EFFECTIVENESS OF NEWER TIP DESIGN OF LASER IN REMOVING THE SMEAR LAYER AT THE APICAL THIRD OF CURVED ROOT CANALS -AN EX VIVO STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

APRIL 2012

CERTIFICATE

This is to certify that this dissertation titled **"EFFECTIVENESS OF NEWER TIP DESIGN OF LASER IN REMOVING THE SMEAR LAYER AT THE APICAL THIRD OF CURVED ROOT CANALS-AN EX VIVO STUDY"** is a bonafide record work done by **Dr.M.SABARI** under our guidance during his postgraduate study period between 2009 - 2012.

This dissertation is submitted to **THE TAMILNADU Dr.M.G.R.MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

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This is to certify that this dissertation titled "**EFFECTIVENESS OF NEWER TIP DESIGN OF LASER IN REMOVING THE SMEAR LAYER AT THE APICAL THIRD OF CURVED ROOT CANALS-AN EX VIVO STUDY"** is a bonafide record work done by **Dr.M.SABARI** under our guidance during his postgraduate study period between 2009 - 2012.

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INTRODUCTION

The aim of endodontic treatment is to eliminate microorganisms from the root canal system and to prevent reinfection. However, after chemomechanical preparation, an amorphous, irregular layer that is 1- 2 µm thick which is known as the smear layer is formed on the root canal system, covering the dentinal walls. The smear layer contains remnants of necrotic pulp tissue, fragments of the odontoblastic processes and microorganisms.[30]

The smear layer itself can be infected and might inhibit penetration of the root canal irrigant and medicament into the dentinal tubules. Moreover, the deeper portion of this smear layer is packed into the dentinal tubules up to 40µm. This is why elimination of the smear layer before root canal obturation is generally recommended, despite the controversy surrounding its removal.[29]

Besides instrumentation, irrigation is the other important step in preparing root canals. The effectiveness of irrigation depends on both mechanical flushing and chemical action. With syringe irrigation, the ability to flush the root canal is limited and primarily depends on the depth and placement of the irrigation cannula. The efficiency of irrigation can be increased by activating the solution with an ultrasonic or hydrodynamic device. Passive ultrasonic irrigation is defined as the activation of rinsing solution in the root canal using an ultrasonic file without continuous flow. In combination with sodium hypochlorite, this method has been shown to be more effective than conventional hand irrigation in removing dentin debris from the root canal. The hydrodynamic irrigation system (RinsEndo) is based on pressure suction technology and has been shown in a few studies to be effective.[2]

The efficiency of different irrigation systems, including ultrasonic, hydrodynamic and syringe irrigation was compared regarding their ability to remove dentin debris in straight root canals. The ultrasonic irrigation was more effective than hydrodynamic irrigation and syringe irrigation in straight canals. However, in curved root canals, the efficiency of the irrigation systems may be affected. Syringe cannula insertion to the apical region is more difficult in narrow and curved canals. Even the performance of ultrasonically activated files is reduced because of instrument restriction.[2]

All file systems generate a smear layer and leave debris in the root canal. Irrigation with 5.25% sodium hypochlorite alone is unable to remove debris and the smear layer .Thus other irrigants such as 2% chlorhexidine gluconate (CHX), 17% ethylenediamine tetraacetic acid (EDTA) and 10% Citric acid have been used to remove debris, but many studies have demonstrated the limited ability to effectively reach all internal faces of seemingly complicated root canal architecture.[12]

Lasers have been proposed as an alternative to the conventional approach to cleaning and disinfecting.[10] Physical techniques to remove the smear layer include the use of ultrasound (endosonics) and pulsed middle infrared lasers, both of which cause cavitation and pressure waves within the root canal space.[16]

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.[30]

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 smear layer, on thermal effects such as evaporation and contraction of the smear layer, and the thermal heating of microorganisms.[30]

Removal of smear layer by using lasers delivered with conventional (forward-firing) optical fibers report a lack of consistency. A recent study in the literature reveals, that using a simple tube etching method which created long conical ended fiber with lateral emission was found to perform well for lasers used in endodontics. This method gives better control of fiber shape than earlier methods such as polishing or heating and pulling, such conical-ended fibers also provide improved debriding actions in the root canal when used to deliver energy from a water absorbing middle infrared laser (Er,Cr:YSGG) into an aqueous irrigant, because absorption of laser energy would induce shock waves into the irrigant.[15]

The aim of this ex vivo study was to investigate the effectiveness of newer tip design of Er,Cr:YSGG laser in removing the smear layer at the apical third of curved root canals.

Objectives of the study:

1. To compare the smear layer removing efficacy of conical fiber tip Vs plain fiber tip for removing smear layer in the apical third of the curved root canal.
2. To compare the smear layer removing efficacy of different irrigants activated using Er,Cr:YSGG laser at the apical third of the curved root canal observed under SEM.

REVIEW OF LITERATURE

Ciucch et al (1989)[7] compared the effectiveness of different irrigation procedures on the removal of the smear layer. He concluded that Ultrasonic stirring of NaOCl removed the smear layer moderately, while EDTA produced almost smear free surfaces and Ultrasound in association with EDTA did not enhance the dissolving capability of the chelating agent, a definite decline in the efficiency of the irrigation procedures was also observed along the apical part of the canals.

Levy et al (1996)[26] studied the pressure waves induced in root canals by either Nd:YAG laser, sonically vibrated files or ultrasonically vibrated files. He concluded that Nd:YAG laser irradiation induced pressure waves, with difference characteristics waves induced by freely vibrating sonic and ultrasonic endodontic instruments when applied to water filled root canals.

Anic et al (1998)[3] compared the morphological changes on the dentin surface induced by laser light delivered perpendicular or parallel to the dentin surface. He concluded that the angle of the laser beam in relation to the target surface can be a deciding factor of how much energy will be absorbed by the dentin and consequently of the morphological changes induced by the laser.

Stockle et al (1999)[40] discussed a method called tube etching for the fabrication of near field optical probes. He also studied the influence of temperature, etchant concentration and fiber type on the tip quality. He concluded that after aluminum coating, optical probes with well defined apertures are obtained and due to the smooth glass surface the aluminum coating is virtually free of pinholes.

Takeda et al (1999)[42] summarizes the effectiveness of three type of lasers, argon, Nd:YAG and Er:YAG laser to remove smear layer in the prepared root canal. He concluded that argon, Nd:YAG lasers are useful to remove the smear layer and that the Er:YAG laser irradiation is the most effective to remove smear layer from the root canal walls.

Takeda et al (1999)[41] evaluated the effect of three endodontic irrigants and two types of laser on a smear layer created by hand instrumentation in middle and apical third of root canal. He concluded that irrigation with 17% EDTA, 6% phosphoric acid and 6 % citric acid did not remove smear layer from root canal system. In addition these acidic solutions demeneralized the intertubular dentine around tubular openings, which became enlarged. The Co_2 laser was helpful in removing and melting the smear layer on the instrumented root canal walls and the Er:YAG laser was the most effective in removing smear layer from the root canal wall.

