COMPARATIVE EVALUATION OF LASER IRRIGATION SYSTEM AND GENTLEWAVE SYSTEM IN REMOVAL OF ROOT CANAL FILLING MATERIALS

By

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This work is dedicated to

ALMIGHTY GOD,

MY PARENTS

&

My Family Members

ACKNOWLEDGEMENT

At the outset, I would like to acknowledge a deep sense of gratitude to all my teachers and my family who has been for me a teacher in the fullest and most complete sense of the word. Their unlimited patience, constant encouragement, meticulous supervision and moral support at every step has enabled me to complete my dissertation and has also helped me tremendously during my career.

I would like to extend my gratitude to my colleagues for statistical analysis and for helping me in the completion of my research.

Dr. Deepti Dua

LIST OF ABBREVIATIONS USED

ISO	International organization for Standardization.
NaOCl	Sodium Hypochlorite
EDTA	Ethylene di-amine tetra acetic acid
mm	millimeters
secs	seconds
Ni-Ti	Nickel-Titanium
W.L.	Working length
S.D	Standard Deviation
%	Percentage
ANOVA	Analysis of Variance
SEM	Scanning Electron Microscope

ABSTRACT

- **AIM OF THE STUDY:** The objective of this research is to compare and evaluate the Er,Cr:YSGG laser assisted irrigation and the GentleWave system in removal of root canal filling materials from different regions of root canals using micro-computed tomographic imaging.

- **MATERIALS AND METHOD:** Fifty single rooted, noncarious, extracted human maxillary and mandibular canines were initially selected and the canals were prepared with ProTaper Universal rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) in the sequence recommended by the manufacturer upto a master apical size (MAF) of F4 having D_0= 0.40mm. Root filling was performed with tapered gutta-percha master cones (ProTaper) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) following the lateral compaction method. All teeth were subsequently scanned using micro-computed tomography, and the volume of root filling was determined. The retreatment procedure consisted of 2 stages. First, the bulk of the root filling material was removed using ProTaper retreatment instruments, which was followed by the removal of the remaining material using the F1 and F2 ProTaper files. The experimental groups were divided into following groups depending upon the final irrigation system used for removal of remaining root canal filling material:

- **Group A: Positive control ; Group B: Er,Cr:YSGG laser activated irrigation; Group C: GentleWave system treatment**

- Each specimen was subjected to high-resolution Micro-CT scanning at three stages:

- 1. After canal instrumentation

- 2. After root filling

- 3. After the retreatment procedure using different final irrigation systems

- One-way analysis of variance with the post hoc Tukey test was used to test for differences between volumes of root canals filling after instrumentation and final irrigation and volumes of root canal filling in canals after obturation among groups

- **RESULTS:** . None of the procedures removed all of the remains of the root canal filling material. There was no significant difference in the root canal volume after instrumentation among the 3 groups. Although the percentage of root canal filling removed from the middle and apical thirds of canal was slightly higher in Er,Cr:YSGG laser group in comparison to GentleWave group, there was no significant difference between the two groups (P > .05).

- **CONCLUSION:**

Er,Cr:YSGG laser assisted irrigation and GentleWave irrigation system were highly effective in removing root canal fillling from the coronal, middle and apical thirds of the root canal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

Root canal therapy of teeth involves the use of mechanical instruments and chemicals to clean, shape and disinfect the root canal system as well as materials to fill the root canal space. There have been a lot of advances in endodontic instruments and devices which have made proper root canal treatment more predictable; however, sometimes failure may occur. In such cases of failed endodontic therapy, the preferred approach has been nonsurgical re-treatment. The primary objective of nonsurgical retreatment is to re-establish healthy periapical tissues by thorough disinfection of the root canal space. This is achieved by the removal of the old root canal filling materials, further cleaning and shaping, and re-filling of the root canal. Any remnants of filling material can impair disinfection by avoiding irrigants to contact the persisting microorganisms. Therefore, the removal of as much filling material as possible from an infected root canal system is necessary to eliminate the bacteria responsible for periapical inflammation.

Gutta percha, in combination with a variety of sealers, is the most commonly used material for canal filling; however, it is difficult to remove it completely from root canals when retreatment is required. Traditionally, removal of root canal filling material has been accomplished using chemical solvent and hand instruments. With the recent advances in the rotary nickel-titanium instruments, specific instruments have been designed for retreatment to remove the bulk of the filling material. However, several reports have showed substantial amounts of filling remnants in the canal after retreatment using rotary instruments.

In order to enhance the removal of filling material, there have been attempts to use different solvents, ultrasonic systems, heat carrying instruments and lasers. The most common laser that has been investigated and has shown promising results is Er:YAG (Erbium: Yttrium, Aluminium, Garnet) laser. The application of lasers in retreatment procedures relies mainly on the thermal effect of irradiation. Another laser that has been tried for the removal of smear layer in the root canal is Er,Cr:YSGG laser. Currently, there has been no published research on the efficacy of Er,Cr:YSGG laser in the removal of filling materials from the root canal.

Recently, another endodontic device has been developed for cleaning the root canal system, the GentleWave system (Sonendo, Inc, Laguna Hills, CA). This system is based on advanced fluid dynamics to deliver irrigant into the root canal system without requiring the tip of the handpiece to enter the root canals. The system is designed to develop a broad spectrum of sound waves within the irrigating solutions to remove soft tissue and bacteria from the root canals. Its effectiveness in removing calcium hydroxide medicament from the root canal has been shown, but so far no evidence on its efficacy in removal of old filling material has been evaluated.

