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Sonic vs Ultrasonic activation of sodium hypoclorite for root canal treatments. In vitro assessment of debris removal from main and lateral canals

Attivazione Sonica vs attivazione Ultrasonica dell'ipoclorito di sodio per i trattamenti endodontici. Valutazione in vitro della rimozione dei detriti dai canali principali e laterali

KEYWORDS
Root canal irrigation, Sodium hypoclorite, Sonic activation, Ultrasonic activation, Accessory canals

PAROLE CHIAVE
Irrigazione canalare, ipoclorito di sodio, Attivazione sonica, Attivazione ultrasonica, Canali accessori

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Abstract

Aim: *Aim of this study is to evaluate the efficacy of two different sonic and ultrasonic devices in the elimination of debris from artificial main and accessory canals.*
Methodology: *Two different irrigant activator devices were tested: the sonic handpiece Endo-Activator (Dentsply Maillefer, Baillagues, Switzerland) and the ultrasonic handpiece Ultra X (Eighteeth, Changzhou Sifary Medical Technology Co., Ltd, Changzhou City, China). Two groups of 18 artificial root canals were analyzed (n=36): main and lateral canals were embedded in a transparent resin model. Canals were filled with organic paste to simulate the necrotic pulp tissues. With both devices, irrigation was performed using 5% sodium hypoclorite and two activation times of 30 seconds each. Sodium hypochlorite was replaced every 30 seconds. After a photographic exam, debris removal was evaluated by a software and assessed in terms of percentage of cleaned canal. Means and standard deviations were calculated and data were statistically analyzed with the Anova test.*
Results: *Under the same experimental conditions (same canal, time and irrigant), both sonic and ultrasonic devices completely cleaned the*

Obiettivo: *la valutazione dell'efficacia di due differenti apparecchiature, una sonica e un'altra ultrasonica, per l'eliminazione dei residui dentinali dai canali endodontici principali e accessori.*
Metodologia: *sono stati testati due diversi attivatori per irriganti endocanalari: il manipolo sonico EndoActivator (Dentsply Maillefer, Baillagues, Switzerland) e il manipolo ultrasonico Ultra X (Eighteeth, Changzhou Sifary Medical Technology Co., Ltd, Changzhou City, China). Sono stati analizzati 18 canali artificiali per ciascuno dei due gruppi presi in esame (n=36): i canali principali e laterali sono stati creati all'interno di blocchi in resina trasparenti.*
È stata introdotta una pasta organica nei canali per simulare la consistenza dei tessuti pulpari necrotici. Con entrambe le strumentazioni sono state effettuate due attivazioni da 30 secondi ciascuna, utilizzando ipoclorito di sodio al 5%. Dopo un esame fotografico, la rimozione dei tessuti è stata valutata attraverso l'uso di un software e riportato in percentuali: sono state calcolate le medie le deviazioni standard e i risultati sono stati analizzati statisticamente attraverso il test Anova.
Risultati: *alle stesse condizioni sperimentali, (stesso canale, tempo di irrigazione e irrigante), entrambi i dispositivi hanno deterso completamente il canale*

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Abstract

main canal. On the contrary, a statistically significant difference was noted in the debridement of lateral canals, with ultrasonic device removing more debris than the sonic one ($p<0.05$). No tested device was able to remove all debris from accessory canals.
Conclusions: *The cordless ultrasonic handpiece Ultra X used with maximum power showed significantly greater efficacy in cleaning accessory canals when compared to the sonic EndoActivator.*

principale. Al contrario, è stata evidenziata una differenza statisticamente significativa nella detersione dei canali laterali, con una migliore performance del dispositivo ultrasonico rispetto a quello sonico ($p<0.05$). Nessun dispositivo è stato in grado rimuovere completamente i residui dai canali accessori.
Conclusioni: *il dispositivo a ultrasuoni Ultra X utilizzato alla massima potenza ha dimostrato un'efficacia significativamente superiore rispetto al dispositivo sonico EndoActivator nella detersione dei canali laterali.*