Di Lenarda et al (2000)[11] evaluated the in vitro the cleansing and smear layer removal capability of alternate canal irrigation with citric acid and NaOCl. He concluded that 1 mol L^{-1} citric acid solution was as effective in removing smear layer as EDTA, but was superior in specimens treated with ProFile .04 taper instruments.

Kimura et al (2000)[25] studied the Laser applications in endodontics,including their use in pulp diagnosis, dentinal hypersensitivity, pulp capping, pulpotomy, sterilization of root canals, root canal shaping, obturation and apicectomy. He also discussed the effects of laser on root canal walls and periodontal tissues.

Shoji et al (2000)[38] examine the effect of Er:YAG laser irradiation using the cone shaped irradiation tip on root canal enlargement and debridement. He concluded that Scanning electron microscopic observations revealed that the dentin surface after laser preparation appeared cleaner than that obtained after preparation by drilling. This technique may have the advantage of decreasing the preparation time.

Yamazaki et al (2001)[47] evaluated the morphological changes in root canal walls and temperature changes at root surfaces as a result of intracanal irradiation by Er,Cr:YSGG laser under cooling and without cooling conditions in vitro. Results of the study showed that Er,Cr:YSGG laser irradiation with water spray cooling is a useful method for removal of smear layer and debris from root canals.

Martin et al (2002)[27] discussed the influence of metal roughness on the near-field distribution generated by an aperture or an aperture less (scattering) probe. He concluded that aluminium roughnes has a dramatic impact on the emission characteristics of a near field probe and in particular on its polarization sensitivity. Aperture less or scattering probes appear to be less sensitive to roughness and to provide a well confined even with a somewhat rough probe.

Burgos et al (2003)[6] summarizes the bent near field optical probes for biological applications and fabricated using a combination of a two-step chemical etching method and focused ion beam milling to create a well defined aperture. He concluded that both pulled and double etched probes are suitable for fluorescence imaging of polymer spheres. The images obtained with the double etched probes show excellent spatial resolution and signal or noise, illustrating the potential of these probes for imaging of biological samples.

Prabhu et al (2003)[32] compared the ability of maleic acid in different concentrations, NaOCl and EDTA in the removal of smear layer formed along the root canal walls after chemo mechanical preparation. The results showed that NaOCl failed to remove the smear layer. Smear removing ability of maleic acid was significantly better than EDTA.

Torabinejad et al (2003)[43] investigate the effect of a mixture of a tetracycline isomer, an acid, and a detergent (MTAD) as a final rinse on the surface of instrumented root canals. The presence or absence of smear layer and the amount of erosion on the surface of the root canal walls at the coronal, middle, and apical portion of each canal were examined under a scanning electron microscope. The results show that MTAD is an effective solution for the removal of the smear layer and does not significantly change the structure of the dentinal tubules when canals are irrigated with sodium hypochlorite and followed with a final rinse of MTAD.

Walsh et at (2003)[45] summarizes current and emerging applications for lasers in clinical practice. He discuss the laser fluorescence as effective method for detecting and quantifying incipient occlusal, cervical carious lesions, and proximal lesions. He also studied the Photo activated, dye techniques to disinfect root canals, periodontal pockets, cavity preparations and sites of peri implantitis and also dicuss the combination of laser irradiation with fluoride improve the resistance of tooth structure to demineralization and this application is of particular benefit for susceptible sites in high caries risk patients.

Haber et al (2004)[21] evaluated the dynamic etching method for fabricating fibre optic tips. By vertically translating the fibre during etching by an HF solution under an organic protective layer, a variety of tip shapes were created. He concluded that fibre motion, etching rate, meniscus distortion and etching time were all found to be important variables that can be used to control the final probe shape.

Stabholz et al (2004)[39] studied the current and possible future clinical applications of lasers in endodontics, including their use in alleviating dentinal hypersensitivity, modification of the dentin structure, pulp diagnosis, pulp capping and pulpotomy, cleaning and shaping of the root canal system, and endodontic surgery.

Foschi et al (2004)[14] studied to compare scanning electron microscopy following instrumentation with two different rotary NiTi instruments. He conclude that both instruments produced a clean and debris free dentine surfaces in the coronal and middle thirds, but were unable to produce a dentine surfaces free from smear layer and debris in the apical third. The presence of deep grooves and depression on dentine walls in the apical third may well explain the presence of less instrumented areas.

Wang et al (2005)[46] discuss the rise of temperature in root surfaces during and immediately after diode laser irradiation and to observe morphological changes of root canal wall after irradiation and to evaluate the apical leakage after irradiation and obturation. He concluded that the diode laser is useful for removing smear layer and debris from root canal walls, and reducing apical leakage after obturation.

Altundasar et al (2006)[1] studied the ultra-morphological and chemical changes in Er,Cr:YSGG laser-treated radicular dentin in comparison with two different irrigation regimes .He concluded that Scanning electron microscopic(SEM) evaluations revealed failure of smear removal in NaOCl irrigated specimens. RC-Prep + NaOCl treated dentin revealed moderate total presence of the smear layer with distinct areas of exposed collagen. Er,Cr:YSGG laser irradiation of radicular dentin also resulted in partial or total removal of the smear associated with a few small regions of thermal injury, including carbonization and partial melting.

Berber et al (2006)[5] evaluate the efficacy of 0.5%, 2.5% and 5.25% sodium hypochlorite (NaOCl) as intra canal irrigants associated with hand and rotary instrumentation techniques against Enterococcus faecal is within root canals and dentinal tubules He concluded that at higher concentrations, NaOCl was able to disinfect the dentinal tubules, independent of the canal preparation technique used.

Grande et al. (2006)[18] conducted a study to verify through nuclear magnetic resonance (NMR) analysis if the oxidizing property of sodium hypochlorite inactivates EDTA. Solutions of sodium hypochlorite and EDTA were analyzed. Results showed tracings of NMR analysis confirmed that the reaction between sodium hypochlorite and EDTA lead to a very slow but progressive degradation of this compound and a final flush with sodium hypochlorite cannot limit the chelating effects of EDTA in a clinically realistic time period.

George et al (2008)[16] studied Consistent and reproducible evaluation techniques of the smear layer in root canals in scanning electron microscopy studies and compared various instruments and techniques. In this study, the performance of 3 experienced blinded evaluators applying the Hulsmann technique was compared with a digital analysis method. He concluded that the image analysis might be useful for evaluating the degree of smear layer removal in endodontic research.

George et al(2008)[15] examined the ability of the improved laser tips when Er:YAG and Er,Cr:YSGG lasers were used in root canals in which thick smear layers had been created intentionally to provide a challenge for the laser system. Smear layer was assessed from scanning electron microscopy images with an objective digital method. Lasing improved the action of ethylenediamine tetraacetic acid with cetavlon (EDTAC) in removing smear layer. Conical fibers performed better than plain fibers, but there was no difference in performance between the two laser systems when matched for all other parameters. These results provide a "proof of concept" for lateral emitting fibers for endodontic procedures and illustrate the novel contribution of lasing to the action of EDTAC in dissolving smear layer.