The most common method of assessing the remaining filling material in the root canal after retreatment procedures has been scanning electron microscope; however it exhibits lack of sensitivity. It has been shown that a 3-dimensional quantitative evaluation of residual filling material in the root canal can be assessed with greater sensitivity using micro-computed tomographic (micro-CT) imaging technique.

Hence, the objective of this research is to compare and evaluate the Er,Cr:YSGG laser assisted irrigation and the GentleWave system in removal of root canal filling materials from different regions of root canals using micro-computed tomographic imaging.

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LITERATURE REVIEW

The initial stage of any retreatment procedure is the removal of previous root filling material to allow adequate cleaning, disinfection, and obturation of the root canal space. This task can easily be accomplished with rotary files, which allow the removal of the bulk of gutta-percha–based root filling material within a few minutes. However, recent studies have indicated that such a procedure performed on its own leaves a significant amount of root filling residue along the canal wall. This finding may partly explain the low reported success rate of retreatment in cases with posttreatment disease. The main goal of nonsurgical canal retreatment is to re-establish healthy periapical tissues by the removal of the root canal filling materials, further cleaning and shaping, and refilling. Therefore, the removal of as much filling material as possible from an inadequately prepared and/or filled root canal system is necessary to uncover remaining necrotic tissues or bacteria that might be responsible for periapical inflammation and, thus, post-treatment disease.

Although shaping of the root canal has been improved with advances in metal technology, cleaning of the canal still relies heavily on the adjunctive use of chemical rinsing and soaking solution because of the anatomical complexity and irregularity of teeth. The irrigation procedure is a very important part of root canal treatment. However, hand irrigation is not sufficiently effective in the apical third of the root canal or in oval extensions, isthmuses, and anastomoses. Several studies have shown that large areas of the canal wall, particularly in the
apical third but also in ribbon-shaped and oval canals, cannot be cleaned mechanically, which means that microorganisms that are present in these untouched areas might survive. Residual bacteria and other microorganisms can persist either in these spaces or in tubules. Irrigants and other intracanal medicaments are necessary adjuncts that enhance the antimicrobial effect of mechanical cleansing and thus increase the overall clinical efficacy of the procedure.

Traditionally, root canal retreatment has been accomplished using solvent and hand files. An attempt to use rotary nickel-titanium (NiTi) instruments specifically designed for retreatment, such as the R-Endo system (Micro-Mega, Besanc¸on, France), has led to the development of a more efficient way to remove the bulk of the filling materials in comparison with conventional techniques. Unfortunately, several reports showed substantial amounts of filling remnants in the canal after retreatment using rotary instruments. perforation or canal transportation. Additional attempts to improve the removal of filling remnants have been made with ultrasonic systems, heat-carrying devices, solvents, and lasers. However, the safety, efficacy, and/or reliability of all these techniques have been questioned in many studies. The positive pressure induced by some of these techniques may result in irrigant extrusion to the peri-apex, which may lead to severe patient trauma and post-operative pain. Further, tissue debris and biofilm cleaning of even contemporary techniques is often insufficient to provide an environment conducive for long term success. Furthermore, most of these techniques require increased dentin removal from the roots to facilitate the penetration of irrigants into the root canal system, which may weaken the remaining tooth and thereby also negatively affect long-term healing rates.

The GentleWave® System (Sonendo, Inc., Laguna Hills, CA), which consists of a console and a treatment instrument should be capitalized, has been developed as a novel approach to clean and disinfect the root canal system. A high speed, degassed treatment fluid is delivered into the pulp chamber of the tooth by a Treatment Instrument positioned on the occlusal surface of an accessed tooth. The treatment fluid flow reaches the entire root canal system while a built-in suction within the treatment instrument removes the excess fluid.

To enhance the dispersal of the irrigant and to activate it, sonic and ultrasonic techniques have been investigated and developed. Lasers have been proposed as an alternative to the conventional approach to cleaning and disinfecting The application of lasers in retreatment procedures relies mainly on the thermal effect of irradiation, which presents evidence to improve the removal of filling remnants. The use of lasers at different wavelengths has been proposed to supplement conventional endodontic cleaning procedures. However, a considerable limitation has been the unidirectional emission of the laser beam. In the conventional technique, the entire root canal wall must be exposed directly to the laser beam. The laser fiber must be moved repeatedly in a spiraling motion along the root canal wall and kept as close as possible to the apex to maximize the area exposed to the laser beam, but even
this technique is not completely efficient. Ideally, the fiber should be inserted centrally in the pulp chamber without contact with the root canal wall and kept stationary during emission. The interaction between the laser and the root canal walls is based on absorption of the laser energy by the dentin, microorganisms, and/or smear layer, on thermal effects such as evaporation and contraction of the smear layer, and the thermal heating of microorganisms.

Use of an Er,Cr:YSGG (erbium chromium-yttrium-scandium-garnett) laser was first introduced by Blanken and Verdaasdonk. Matsumoto *et al.* found that the liquid beside the laser tip evaporated and created bubbles. Once the laser was stopped, the bubbles began to shrink and eventually collapsed due to the increase of the surrounding pressure. The explosion of the bubble develops a powerful liquid stream without rising the temperature.