Introduction

Remains of pulpal debris and bacteria in the dental root canal are the principal cause of endodontic treatment's failure: only a complete disinfection and subsequent obturation of the endodontic space could lead to success (1, 2). Satisfying instrumentation and irrigation are considered mandatory to decrease the amount of bacteria and necrotic tissues within the root canal system (3-5). In the last decades, research was mainly focused on improving shaping of the root canal with many new instruments and techniques (6-11). However, irrigation still plays a fundamental role in the root canal therapy and it should be never underestimated (12-14). Mechanical instrumentation is not able to clean all the root canal system, and remaining biofilms and infected debris can be a possible source of persistent infection and treatment failure (15). The main factors that prevent complete debridement are: the polymicrobial nature of bacteria and their organization in biofilm, the presence of the smear layer produced by instrumentation, but above all, the complex root canal anatomy that hinders the instrumentation and the penetration of the irrigants in unreachable areas of the root canal system, like fins, accessory canals and isthmuses (16). Therefore, the irrigants should be activated inside canals by proper devices to increase the amount of contact with pulp tissue and debris inside canals.
Many articles tested and compared ultrasonic and sonic devices for irrigants activation (17-21): the main function of sonic handpieces is to produce a vigorous movement of the intracanal liquid through "cavitation" and "acoustic streaming". By activating the flow of irrigants, bubbles are produced, so they expand, become unstable and subsequently collapse in an implosion. This can dissolve impurities and penetrate powerfully into the channels, breaking bacterial biofilms and clean surfaces.
Many different sonic and ultrasonic devices have been commercialized during the last decades. Among sonic devices, Endoactivator (Dentsply Maillefer, Baillagues, Switzerland) is the most studied (22-24); ultrasonic devices, using higher frequencies, create vibrations that produce a continuous current close to the file, keeping the irrigant moving continuously. Eighteeth Ultra X (Eighteeth, Changzhou Sifary Medical Technology Co., Ltd, Changzhou City, China) is a new ultrasonic battery operated device. No studies have been published so far on this device.
Aim of this study is to compare the in vitro efficacy of the two above mentioned sonic and ultrasonic devices in the elimination of debris from canal irregularities in artificial root canals.

Materials and Methods

Power analysis was performed to evaluate sample size. A transparent resin model simulating a radicular canal was divided into two parts of equal thickness and adopted for this study (figure 1). Model and testing methodology have been validated in a previous study (12). The dimensions of the resin model were 10 mm length and 2.5 mm width. Both parts were specular, with a depression inside, at the same level, so that once assembled (by means of two screws) each depression overlapped to its counterpart to reproduce the lumen of a root canal. The canals were embedded with three semi-circular cavities, simulating the presence of irregular lateral canals at different levels (coronal, middle and apical). The three semicircles per side were filled with organic paste similar in consistency and density to the dental pulp, simulating the debris accumulated in the non-instrumented areas of the root canal. Organic paste was obtained by crushing bovine dental pulp and add a bit of dark stain (tempera colour) for better visualization.

The same simulator of the root canal was employed for both groups and the test was repeated 3x3 times for each experimental group (18 repetitions in total). The same irrigation procedure was adopted for all the tests: a 2,5 cc Luer-lock sterile syringe with endodontic needle (Navi Tip, Ultradent, Utah, USA) was placed at 1 mm from the working length (WL). 5% sodium hypoclorite (Ogna, Muggiò, Italy) was activated for 1 minute per procedure. The protocol used for both groups tested was the one suggested by the manufacturer in their instructions for use and included the following phases:

1. First irrigation with a disposable sterile syringe with endodontic needle (2,5 cc 5% NaOCl)
2. Activation time 30 sec.
3. Second irrigation with a disposable sterile syringe with endodontic needle (2,5 cc 5% NaOCl)
4. Activation time 30 sec.

For the group 1, the sonic handpiece EndoActivator was used at the maximum power of 10 kHz. The selected activator tip was a 25.04 red insert, used by following manufacturer instructions. For the group 2, the ultrasonic handpiece Ultra X worked at the maximum power of 45 kHz, using the soft and flexible X Silver tip. In both cases, the selected activator tip fitted passively when placed 2 mm short from the working length. The irrigant solution was activated using short vertical strokes for 30 seconds.

Digital photographs of the artificial canals were taken before, during and after the activation, due to record the amount of debridement. The resulting images were viewed and analyzed using a default

Figure 1
The transparent resin block containing artificial canals: block can be split in two halves for better placement of organic material inside and then reassembled.