George et al (2008)[4] examined the fluid extrusion beyond the apical constriction by pressure waves generated by pulsed middle infrared lasers using needles and Max-I-Probes as controls. Both free-running pulsed Er:YAG and Er,Cr:YSGG lasers with bare or conical fiber tips at distances of 5 or 10 mm from the apex displaced fluid past the apex. Larger apical openings showed greater extrusion of fluid. Results showed that pulsed lasers create pressure waves in irrigant fluids within the root canal, the potential for extrusion of fluid from the apex should be considered when assessing intracanal laser treatments in endodontics.

Helmy et al (2008)[22] evaluated the effect of diode laser and some irrigants such as sodium hypochlorite and hydrogen peroxide on surface morphology of the root canal dentinal wall by using Scanning Electron Microscope. The results showed that, laser irradiation removed debris and the smear layer that resulted from root canal preparation better than sodium hypochlorite and hydrogen peroxide. It also obliterates the dentinal tubule orifices and the dentin surface appeared glaze

Samaksamarn et al (2008)[36] compared the antibacterial effect of the Er,Cr:YSGG laser irradiation with two irrigating solutions in root canals of extracted human teeth. He concluded that Er,Cr:YSGG laser irradiation can reduce the viable microbial population in root canals to a certain extent but is less effective than irrigating with 2.5% NaOCl and 2% CHX solutions..

Asnaashari et al (2009)[4] evaluated the effect of removing debris and smear layer by Er,Cr:YSGG laser irradiation on the apical leakage of retrograde cavities. He concluded that dye penetration was less in lased group because of the better seal of the dissected surface due to the better removal of the debris and smear layer by laser .

De Groot et al (2009)[8]evaluated the efficiency of laser-activated irrigation in removing dentine debris from the apical part of the root canal and to visualize in vitro the fluid dynamics during the activation of the irrigant by laser. He concluded that streaming, caused by the collapse of the laser induced bubble, is the main cleaning mechanism of LAI.

Gu et al (2009)[19] discuss the effective irrigant delivery and agitation techniques for successful endodontic treatment and presented an overview of the irrigant agitation methods available and their debridement efficacy. He conclude that understanding the fundamental issues is crucial for clinical scientists to improve the design and user-friendliness of future generations of irrigant agitation systems and for manufacturers' contentions that these systems play a pivotal role in contemporary endodontics.

Roy George (2009)[34] summarizes the laser as one of the most captivating technologies in dental practice since Theodore Maiman in 1960 invented the ruby laser. Even though, introduced as an alternative to the traditional halogen curing light, the laser now has become the instrument of choice, in many dental applications. He discuss the use of laser in diagnosis, hard and soft tissue application, in bleaching and in root canal disinfection.

Sainsbury et al (2009) [35] evaluated the real-time assessment of the microbial status of the root canal system in clinical endodontic practice for determining endpoints of biomechanical treatment and he used a laser fluorescence device, the DIAGNOdent, in a proof-of-concept study. He concluded that the use of the DIAGNOdent fluorescence approach for the assessment of the status of the pulp chamber and root canal system holds promise for clinical application; once more, flexible tips can be developed for gaining greater penetration into middle and apical thirds of the root canal.

Schoop et al (2009)[37] examined the effects of the Er,Cr:YSGG laser irradiation in conjunction with the newly designed tip. He concluded that the Er,Cr:YSGG laser, in conjunction with radial firing tips, is a suitable tool for the elimination of bacteria in root canals and for the removal of smear layer.

Dewsnup et al (2010)[10] discussed to compare the reduction of Enterococcus faecal is in straight and curved canals using an erbium, chromium:yttrium-scandium-gallium garnet laser and irrigation with 6.15% sodium hypochlorite (NaOCl). He concluded that traditional irrigation techniques using 6.15% NaOCl effectively eliminated all bacteria in straight and curved canals. Er,Cr:YSGG laser also effectively removed all bacteria from straight canals. However, in curved canals, even though there were significant bacterial reductions, they failed to render canals completely free of bacteria

DiVito et al (2010)[12] analyze an in vitro the debriding ability of an Er:YAG laser system (2,940 nm) equipped with a newly designed radial and stripped tip of 400 µm diameter by scanning electron microscopy (SEM). He concluded that standardized instrumentation, followed by a final Er:YAG laser irradiation in wet canals with EDTA irrigation resulted in more cleaning of the root canal walls and a higher quantity of open tubules in comparison with the traditional irrigation method.

Haapasalo et al (2010)[20] investigate the success of endodontic treatment depends on the eradication of microbes from the root-canal system and to prevention of reinfection and the root canal is shaped with hand and rotary instruments under constant irrigation to remove the inflamed and necrotic tissue, microbes or biofilms, and other debris from the root canal space and he stated there is no single irrigating solution that alone sufficiently covers all of the functions required from an irrigant. He studied the optimal irrigation is based on the combined use of two or several irrigating solution and he stated that classic approach typically results in ineffective irrigation, particularly in peripheral areas such as anastomoses between canals, fins, and the most apical part of the main root canal. Thus he conclude that ,many of the compounds used for irrigation have been chemically modified and several mechanical devices have been developed to improve the penetration and effectiveness of irrigation., in a specific sequence, to predictably obtain the goals of safe and effective irrigation .

Ho Quan et al (2010)[24] evaluated the assessment of microbial status of the root canal system using laser fluorescence. He concluded that fluorescence analysis of root canals with optical fiber probes has the potential for real time assessment of the microbial status of the root canal system

Hmud et al (2010)[23] summarizes the laser-generated pressure waves application for removing debris and smear layers from root canals. He concluded that diode laser systems (near infrared 940 and 980 nm diode lasers) could induce cavitation in water base media by the formation and implosion of water vapour. Optimal laser initiated cavitation occurred when weak (3%) peroxide solutions were used as the target irrigant, rather than water.

Moon et al (2010)[29] evaluate the effect of different final irrigation regimens on the sealer penetration into dentinal tubules of curved root canals. He concluded that in curved canal, final rinse with NaOCl after the use of EDTA had no additional effect on sealer penetration. Complete debridement with a one minute application of EDTA remains a challenge in the apical area of curved canals.

Amato et al (2011)[2] compare the efficacy of hydrodynamic and ultrasonic-activated irrigation to conventional syringe irrigation in removing dentin debris in straight and curved root canals. He concluded that in the straight canals, ultrasonic irrigation was the most effective, but in the curved root canals, hydrodynamic irrigation was superior .