Recently, photon-induced photoacoustic streaming (PIPS), a new laser-activated irrigation system device, has been introduced. This system uses a very low-power source (subablative) to rapidly pulse laser light energy, which is absorbed by the molecules within the irrigant. This transfer of energy results in a series of rapid and powerful shock waves capable of forcefully propelling the irrigant throughout the root canal system.

Several destructive and two-dimensional techniques have been used to evaluate the quantity of remaining filling materials after retreatment; however, these methods are not able to evaluate precisely the volume of remaining filling material after the retreatment procedures.Shortcomings of these methods are loss of remaining filling during splitting, variation among different observers due to subjective evaluation, and underestimation of remnants due to two-dimensional imaging. Recently, the micro-CT imaging method (a nondestructive and non- invasive method) has been used to evaluate the efficacy of different retreatment techniques. It allows for the reconstruction and volumetric evaluation of tooth tissues as well as filling materials, overcoming the limitations of conventional methods. For these reasons, the micro-CT imaging method was chosen in this study.

Michael Solomonov and Frank Paque evaluated the efficacy of removing gutta-percha–based root fillings with ProTaper retreatment files (Dentsply Maillefer, Ballaigues, Switzerland) followed by F1 and F2 ProTaper instruments and compared these results with those obtained with a #25 .06 ProFile instrument (Dentsply Maillefer) followed by the Self- Adjusting File (SAF; ReDent, Ra'anana, Israel) using high resolution micro–computed tomography (CT) scanning. None of the retreatment methods rendered all of the canals completely free of all root filling residue. They however did not use newer final irrigation systems to ensure better root canal filling material removal. Further the standardization of apical size of the preparation was not done.

Topcuoglu et al compared the ability to remove Root canal filling using conventional syringe irrigation, a canal brush, passive ultrasonic irrigation (PUI) (EMS, Dallas, TX), a self-adjusting file (Re-Dent-Nova, Ra'nana, Israel), and the EndoActivator (Advanced Endodontics, Santa Barbara, CA). CA). The authors found that these treatments were unable to completely remove Root canal filling from simulated internal resorption cavities. However, in this study the canal preparation sizes were not standardized which might affect the accessibility of irrigant in different parts of root canal especially the apical most area.

Al-Garni et al evaluated Root canal filling removal using the EndoActivator and hand files with irrigation in single-rooted teeth using scanning electron microscopic assessments. It was found that the coronal region was clean, whereas the apical region still contained a significant amount of Root canal filling particles for both the EndoActivator and hand files with irrigation. Optical and scanning electron microscopic assessments both suffer from a lack of sensitivity in comparing Root canal filling removal ability between different groups. It has been shown that a 3-dimensional quantitative evaluation of residual radiopaque Root canal filling in the root canal can be assessed with greater sensitivity using micro–computed tomographic (micro-CT) imaging.

Prashanthi Vandrangi has evaluated the depth of sodium hypochlorite (NaOCl) penetration into dentinal tubules by using the GentleWave System when compared with ultrasonic agitation. They have compared passive ultrasonic activation using PiezonMasteR 700 (EMS) with ESI-tip, active ultrasonic activation using PiezonMaster 700 with ESI-tip with maximum irrigation rate, and the GentleWave System. The results demonstrated GentleWave System to be approximately four times greater NaOCl penetration depth in apical region than active ultrasonic system and was effective throughout the root canal system. However, they had compared Gentlewave with other ultrasonic systems and not with the more recent laser based or apical negative pressure based systems. Further the apical preparation size was kept to a minimum of size 15 which is usually larger in clinical scenarios. Further the investigating method was an invasive one which might have led to loss of tooth tissue affecting the data findings.

Haapasalo *et al.* demonstrated that the tissue dissolution efficacy of the GentleWave System is at least eight times greater than that of conventional irrigation systems, ultrasonic irrigation, and EndoVac. Ma *et al.* performed micro-CT analysis and compared the cleaning efficiency of the GentleWave System with passive ultrasonic system and conventional needle irrigation configuration. The authors showed cleaning of the entire root canal system including the apical-third regions. The GentleWave System was the only technique that removed all the calcium hydroxide even in the apical thirds. However, these studies were performed *in-vitro* using extracted teeth. While *in-vitro* studies have demonstrated excellent results by the GentleWave System with regards to canal cleanliness and safety, in- vivo studies would always be more reliable. Further, the Gentlewave system was not compared with laser based final irrigation systems which have demonstrated comparable results with other ultrasonic irrigation systems.

There have not been any studies that have compared these two different methods of irrigation in removal of root canal filling material. Hence, the objective of this research is to compare and evaluate the Er,Cr:YSGG laser assisted irrigation and the GentleWave system in removal of root canal filling materials from different regions of root canals using micro-computed tomographic imaging.

HYPOTHESES

NULL HYPOTHESIS

It states that there is no significant difference in efficacy of Er,Cr:YSGG laser assisted irrigation and the GentleWave system in removal of root canal filling materials from coronal and apical regions of root canals.

ALTERNATE HYPOTHESIS

It states that there is significant difference in efficacy of Er,Cr:YSGG laser assisted irrigation and the GentleWave system in removal of root canal filling materials from coronal and apical regions of root canals.

