 µM, 3 min pre-irradiation time) and irradiated with red diode laser (γ = 660 nm, P = 40 mW for 3 min, E = 7.22J). The cavity was dried and the laser tip changed to allow access to the retrograde cavity. Irradiation inside the retrograde cavity was performed with an optical fiber (Φ = 200 mm, MMOptics, São Paulo, Brazil). After PDT, the retrograde cavity was filled with MTA (Angelus, Londrina, Paraná, Brazil) and the flap was repositioned. Microbiological samples were obtained. The study suggests that the use of PDT as adjunct to conventional endodontic surgery leads to significant reduction in bacterial load and it is even more effective than surgical treatment. PDT provides atoxic means of destroying microorganisms after conventional therapy.

Ayranci et al⁵ compared 48 single roots prepared with ProTaper rotary instruments up to file #40 (F4) in the working length. Specimens were divided into four groups: A = PUI with 5 ml of 2.5% NaOCl for 60 seconds; B = PUI with 2.5 ml of 17% EDTA and 2.5 ml of 2.5% NaOCl for 30 seconds each; C = IAL (irrigation assisted by laser) with 5 ml of 2.5% NaOCl for 60 seconds; and D = laser with 2.5 ml of 17% EDTA

and 2.5 ml 2.5% NaOCl for 30 seconds each. In the PUI groups, ultrasonic tips were inserted 1 mm below the working length, but in the IAL groups, the fiber tip was applied at the pulp chamber. IAL in the pulp chamber combined with 17% EDTA and 2.5% NaOCl removed more smear layer than the other groups ($p < 0.018$). IAL in the pulp chamber combined with 2.5% NaOCl and 17% EDTA was better at removing smear layer than IAL applied in the same manner, but without EDTA or PUI with the same concentration of NaOCl and EDTA.

Li et al³¹ studied 24 premolars which were chosen based on the presence of isthmus regions, as confirmed by microCT exams (micro computed tomography). Root canals were instrumented with a F2 ProTaper file and filled with calcium hydroxide (CH). Samples were divided into four groups ($n = 6$), according to the irrigation technique: conventional needle, ultrasound, EndoActivator, and PIPS (Photon-Induced Photoacoustic Streaming). Samples were assessed by microCT prior to instrumentation, after filling with CH and after irrigation. PIPS and ultrasonic irrigation showed greater effectiveness in the removal of CH from the main canal and isthmus of maxillary premolars than EndoActivator or irrigation with conventional needle.

Azim et al³² compared the efficiency of four irrigation systems in the elimination of bacteria from root canals ($n = 15$). Root canals were disinfected by: 1 = conventional needle irrigation; 2 = activation with EndoActivator; 3 = finishing with XP Endo; or 4 = PIPS. Bacteria reduction in the root canal was determined with cytotoxicity assays by MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazoline bromide]. However, results revealed XP Endo was more effective than the other three techniques of disinfection of root canal openings up to 50 μ m deep inside dentinal tubules. PIPS was more effective at eliminating bacteria inside dentinal tubules.

Discussion

It is known that instrumentation and copious irrigation of the root canal system are essential for successful endodontic treatment. Over the years, new techniques used to enhance elimination of microorganisms and leverage the action of auxiliary chemicals have been used.²⁹

Current methods employed to remove smear layer and debris include chemical methods, ultrasound and laser techniques; however, none of them is fully effective throughout the length of the root canal system or is universally accepted.³⁰

In order to be effective, the irrigating solution must touch all walls of the main canal, which is more difficult when only conventional irrigation is used.³¹ The use of ultrasound in irrigation allows the irrigating solution to touch more walls of the root canal, as well as to penetrate more in the tubules, consequently bringing better efficiency to decontamination of the root canal system.³²

Ultrasonic activation of sodium hypochlorite is the most used in studies, and serves as a control in comparison to other systems that employ mechanical agitation.³³

Ultrasonic activation of NaOCl from 30 seconds to 1 minute, with three cycles of 10-20 seconds (with constant renewal of irrigating solution), proves to be enough to achieve a clear canal at the end of root canal biomechanical preparation (BMP).⁷ Ultrasound has shown to be less effective in increasing the activity of EDTA, but still can contribute to improving the removal of smear layer.^{7,34}

What cannot be ignored is that any improvement in root canal cleaning is a major advance. Even if the apical third is not completely clean, it has been proved that a large amount of debris that remain in the region are removed with ultrasonic agitation.¹⁵

Therefore, when it comes to reduction of microorganisms, it may be noted that efficiency is more focused on the concentration of the irrigating solution than ultrasonic agitation.¹⁷

Ultrasound comes to assist in cleaning in general, but alone it does not show efficiency, only when associated with a disinfectant solution.

Photodynamic therapy (PDT) emerges as a new therapy adjuvant to endodontic treatment in the attempt to eliminate microorganisms that have persisted after chemo-mechanical preparation. Due to being quick and of easy clinical application, it does not lead to microbial resistance, and may be recommended in root canal treatment carried out in a single session or multiple sessions.³⁶

In addition to more common methods, such as ultrasound and laser, new methods have been employed at

present, namely: PIPS, functioning as photon-induced photoacoustic streaming; EndoActivator™, a sonic system developed to safely activate the irrigating solution by vibration of a tip inserted into the root canal flooded with irrigating solution, thereby resulting in a hydrodynamic phenomenon;³⁷ Canal brush, used on the contra-angle as a “brush” for cleaning; and XP Endo, which is coupled to a rotary engine and will clean only the apical third without enlargement of the root canal. The latter is not yet available in the Brazilian market.

Conclusion

All of the aforementioned techniques used to improve root canal cleaning showed some advantage. The most common technique is still ultrasonic agitation due to being an effective and practical procedure.

It can be concluded by this literature review that microbial reduction efficiency is higher when a more concentrated irrigating solution is used, regardless of agitation with ultrasound or laser.

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