De moor et al (2011)[8] studied the efficacy of laser activated irrigation with Erbium: Yttrium Aluminum Garnet and Erbium Chromium:Yttrium Scandium Gallium Garnet wavelengths as compared with passive ultrasonic irrigation to remove artificially placed dentin debris plugs. He concluded that LAI techniques using erbium lasers (Er:YAG or Er,Cr:YSGG) for 20 seconds (4 x 5 seconds) are as efficient as PUI with the intermittent flush technique (3 x 20 seconds)

DiVito et al (2011)[13] investigate the scanning electron microscopy (SEM) analysis, the debriding ability of an Er:YAG laser system equipped with a new tapered and stripped tip of 400 µm diameter and auxiliary irrigating solutions after mechanical preparation. He concluded that SEM evaluation at the apical third showed that standardized instrumentation, followed by a final Er:YAG laser irradiation in EDTA wetted canals, resulted in more debriding and cleaning of root canal surfaces in comparison with Er:YAG laser irradiation in saline solution or saline solution alone.

Matsumoto et al (2011)[28] studied the action of laser-induced bubble and fluid flow in vitro to better understand the physical mechanisms underlying LAI. He used Er:YAG laser with a novel cone-shaped tip with a lateral emission rate of approximately 80%. He conclude that the cleaning mechanism of an Er:YAG laser within the root canal might depend on rapid fluid motion caused by expansion and implosion of laser induced bubbles.

Peeters et al (2011)[30] compared the efficacy of laser driven irrigation in removing the smear layer and debriding the apical region of the root canal (the root tip) with that of ultrasonic irrigation .He concluded that the use of a laser with a plain fiber tip, which produces cavitation in the irrigant, has potential as an improved alternative method for removing of the smear layer from the apical region of a straight root canal.

Peters et al (2011)[31] compared the efficacy of laser-activated and ultrasonically activated root canal disinfection with conventional irrigation, specifically its ability to remove bacterial film formed on root canal walls. He concluded that activated disinfection did not completely remove bacteria from the apical root canal third and infected dentinal tubules. However, the fact that laser activation generated more negative bacterial samples and left less apical bacteria/biofilm than ultrasonic activation.

MATERIALS USED

1. Freshly extracted human mandibular premolars.
2. Syringe-28 gauge needle [Hindustan Syringes & Medical Devices LTD, India]
3. EDTA 17%.[Tulsa, OK, USA]
4. Chlorhexidine gluconate 2% [Anabond Stedman Pharma Research Ltd, India]
5. Sodium Hypochlorite 3% [Prime Dental Products Ltd., India]
6. Distilled water
7. Diamond disc.
8. Chisel

ARMAMENTARIUM

9. K-Files [Mani Inc, Japan]
10. Micromotor with straight angled hand piece. [NSK, Japan]
11. Rotary nickel titanium (Ni-Ti) instrument [Anthogyr, Mallifer, Dentsply, Ballaigues, France]
12. Rotary protaper [Mallifer, Dentsply, Ballaigues, Switzerland]

EQUIPMENTS

13. Er,Cr:YSGG laser [Waterlase MD, Biolase, san Clemente, USA]
14. MZ 3 Plain Endodontic Fiber tip [Biolase, Irvine, CA]
15. RFT 3 Radial Firing Tip [Biolase, Irvine, CA]
16. Scanning Electron Microcsope [Philips XL 30 SEM,Netherlands]

METHODOLOGY

A total of 81 intact single rooted human mandibular premolars extracted for orthodontic reasons were collected and stored in water containing 0.1% thymol until needed for the study. The teeth were cleaned ultrasonically for removing calculus and debris.

Selection criteria of teeth

Roots of mandibular premolars having curvature more than 15º to 30º (curvature determined by radiograph) were selected. The degree of canal curvature was determined for each tooth using the Schneider method and separated into three groups.

In brief, canal curvatures of ≤5° divergence between the apical foramen and the long axis of the root were considered straight, canal curvatures of >5° and ≤15° were considered moderately curved, and canal curvatures of >15° were considered severely curved .[24]

The Schneider method involves, first drawing a line parallel to the long axis of the canal in the coronal third, a second line is then drawn from the apical foramen to intersect the point where the first line left the long axis of the canal. The Schneider angle is the intersection of these lines

The teeth were then decoronated using a diamond disc to produce a standard root length of 14.0 mm. The working length was determined by measuring the length of a #10 K-file passively inserted into the canal until it was visible at the apex and then backing off 1 mm.

Canal preparation

Root canals were prepared with protaper rotary instruments to a working length 1 mm short of the apex up to size F3 in a crown down technique under irrigation with 3% NaOCl (2ml). Final rinse was done with distilled water (10ml) in all the canals using disposable syringe and needle to prevent chemical interaction between the irrigant.

Laser Parameters

The Waterlase MD laser (Biolase) was used at panel settings of 1.25 W average power and 20 Hz (62.5 mJ/pulse) and was delivered into a 300 µm (size ISO 30) endodontic fiber with either plain and conical tips. No air or water spray was used. The fiber tip was fixed in the handpiece of an Erbium chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) lasers.

Grouping of samples was done as follows:

81 Teeth were randomly divided in to 3 groups of 27 specimens each which in turn further divided in to 3 sub groups each containing 9 teeth.

MAIN GROUPS

Group I : Irrigants not activated by laser(Non lased group)

Group II : Irrigants activated by Er,Cr:YSGG laser with plain tip

Group III : Irrigants activated by Er,Cr:YSGG laser with conical tip

SUB GROUPS	**:**	**IRRIGANTS**
A	:	17% EDTA
B	:	2% CHX
C	:	3% NaOCl

DIVISION OF SAMPLES

81 teeth were randomly divided into three groups

Group I- 27 **Specimens of irrigants not activated by laser (non lased group)**

Group II- **27 Specimens of irrigants activated by Er,Cr:YSGG laser with plain tip.**

Group III**- 27 Specimens of irrigants activated by Er,Cr:YSGG laser with conical tip.**

IA -9 Teeth with 17% EDTA
IB -9 Teeth with 2% CHX
IC -9 Teeth with 3% NaOCl

IIA-9 Teeth with 17% EDTA
IIB -9Teeth with 2% CHX
IIC-9 Teeth with 3% NaOCl

IIIA- 9 Teeth with 17%EDTA
IIIB -9 Teeth with 2% CHX
IIIC -9 Teeth with 3% NaOCl

Group I: Irrigants not activated by laser (Non lased group).

Instrumentation of root canal was done apically with rotary nickel-titanium (Ni-Ti) instruments up to size F3 by using Protaper instruments. The canal was irrigated with 17% EDTA, 3% NaOCl and 2% Chlorhexidine. Laser activation was not done in this group.

Group II: Irrigants activated by Er,Cr:YSGG laser with plain tip.

Instrumentation of root canal was done apically with rotary nickel-titanium (Ni-Ti) instruments up to size F3 by using Protaper instruments. The canal was irrigated with 17% EDTA, 3% NaOCl and

2% Chlorhexidine. Plain Laser fiber tip was placed into the appropriate irrigant solution in the root canal to a depth 5 mm short of the apex and then activated for 5 seconds. Treatment was undertaken for 4 passes of 5 seconds each, with an interval of 5 seconds between each, and fresh irrigation was used. Each pass was done at a fiber withdrawal rate of 1 mm/sec.