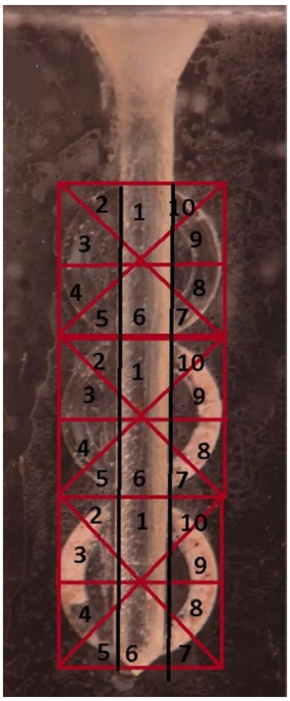

Figure 2
The artificial canal was divided in sectors, allowing more precise and easier visualization of the debridement.

template, realized with a computer-aided technical drawing program (AutoCAD® 2012, Autodesk, San Rafael, USA). The percentages obtained were derived from a graphic interpretation of the results. Specifically, each section in which the artificial channel was divided (coronal, middle and apical third), was further divided into 10 parts, considering both the main channel and the lateral canal irregular extensions (figure 2). At the end of the irrigant activation process, it was made a percentage calculation of the parts that visually appeared to be completely cleaned. Means and standard deviations were statistically analyzed with Anova test to highlight the differences in the ratios of removed debris between groups. The level of significance was set at $p=0.05$.

Results

Results are shown in table 1. Shapiro-Wilk was performed to verify the normality of data. Both sonic and ultrasonic irrigant activators completely cleaned the main canal of all resin models, while statistically relevant differences have been found in cleaning the lateral canals. Ultrasonic handpiece statistically removed more debris than the sonic one ($p< 0.05$), but none of the tested devices completely removed debris from lateral canals.

Discussion

The majority of ultrasonic handpiece are electric devices with plug-in or handpieces to be connected to the dental unit. The new handpiece is cordless, light in weight, very easy to handle, store, transport and use, even if it is not connnected to a source of irrigating solution. The main advantage of a cordless handpiece is the easier practical use, but there are some concerns about efficacy. More precisely, the power of cordless handpieces is sometimes not predictable, due to problems related to battery and charge. A lower input from battery could easily generate a vibration with reduced frequency, thus reducing the effectiveness of ultrasonic activation. So far, research about improving endodontic irrigation followed two parallel paths: the search for more effective and diffusible irrigants and the search for improved irrigant activation. Different irrigating solutions have been used throughout the years and, among them, sodium hypochlorite has proved to be the best solution (19, 25). Data from literature clearly demonstrated that the increase in temperature has the effect of enhancing the solvent action on the collagen of the hypochlorite, while the bactericidal activity is influenced by the concentration and the time of contact with the bacteria; the optimal concentration is considered to be 5.25% (26). The bactericidal action is carried out in 2-5 minutes, if there is a direct contact between hypochlorite and bacteria. Mechanical activation of sodium hypochlorite is considered capable to increase tissue dissolution and its agitation could provide a continuous flow of renewed chlorine (17, 18).
Disinfection and debridement could be improved by different irrigation delivery devices which use sonic, ultrasonic and negative pressure. In the last decades many new devices and techniques have been proposed for the purpose, but still there is no consensus on which one is the most reliable and efficient for the clinical use (20). Besides the concepts of positive and negative pressure, the differences amongst devices are mainly based on the source and quantity of the released energy, but in similar devices, the conformation of the tip could reach different results.
Aim of this study was to compare the efficacy of sonic and ultrasonic devices for the cleanliness of canal irregularities using the following similar parameters: anatomy, irrigant, activation time and amount of residuals. Results showed that both sonic and ultrasonic irrigant activators completely cleaned the main canal of all resin models, while statistically relevant differences have been found in cleaning the lateral canals. Statistical analysis revealed that the ultrasonic handpiece removed more debris than the sonic one ($p<0.05$). Such difference can be explained by the fact that a more efficient transmission of energy allows a better irrigant activation and progression in endodontic

Table 1

Percentage of debris removal between Endoactivator and Eighteeth experimental groups

Activation	1	2	3	4	5	6	7	8	9	Mean	Std.Dev
Endoactivator (S) main canal	100	100	100	100	100	100	100	100	100	100	0
Eighteeth (US) main canal	100	100	100	100	100	100	100	100	100	100	0
Endoactivator (S) accessory canal	60	58	55	47	64	61	44	58	72	57,66a	8,44
Eighteeth (US) accessory canal	72	69	80	71	82	70	74	68	73	73,22a	4,81