RESEARCH METHODOLOGY

Selection of Teeth

Fifty single rooted, noncarious, extracted human maxillary and mandibular canines were initially selected on the basis of radiographs taken in both buccolingual and mesiodistal directions to detect any possible root canal obstruction. Initial inclusion criteria were a single distal root canal, no previous root canal treatment, straight roots of similar length, and completely developed apices. Any tooth with more than one canal, apical curvature, previous endodontic treatment, crack or resorptive defect was excluded. Teeth were immersed in 3% NaOCl for 48 hours to remove any organic debris. Thereafter, the external tooth surfaces were scaled with ultrasonic instruments, and the teeth were then stored in distilled water until use. A flat occlusal surface was made as a reference for determining working length and pulp chamber of each tooth was accessed. A#15 K-file (Kendo, VDW, Germany) was then introduced into the root canal until its tip was just visible at the apical foramen. The working length for the preparation was determined by deducting 1 mm from the length recorded when the file was just visible at the apex of root. Root apices were covered with sticky wax to create closed end canal model that more accurately simulates in-vivo situations by creating vapor-lock effect.

Root Canal Preparation and Filling

The canals were prepared with ProTaper Universal rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) in the sequence recommended by the manufacturer upto a master apical size (MAF) of F4 having D_0= 0.40mm. The rotary files were used with VDW Gold motor (VDW GmbH, Munich, Germany) at a speed of 300 rpm and a torque of 300 Ncm. The coronal orifices of the canals were enlarged using ProTaper SX files (Dentsply Maillefer) that were inserted to a depth of 5 mm from the canal orifice. Subsequently, S1 and S2 files were used to the working length and followed by F1 and F2, which were used to the working length as well. The SX, S1, and S2 were operated with a brushing motion according to the shape of the canals. During instrumentation, the root canals were irrigated with 2 ml of 1% sodium hypochlorite (NaOCl) solution after each instrument delivered by 30-gauge Max-I Probe needle (Dentsply-Rinn, Elgin, IL, USA) placed 1 mm short of the working length.

When instrumentation was complete, a final irrigation protocol was performed on all canals with a 27-G needle inserted to 2 mm short of the entire working length using 10 mL 5% NaOCl for 5 minutes followed by 5 mL 17% EDTA solution (Pulpdent Corporation, Watertown, MA) for 2 minutes. Any remaining solution was removed by aspiration and the canals were dried with paper points (Dentsply Maillefer). Root filling was performed with tapered gutta-percha master cones (ProTaper) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) following the lateral compaction method. A lentulo spiral was used to fill the canal with sealer. After insertion of the master cone, accessory gutta-percha cones were added with a #25 finger spreader (Dentsply Maillefer). Any excess of gutta-percha was removed with a hot excavator at the level of the canal orifice. The sealer was allowed to set for 30 days at 37_C and 100%

humidity. All teeth were subsequently scanned using micro-computed tomography, and the volume of root filling was determined.

Retreatment: ProTaper

The retreatment procedure consisted of 2 stages. First, the bulk of the root filling material was removed using ProTaper retreatment instruments, which was followed by the removal of the remaining material using the F1 and F2 ProTaper files.

Stage 1. ProTaper Universal retreatment files D1-D3 (Dentsply Maillefer) were used to remove the root filling material. The files were operated with the VDW Gold motor with a torque of 300 Ncm and a rotation speed of 180 rpm for D1 and 150 rpm for D2 and D3. D1 was used from the coronal to the middle thirds until no debris was visible on the file surface when it was removed from the canal (18). A drop of chloroform (10 mL) was placed in the canal, and the D2 instrument was used to 2 mm short of the working length. Next, the canal was irrigated, with 2 mL 5.25% NaOCl followed by 2 mL 17% EDTA, which were delivered with a syringe and a 27-G needle. The canal was subsequently dried with paper points, and another drop of 10 mL chloroform was placed in the canal. Next, the D3 instrument was inserted to the working length using the previously mentioned endpoint criterion. Subsequently, the canal was irrigated with 2 mL 5.25% NaOCl followed by
2 mL 17% EDTA.

Stage 2. F1 and F2 ProTaper files were used with an added brushing motion because of the shape of the canal. Irrigation with 1 mL 5.25 % NaOCl and 1 mL 17% EDTA was performed after each instrumentation. A total of 20 mL chloroform, 8 mL 5.25% NaOCl, and 8 mL 17% EDTA were used for the entire procedure. The time required to accomplish this procedure was recorded using a stopwatch. The canals were subsequently washed with 2 mL distilled water, dried with paper points, and stored at 100% humidity at room temperature. The retreatment procedure was performed by an operator who had extensive clinical experience with this type of procedure (SYO). The retreatment files were replaced after every 2 retreatment procedures. Retreatment was considered completed when the WL was reached, no material was observed between the flutes of the instruments, and the irrigating solution appeared clear of debris after the final rinse. Then, a flip of a coin was used to define which experimental group would be treated with each of the following additional final irrigation systems:

The operator was blinded to the group assignments.

The experimental groups were divided into following groups depending upon the final irrigation system used for removal of remaining root canal filling material:

Group A: Positive control [n = 10]. The canals were only mechanically instrumented with a F4 instrument (MAF), with no final irrigation.