GROUP III: Irrigants activated by Er,Cr:YSGG laser with conical tip

Instrumentation of root canal was done apically with rotary nickel-titanium (Ni-Ti) instruments up to size F3 by using Protaper instruments. The canal was irrigated with 17% EDTA, 3% NaOCl and 2% Chlorhexidine. Conical Laser fiber tip was placed into the appropriate irrigant solution in the root canal to a depth 5 mm short of the apex and then activated for 5 seconds. Treatment was undertaken for 4 passes of 5 seconds each, with an interval of 5 seconds between each, and fresh irrigation was used. Each pass was done at a fiber withdrawal rate of 1 mm/sec.

Roots were dried for 24 hours at room temperature and then grooved longitudinally on their buccal and lingual surfaces by using a diamond disc without water spray, with care being taken not to perforate in to the canal. A chisel was placed into one of the grooves and then twisted gently to split the root into two parts. The split half of the tooth in which apex was most visible used for SEM evaluation

SCANNING ELECTRON MICROSCOPE EVALUATION

For SEM analysis, the specimens were dried for an additional 24 hours and then sputter coated with gold. The entire area 2 mm from the apex was examined for the evaluation of the residual smear layer. Photomicrographs were taken at 1000X magnification and evaluated.

Smear layer on the canal wall was evaluated using Torabinejad scoring system:

Score	Contents
1	No smear layer. No smear layer on the surface of the canal; all tubules were clean and open
2	Moderate smear layer. No smear layer on the surface of the canal, but tubules contained debris. (Smear plug)
3	Heavy smear layer. Smear layer covered the root canal surface and the tubules

METHODOLOGY OVERVIEW

81 freshly extracted Intact human mandibular premolars with 15-30 degree curvature selected, ultrasonically cleaned and stored in 0.1% Thymol

⇓

Teeth decoronated using diamond disc, Root length standardized to 14mm and canal patency established using #10 size K-file.

⇓

Teeth were randomly divided in to 3 groups of 27 specimens for each which in turn further divided in to 3 sub groups each containing 9 teeth

⇓

GROUP I **: IRRIGANTS NOT ACTIVATED BY LASER (NON LASED GROUP).**
Canals were prepared with rotary protaper to a working length 1 mm short of the apex to size F3. Canals were irrigated with

GR IA - 17 % EDTA,
GR IB - 2% CHX
GR IC - 3 % NaOCl

GROUP II: **IRRIGANTS ACTIVATED BY Er,Cr:YSGG LASER WITH PLAIN TIP.**
Canals were prepared with rotary protaper to a working length 1 mm short of the apex to size F3. Canals were irrigated with.

GR IIA - 17 % EDTA,
GR IIB - 2% CHX
GR IIC - 3 % NaOCl

GROUP III: **IRRIGANTS ACTIVATED BY Er,Cr:YSGG LASER WITH CONICAL TIP**.
Canals were prepared with rotary protaper to a working length 1 mm short of the apex to size F3. Canals were irrigated with.

GR IIIA - 17 % EDTA,
GR IIIB - 2% CHX
GR IIIC - 3 % NaOCl

⇓

Teeth were grooved longitudinally with a diamond disc on their buccal and the lingual surface and split in to two halves with chisel.

⇓

Split specimens gold sputtered and subjected to SEM evaluation

⇓

Results tabulated and statistically analysed.