Ultrasonic (US) activation removed a larger amount of debris when compared to sonic (S) one in the accessory canals in all tests. Main canal debris removal was complete in all cases for both groups. Results showing significative differences are evidenced by upper letter (a).

spaces (like lateral canals, isthmus etc) which are not instrumented or directly reached by the tip of the sonic/ultrasonic device. This experimental condition simulates a clinical situation where tips are inserted in the main canal. A better flow and activation of the irrigant results in increased debridement.
The results showed that there is a significant difference between the sonic and ultrasonic devices, with the last one showing significantly better removal for organic tissues.
A possible explanation is that sonic devices were less efficient, mainly due to their lower power and lower frequency of vibration (25, 27, 28, 29). Typically, a sonic device operates at 1-8 kHz and ultrasonic at 25-40 kHz (30). The efficacy is related to the power of the units. The Eighteeth device has only two selectable values of power and for this study it was used the higher one. The provided power, even if derived from a battery, has proved efficacy, but it should be compared to non-cordless ultrasonic units to appreciate differences, if any. A cordless device makes the handpiece more ergonomic and easy to use, even if special cares have to be paid to ensure that the ultrasonic handpiece is always properly charged.
Efficacy is also related to the possibility to insert the tip in the apical portion of canal. In this in vitro study, artificial main canals were wide and straight, allowing easier placement of tips. All main canals were adequately cleaned by both devices. Clinically in curved canals, efficacy could also be dependant on the flexibility of the files/tips (17).
The current increase of the use of cone beam in endodontic practice, has clearly shown clinically more complex anatomies than expected, underlining the necessity to improve our shaping and cleaning procedures (31, 32).
According to literature, if sonic handpiece is used under 2 mm of the working length it may cause extrusion of irrigant over the apex. Another issue could be evidenced when the size of the apical part of the preparation is too narrow respect to the size of the vibrating tip: once forced by the dentinal walls, the cavitation and movement of the irrigant could be ineffectual (33). However, sonic devices are considered

safer than ultrasonic ones because they are embedded with oscillating plastic point which doesn't stop when in contact with the canal surfaces and it doesn't deform the root canal (12). In fact, ultrasonic files are made of metal alloy, therefore, when they touch the root canal wall, this may cause uncontrolled removal of dentin, with deformation of the root canal morphology (34).
Most of the studies about ultrasounds were performed using electric plug-in devices with cord, while only a few ones investigated cordless handpieces. Due to different power supply cordless and plug-in devices are supposed operate at slightly different frequencies (usually varying from 30 to 50 kHz). A small difference was reported to have no effect on the treatment outcome (35). The two different kind of devices are assumed to operate with similar ultrasonic induced flow patterns. In the ultrasonic instrument oscillation, the pressure waves generate acoustic streaming and cavitation, with the main flow factor appears to be acoustic microstreaming.
The present study is the first one which evaluates and compare in vitro performance of the new handpiece. Ultra X works at 45 kHz, by utilizing acoustic microstreaming, agitation and cavitation. Frequency can be modified by the operator that could optimize the efficacy of the tips during the debridement.
In the present study, two activation times of 30 seconds each were used, according to the clinical protocol established at the beginning of the trial. The test, for the two groups, was conducted under the same conditions and by the same operator, however there are some limitations to keep in mind: the in vitro model used in this study was an artificial root canal with artificial lateral extensions simulating inaccessible areas of the main root canal; the organic

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material present in the real canals was simulated by using a paste with a consistency similar to the pulpal tissues; differently from the natural teeth, plastic canals were poor of irregularities; lateral canals were larger than natural ones and activation was performed always at the same level (12). Another limitation of this study is the fact that the assessment of debridment was only two-dimensional, so it was not possible to precisely measure the amount of residual tissues in all the canal complexities.

Conclusions

Both sonic and ultrasonic activation demonstrated a good capacity for debris removal in the main canal, but in the present experimental model, the Ultra X ultrasonic system significantly removed more debris from lateral extensions than the EndoActivator sonic system.

Clinical Relevance

Endodontic irrigation is mandatory for a successful root canal treatment. Devices for mechanical irrigation could improve the irrigant diffusion through main and accessory canals for a better disinfection.

Conflict of Interest

The authors deny any conflict of interests.

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