Group B: Er,Cr:YSGG laser activated irrigation [n = 20]. The Waterlase MD dental laser (Biolase, CA, USA) was used at panel settings of 0.75 Watt average power and

20 hertz and was focused through an endodontic tip of 275 µm diameter.The fiber tip was fixed in the handpiece of an erbium chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser (Waterlase Millenium; Biolase). The pulp chamber served as a reservoir for the irrigation solution. The tip was submerged in the solution and made to hover above the orifice of the pulp chamber. The coaxial water spray and air were switched off. After cleaning the canal by MAF to the WL, 1% NaOCl was deposited in the canal and activated by a 2780 nm wavelength Erbium chromium: Yttrium-Scandium-Gallium-Garnet (Er,Cr:YSGG) for 60 seconds. Thereafter, the canal was irrigated with 1 ml of 17% EDTA solution for 60 seconds. A total of 4 ml each of both the irrigants was used. The pulp chamber served as a reservoir for the irrigation solution. The tip of the optic fiber was placed 3 mm from the WL and it was withdrawn gently from the apical to the coronal region with helical movement and reintroduced to the apex. Ten-second intervals of laser-activated irrigation were followed by 10 seconds of no activation (‘‘resting’’) in between. These intervals were repeated 6 times (for a total of 60 seconds) for each irrigant as mentioned above.

Group C: GentleWave system treatment [n=20]. The GentleWave System was first capitalized and then used with 1 ml of 3% NaOCl for 60 seconds followed by irrigation with 1 ml of 17% EDTA solution for 60 seconds. A total of 4 ml each of both the irrigants was used. The treatment instrument was placed on an accessed occlusal surface to deliver the treatment fluid into the pulp chamber.

Micro-computed Tomography Imaging

Each specimen was subjected to high-resolution Micro-CT scanning at three stages:
1. After canal instrumentation
2. After root filling
3. After the retreatment procedure using different final irrigation systems

The scanning procedure was completed using 100 kV, 100 µA, a 500 millisecond exposure time, 360^0 rotation and 0.7^0 rotation step, with a cross-sectional pixel size of 27.45 µm. The filter used was 0.5 mm aluminium and 0.5 mm copper. High-resolution scans after root canal filling and retreatment procedures were run with a 5-fold integration time to reduce the noise and the scattering effect provoked by radiopaque root filling materials. Series of x-rays were taken using the Skyscan 1172 machine (Bruker Micro-CT, Kontich, Belgium) which was considered as raw data in a form of Tag Image File Format (TIFF). This TIFF file format was reconstructed by NRecon software version 1.6.4.8 (Skyscan 2011, Belgium) to Bitmap (BMP) which is a file readable by CTAn version 1.11.10.0 (64 bit) Skyscan, 2011 to do the analysis of the total root canal filling volume remaining in the canal. To calculate the volumes of the fillings, the original gray scale images were processed with a slight Gaussian low-pass filtration for noise reduction, and an automatic segmentation threshold was used to separate root dentine from filling and voids, using CTAn version 1.11.10.0 software (Bruker-microCT). This process entails choosing the range of gray levels for each filling, dentine, or void, necessary to obtain an image composed only of black and white pixels. Reconstruction parameters were adjusted as follows: Gaussian filter (smoothing, kernel = 2), beam hardening correction of 15% and ring artifact reduction of 10.

The volume of interest was selected by dividing the whole length of the tooth specimen into three parts, that is, coronal, middle and the apical area, resulting in the acquisition of 550 to 750 transverse cross-sections per tooth. In CTAn, reconstructed files were binarised separately for each slices, regions of interest were chosen to allow the calculation of the volume of root canal filling (in mm^3). After standardizing the number of slices and getting the region of interest, we did the automatic thresholding from the dataset separating canal, dentin and calcium hydroxide for analysis.

Thereafter, the images were viewed by CTVol ver. 2.2.1.0 (64 bit) for 3-dimensional realistic visualization and for making the pictures. The percentage of the volume of root canal filling removed from the canals was calculated as:

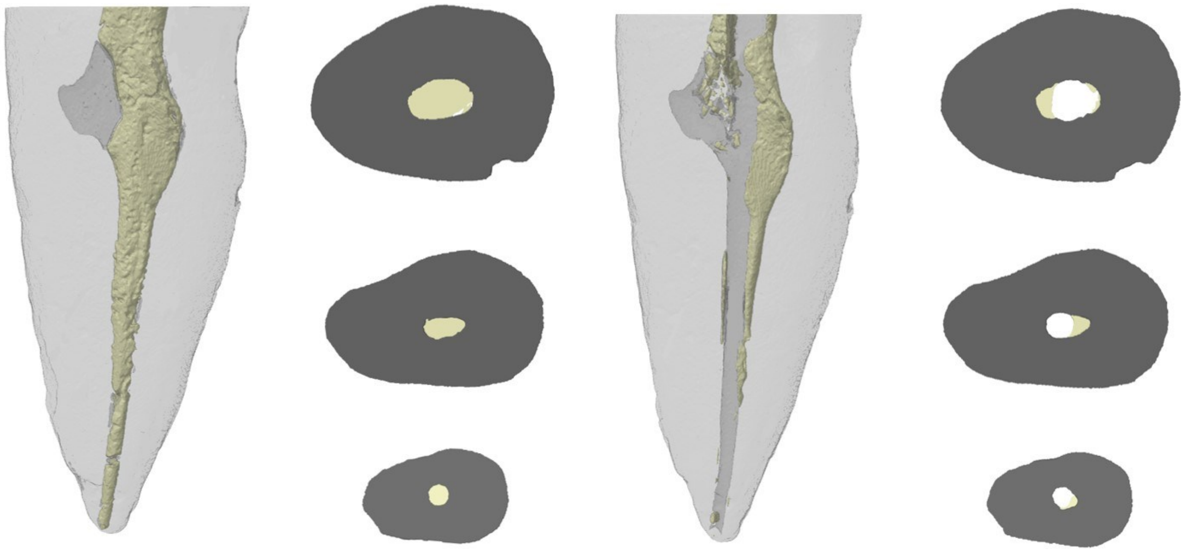
Vol of Root filling material before removal - Vol of Root filling material after removal x 100