Fig.1: TEETH SAMPLES

Fig.2: ARMAMENTARIUM

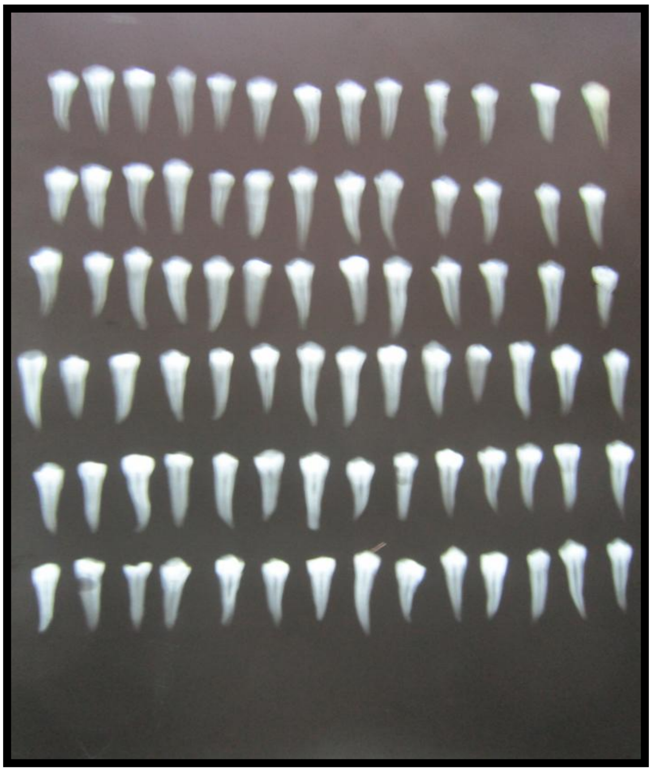


Fig.3: RADIOGRAPH

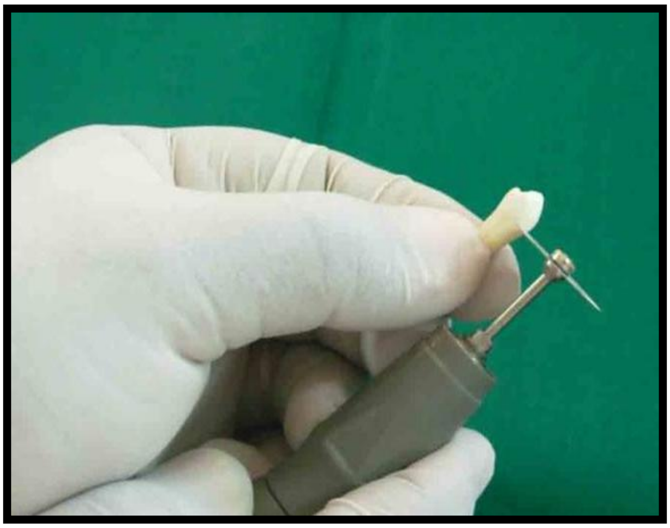


Fig.4: DECORONATION

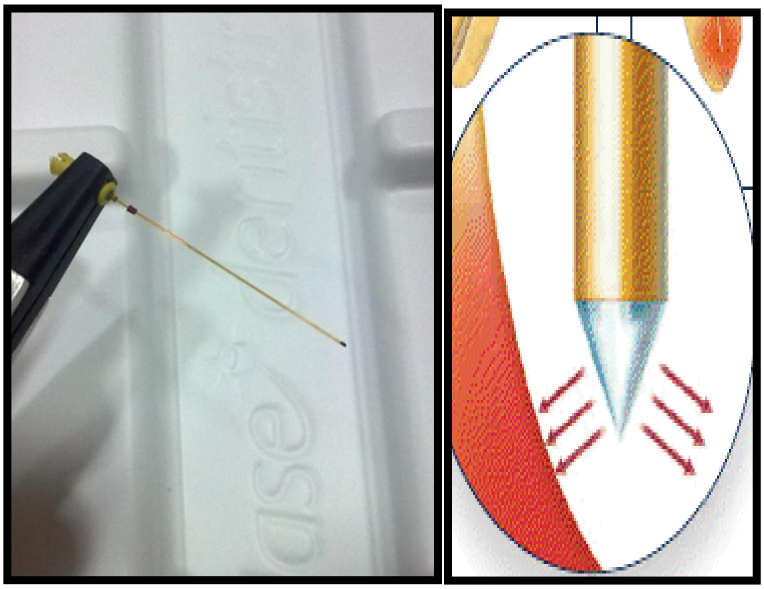
Fig.5: DECORONATED TOOTH

Fig.6: PRELIMINARY PREPARATION OF THE TOOTH

Fig.7: CLEANING AND SHAPING

Fig.8: Er,Cr:YSGG LASER

Fig.9: PANEL SETTING



a **b**

Fig.10a & b: CONICAL FIBER TIP

Fig.11: PLAIN FIBER TIP

Fig.12: SYRINGE IRRIGATION

Fig.13: LASER ACTIVATED IRRIGATION

Fig.14: LONGITUDINAL SECTION

Fig.15: GOLD SPUTTERING UNIT

Fig.16: GOLD SPUTTERED TEETH SAMPLES

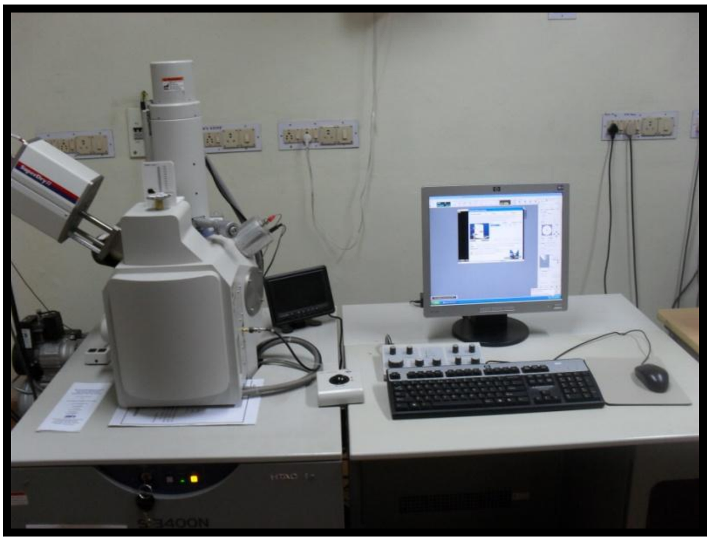


Fig.17: SCANNING ELECTRON MICROSCOPE

RESULTS

The results of the present study were subjected to statistical analysis to interpret the significant differences in smear layer scores within each group and also between the groups using one way anova and Post hoc tukey tests.

One way analysis of variance (ANOVA) is used to study the overall variance within groups. It is the extension of the between groups t-test to the situation in which more than two groups are compared simultaneously. However, it is not possible to identify the difference between the various subgroups with the help of the P values obtained from ANOVA. Therefore a specific statistical test was used for intra group comparison. Hence, the Post hoc Tukey is done in order to determine which groups differ from each other. The Post hoc Tukey Test Honestly significant difference or HSD test is a post hoc test designed to perform a pair wise comparison of the means to identify the specific sub groups in which significant difference expression occurs.

Unpaired ‘t’-test is applied to unpaired data of independent observation made on individuals of two different or separate groups or samples drawn from two populations.

In this study one way anova followed by Tukey HSD test showed statistically significant difference among various subgroup concerning the discrepancy of the smear layer removal in the apical third of the root canal in each group.

REPRESENTATIVE SEM IMAGES FROM NON LASING GROUPS

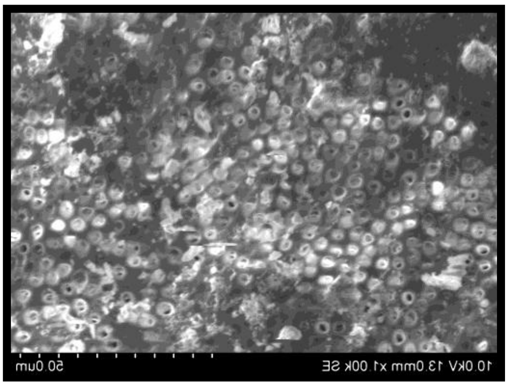


Fig.18a: EDTA

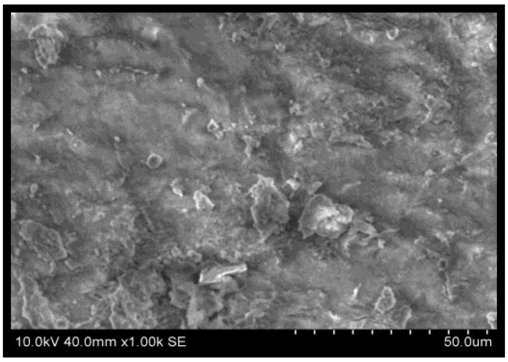


Fig.18b: CHX

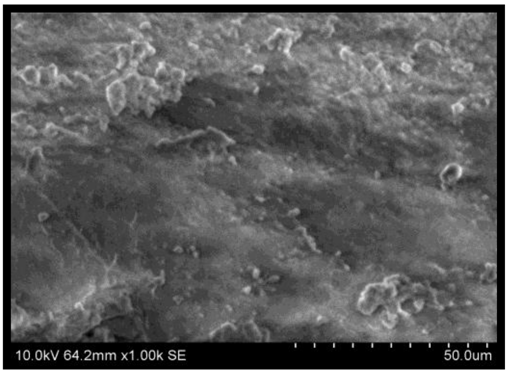


Fig.18c: NaOCl

REPRESENTATIVE SEM IMAGES FROM PLAIN LASER FIBER TIP GROUPS

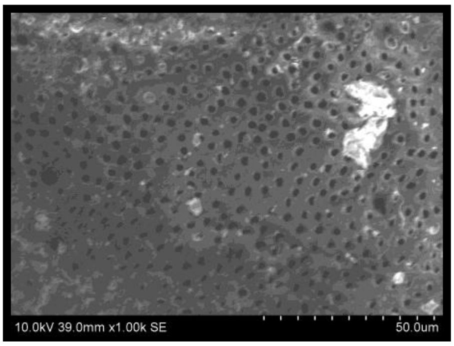


Fig.19a: EDTA

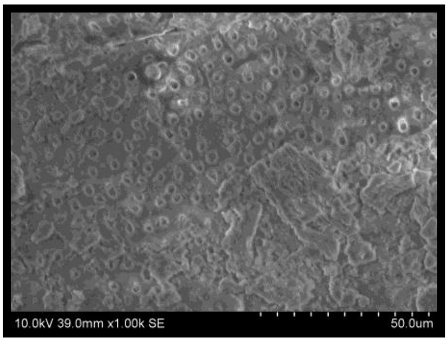


Fig.19b: CHX

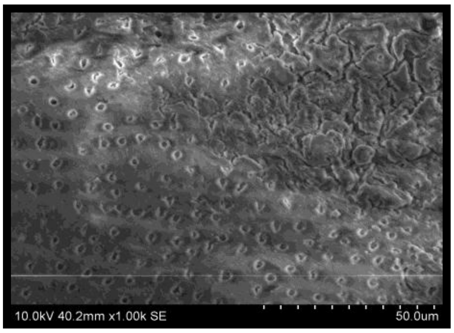


Fig.19c: NaOCl

REPRESENTATIVE SEM IMAGES FROM CONICAL LASER FIBER TIP GROUPS

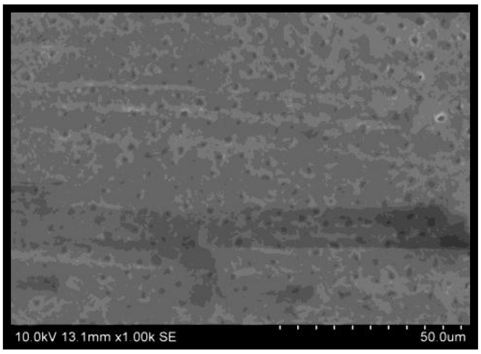


Fig.20a: EDTA

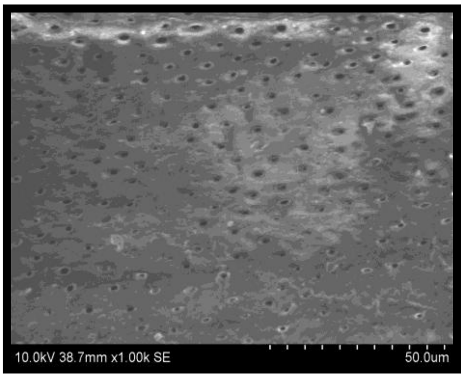


Fig.20b: CHX

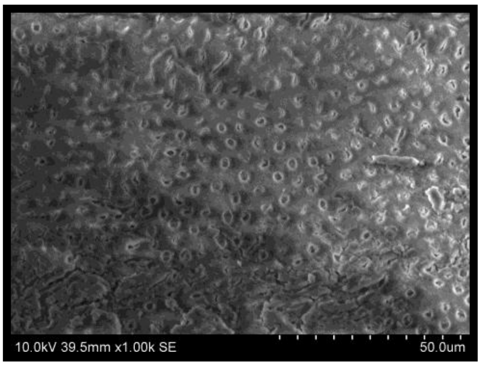


Fig.20c: NaOCl

TABLE-1: ONE- WAY ANOVA FOR INTRA GROUP & INTER GROUP COMPARISON OF SMEAR LAYER SCORES

GROUPS	17% EDTA	2% CHX	3% NaOCl	P VALUE
	Mean ± sd	Mean ± sd	Mean ± sd	
GROUP I	1.78 ± 0.44	2.00 ± 0.00	2.00 ± 0.00	0.123
GROUP II	1.44 ± 0.53	1.56 ± 0.53	1.78 ± 0.44	0.370
GROUP III	0.44 ± 0.53	1.33 ± 0.50	1.56 ± 0.53	0.000**
P-VALUE	0.000**	0.008**	0.079	

**Denotes significant at 1% confidence level.

TABLE-2: POST HOC TUKEY ANALYSIS FOR INTRA GROUP COMPARISON OF SMEAR LAYER SCORES

GROUPS	p- value		
	GROUP I	GROUP II	GROUP III
17% EDTA X 2% CHX	0.175	0.885	0.004**
17% EDTA X 3% NaOCl	0.175	0.350	0.000**
2% CHX X 3% NaOCl	1.000	0.619	0.640

**Denotes significant at 1% confidence level.

TABLE-3: POST HOC TUKEY ANALYSIS FOR INTERGROUP COMPARISON OF SMEAR LAYER SCORES

GROUPS	p- value		
	17% EDTA	2% CHX	3% NaOCl
GROUP I X GROUP II	0.350	0.083	0.471
GROUP I X GROUP III	0.000**	0.007**	0.064
GROUP II X GROUP III	0.001**	0.509	0.471

**Denotes significant at 1% confidence level.

To summarize the results:

- The mean rank scores for the smear layer were highest in the Group I and the mean rank scores for the smear layer were lowest in the Group III (Table-1)

Effect of irrigants on smear layer removal:

- Groups that used EDTA as irrigant was not statistically significant when compared with NaOCl and CHX in both the Group I and Group II. (Table-3)
- Groups that used CHX as irrigant was not statistically significant when compared with NaOCl in all the three groups. (Table-3)
- Groups that used EDTA as irrigant was highly significant when compared with NaOCl and CHX in the Group III. (Table-3)

Effect of laser fiber tips on smear layer removal:

- Group III when compared to the Group I was highly significant when EDTA and CHX were used as irrigants. (Table-2)
- Group III when compared to the Group I was not statistically significant when NaOCl was used as irrigant. (Table-2)

- Group III when compared to the Group II was highly significant when EDTA was used as irrigant. (Table-2)
- Group II was not statistically significant when NaOCl and CHX were used as irrigants. (Table-2)
- Group II when compared to the Group Iwas not statistically significant when EDTA, NaOCl and CHX were used as irrigants. (Table-2)