Volume of Root filling material before removal

STATISTICAL ANALYSIS

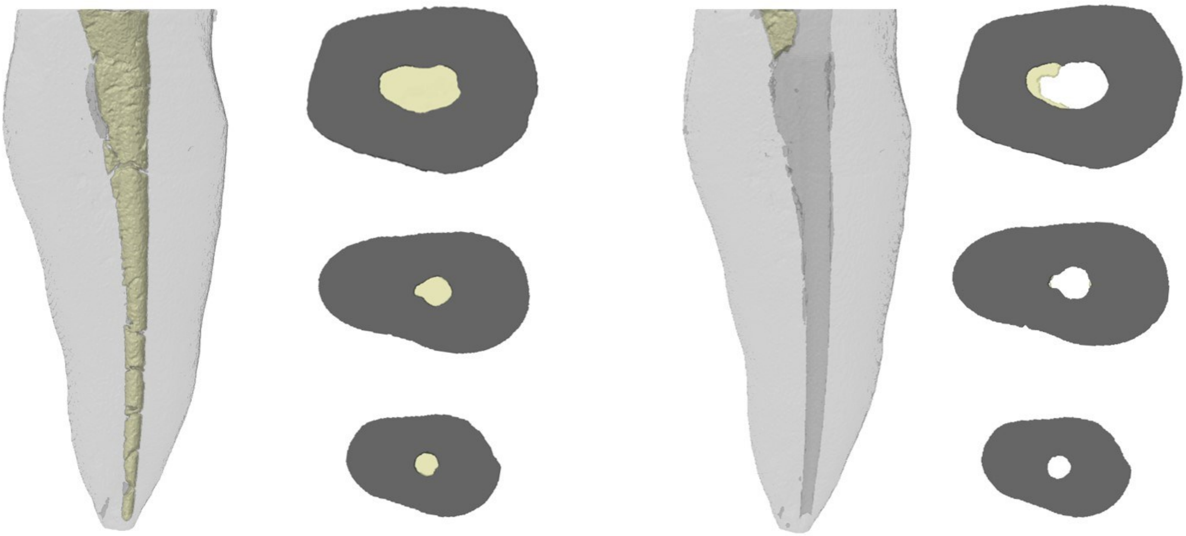
One-way analysis of variance with the post hoc Tukey test was used to test for differences between volumes of root canals filling after instrumentation and final irrigation and volumes of root canal filling in canals after obturation among groups. The Kruskal-Wallis analysis of variance was used to identify any significant difference for other collected data because they failed to pass the normality test and the equal variance test. If significant differences were found, intergroup comparisons were performed using the Tukey test (significance level, $P < .05$).

FIGURES



A) B)

FIGURE 1- POSITIVE CONTROL (Micro-CT images): A) Root canal volume after obturation B) Root canal volume after instrumentation



A) B)

FIGURE 2- Er, Cr: YSGG (Micro-CT images): A) Root canal volume after obturation B) Root canal volume after instrumentation and irrigation

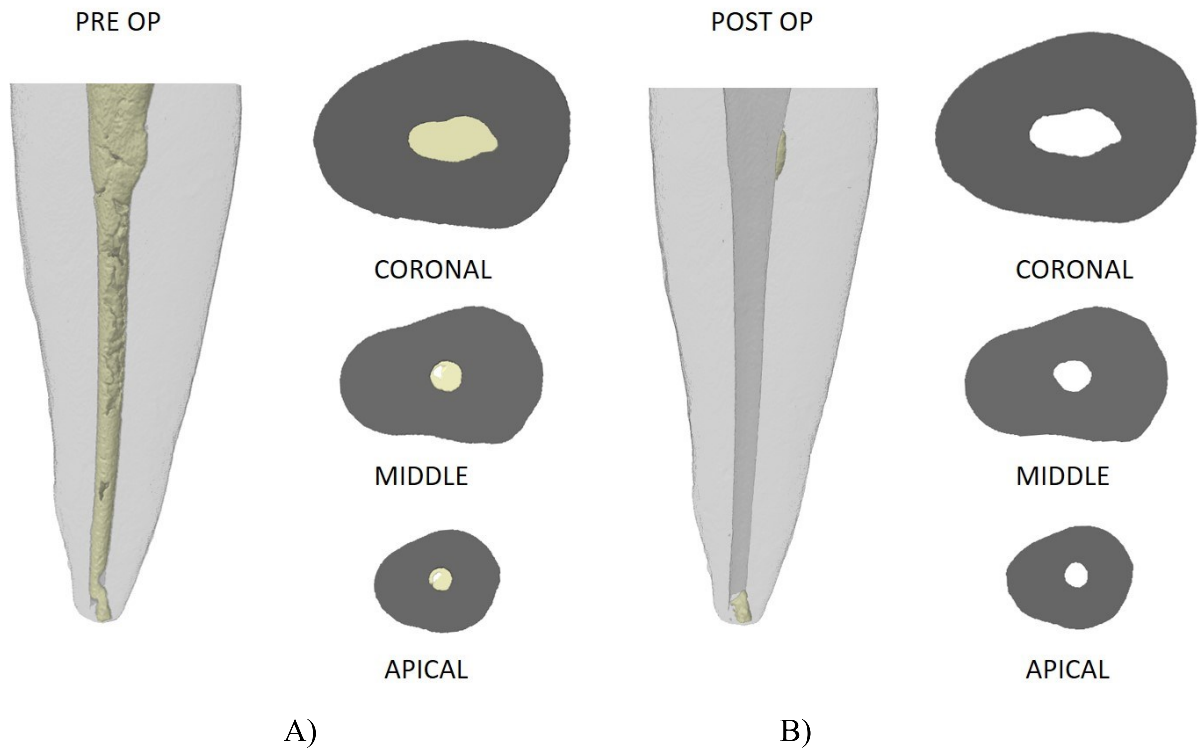


FIGURE 3- GentleWave (Micro-CT images): A) Root canal volume after obturation B) Root canal volume after instrumentation and irrigation

TABLES

Table 1: Mean Percentage of root canal filling Removed in Each Third of Root Canal in Different Groups

	Coronal	Middle	Apical
Group A - No irrigation (n=10)	60.37 ± 14.35[a]	64.56 ±11.75 [a]	29.16 ± 6.75 [b]
Group B - Er,Cr:YSGG laser (n=20)	90 ± 2.76 [c]	98 ± 1.76 [c]	92.78 ± 0.76 [c]
Group C– Gentlewave(n=20)	98.74 ± 0.83 [c]	96.67 ± 1.26 [c]	90.47 ± 1.93 [c]

Different superscript letters indicate statistically significant differences between groups ($P < 0.05$)

DISCUSSION

Post- treatment disease is likely due to the persistence or emergence of microorganisms in the root canal system after cleaning and shaping or the recolonization of the root canal space by bacteria following microleakage. Removing the etiological factors (necrotic tissues, bacterial biofilms, coronal leakage, recurrent caries, and tooth fractures) results in conditions conducive to healing; thus, surgery for treating persistent infections. The basic goal of nonsurgical endodontic treatment is to reduce or eliminate, to the extent possible, the microbial flora. Removing all root fillings is a prerequisite of nonsurgical retreatment in order to uncover the remnants of necrotic tissue or bacteria that might have caused the previous treatment to fail. Gutta-percha in conjunction with sealers is the most common root filling because it is inert, usefully plastic when heated, and stable and is tolerated by the tissues. One of the basic properties of an ideal filling is that it should be removable whenever necessary for retreatment purposes. The key role of root canal irrigants is to clean the canal during the enlarging and shaping process. Consequently, 1 or more irrigants must be used for the complete elimination of smear layer and debris from the root canal system. Syringe irrigation is the standard procedure, but unfortunately, syringe irrigation is not effective in the apical third of the root canal. Consequently, acoustic and hydrodynamic activations of the irrigant have been developed, and these techniques have been shown to increase the efficiency of cleaning. However, the physical mechanisms that underlie these cleaning procedures are not well-understood.

Laser applications that use different wavelengths have also been proposed as adjuncts to conventional endodontic cleaning procedures. The undesirable side effects that occur with the use of lasers are moderate, and within limits this technique is regarded to be safe. Blanken and Verdaasdonk showed that when an Er,Cr:YSGG laser is used within the root canal with a plain endodontic fiber tip, movement of fluid occurs immediately after each pulse. It is known that when an Er,Cr:YSGG laser is used with high pulse energies to activate a root canal irrigant, it can result in the formation of bubbles, as described above. This cavitation effect is sufficient to remove a large dentin plug. However in the present study, the laser tip was placed in the pulp chamber to avoid any deleterious effect that might arise due to heat generation had the tip been placed within the root canal.

Further, to eliminate the confounding factor of the tip position, it was placed in the pulp chamber in both the final irrigation systems.

The goal of the present study was to compare the ability of two different irrigation and cleaning methods to remove root canal filling from the root canals of canines. In our study, both the experimental final irrigation systems performed better than the positive control. There was no significant difference in root canal filling removal amongst the laser based final irrigation and GentleWave system. However, the results may also suggest a wider implication of the effectiveness of liquid circulation and other factors in the root canal system caused by the different treatment methods.

The present study and all earlier studies have suggested that none of the conventional irrigation methods, with or without mechanical or ultrasonic agitation, can predictably clean the canals of root canal filling. The GentleWave system have been shown to remove calcium hydroxide in 90 seconds even when distilled water was used as the irrigating solution. The flow rate of liquid (45 mL/min) by the GentleWave system may be part of the explanation for the effectiveness although the amount of irrigant that circulates in the canals and the amount that only visits the pulp chamber (to generate the multisonics as well as the advanced fluid dynamics) is yet to be determined. However, in a recent study, it was shown that a high flow rate irrigation of 45 mL/min with NaOCl using a 19-G needle did not improve the tissue dissolution over 10 mL/min irrigation, whereas in the same study the GentleWave system with water only dissolved tissue at the same speed as 2% NaOCl by needle irrigation. The authors suggested that cavitation may have played a key role in the ‘‘dissolution’’ effect with water only. Therefore, although not verified in the present study, multisonic energy through a variety of phenomena including the hydrodynamic cavitation mechanism when using the GentleWave device could explain the effectiveness of the GentleWave system in removing Root canal filling from all areas of the root canal system, including the most apical root canal.

The laser irrigation has been shown to provide satisfactory results in calcium hydroxide dressing removal from root canals; there have been no studies that have evaluated the efficacy of Er,Cr:YSGG laser in retreatment procedures. However, it must be pointed out that multiple factors can influence the various types of laser tissue interactions for each wavelength of emission. Most types of interactions are strongly dependent on the inherent optical absorption properties of different materials and tissues. In endodontic retreatment, the laser light interaction with matter may not be energy dependent because of the heterogeneous nature of the root canal materials or obstacles. Therefore, the adequate control of energy, density, and pulse duration in regard to the canal environment for root canal retreatment still needs to be achieved.

The cavitation effect of Er, Cr: YSGG laser might have contributed to better removal of filling material from the root canal system. Cavitation is defined as the formation of vapor or a cavity that contains bubbles inside a fluid. In water, use of a laser at ablative settings can result in the formation of large elliptical bubbles. These vapor bubbles can cause an expansion in volume to 1600 times the original volume. This process can allow the irrigants to access the apical third of the canal more easily, which might assist in the cleaning of canals of various shapes. In addition, the cavitation bubbles expand, become unstable, and then collapse in what is termed an implosion. The implosion will have an impact on the surfaces of the root canal, causing shear forces, surface deformation, and the removal of surface material. By using cinematic holography, Ebeling and Lauterborn observed shock waves that emanate from collapsing bubbles generated by a laser pulse. These laser-generated pressure waves move at high speed and appear to enhance the action of endodontic irrigants in terms of removal of the smear layer.

On the other hand, the technology of the GentleWave System employs various phenomena including a strong hydrodynamic cavitation cloud which is used to generate a broad spectrum of sound waves (Multisonic™ technology) within the degassed treatment fluid inside the canal. The degassed treatment fluid contains a reduced amount of dissolved gas to optimize the interplay of the propagating multisonic energy and fluid dynamics. Multisonic energy travels through the fluid into the entire root canal system, hence cleaning the root canal system. Existence of multisonic energy enables effective penetration of waves into micron sized tubules. The temperature in the root canal increases to a maximum of 45°C, 29°C, and 40°C, when the teeth were treated with passive ultrasonic system, active ultrasonic system, and the GentleWave System, respectively.

In both the groups, there was better removal of filling material from coronal and middle third as compared with apical third.

Several destructive and two-dimensional techniques have been used to evaluate the quantity of remaining filling materials after retreatment; however, these methods are not able to evaluate precisely the volume of remaining filling material after the retreatment procedures.

Shortcomings of these methods are loss of remaining filling during splitting, variation among different observers due to subjective evaluation, and underestimation of remnants due to two-dimensional imaging. Recently, the micro-CT imaging method (a non-destructive and non-invasive method) has been used to evaluate the efficacy of different retreatment techniques. It allows for the reconstruction and volumetric evaluation of tooth tissues as well as filling materials, overcoming the limitations of conventional methods. For these reasons, the micro-CT imaging method was chosen in this study.

The main role of laboratory-based studies is to develop well controlled conditions that are able to reliably compare certain factors. The main confounding factor of ex vivo studies is the anatomy of the root canal system under investigation. Consequently, the results might show the effect of canal anatomy rather than the variable of interest. In the present study, several attempts have been made to create a reliable anatomic baseline to ensure the comparability of the groups, which probably eliminated potentially significant anatomic biases that
could interfere with the results.

Recently, Keles et al concluded that Er:YAG laser application significantly improved the removal of filling material after the retreatment procedure with rotary instruments. Similarly Er,Cr:YSGG laser has been shown to effectively remove debris and smear layer from the apical region of a root canal,though there is no published study that has evaluated its efficacy in removing intracanal root canal filling. The results of this study showed that Er,Cr:YSGG laser and GentleWave were highly effective in removing Root canal filling from the coronal and middle thirds and upto 95% from the apical third of the root canal. Thus the null hypothesis was rejected.

CONCLUSION

Within the limitations of this study, none of the irrigation methods could completely remove root canal filling from the apical third of the root canal. However, Er,Cr:YSGG laser assisted irrigation and GentleWave irrigation system were highly effective in removing root canal fillling from the coronal, middle and apical thirds of the root canal. Micro-CT imaging is a more reliable and less invasive technique which allows for a 3-dimensional quantitative evaluation of residual root canal filling.

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