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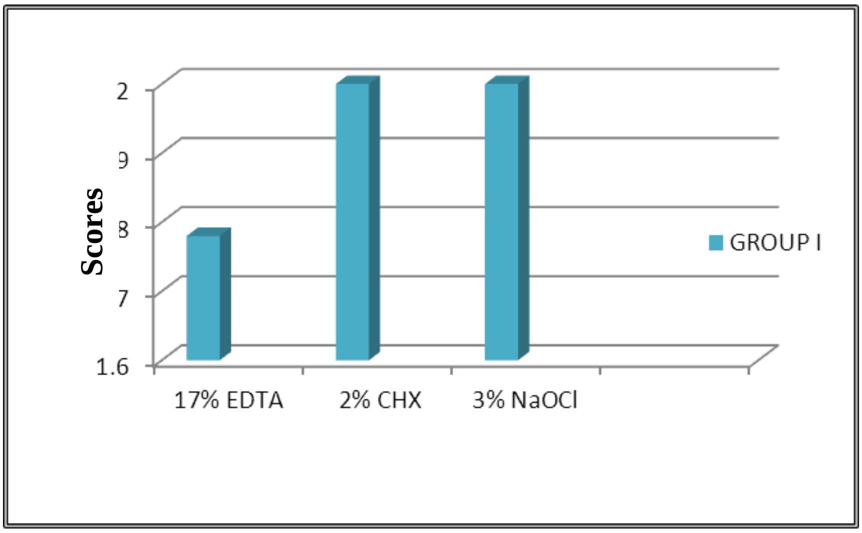
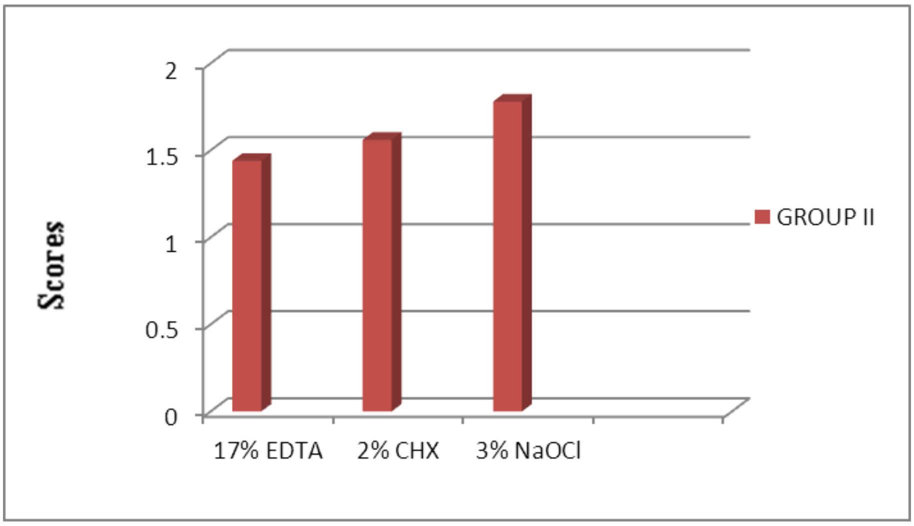
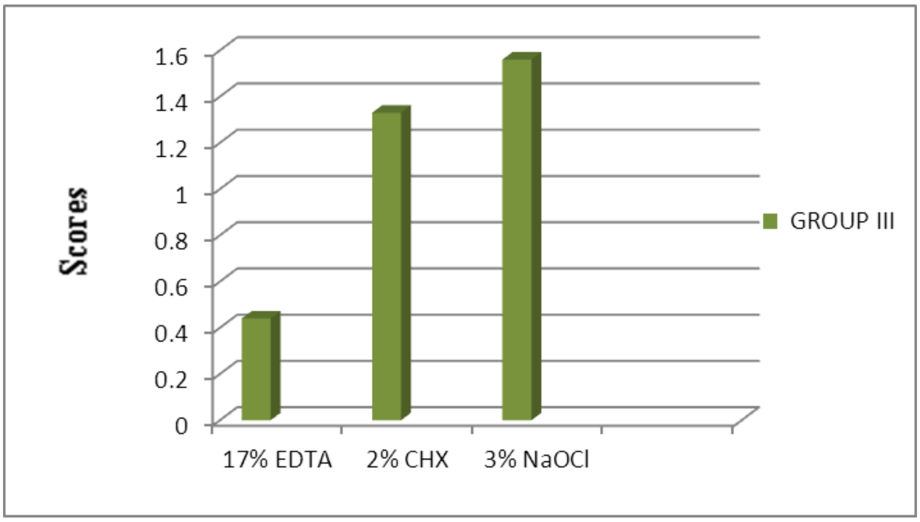
GRAPH -1: COMPARISON OF SMEAR LAYER REMOVAL BETWEEN EDTA, CHX & NaOCl WITH IN GROUP I. (IRRIGANTS NOT ACTIVATED BY LASER)



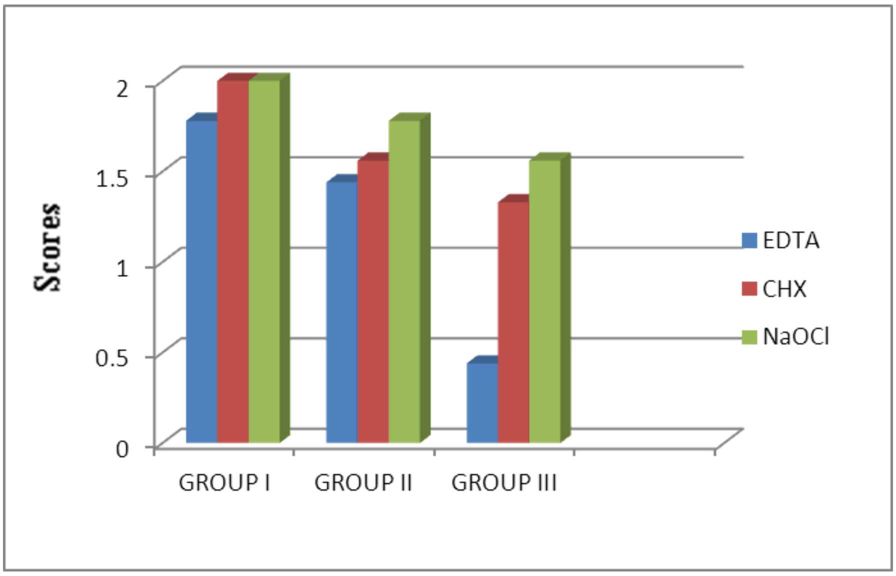
GRAPH -2: COMPARISON OF SMEAR LAYER REMOVAL BETWEEN EDTA, CHX & NaOCl WITH IN GROUP II (IRRIGANTS ACTIVATED BY Er,Cr:YSGG LASER WITH PLAIN TIP)



GRAPH -3: COMPARISON OF SMEAR LAYER REMOVAL BETWEEN EDTA, CHX & NaOCl WITH IN GROUP III (IRRIGANTS ACTIVATED BY Er,Cr:YSGG LASER WITH CONICAL TIP)



GRAPH -4: COMPARISON OF SMEAR LAYER REMOVAL BETWEEN GROUP I, GROUP II & GROUP III WITH EDTA, CHX & NaOCl IRRIGANTS



DISCUSSION

The ability to successfully treat and remove the smear layer and bacteria continues to be a challenge in nonsurgical endodontic treatment of the root canal system. The shaping and cleaning of root canals is a key step during root canal treatment and unless all remnants of debris are removed, subsequent stages of obturation may also be jeopardized. Clinically, endodontic procedures use both mechanical instrumentation and chemical irrigants in the attempt to three dimensionally debride, clean and decontaminate the endodontic system.[12]

Conventional root canal treatment aims at the removal of the infected pulp and dentine layers by using mechanical techniques and bactericidal irrigants. In this context, the method of bactericidal rinsing encounters a major problem. Studies by Kouchi et al have shown that bacteria colonize the periluminal dentine up to a depth of 1,100 µm. Chemical disinfectants penetrate only 100 µm into the dentine.[37]

Even with the use of rotary instrumentation, the nickel-titanium instruments, only act on the central body of the canal, leaving canal fins, isthmi, and cul-de-sacs untouched after completion of the preparation. These areas might harbor tissue debris, microbes, and their byproducts, which might prevent close adaptation of the obturation material and result in persistent periradicular inflammation.[19]

Smear layer has been defined as a layer of debris on the surface of dental tissues created by cutting a tooth. It varies in thickness, roughness, density, and degree of attachment to the underlying tooth structure, according to the instruments and materials used. A smear layer might partially or completely occlude dentinal tubules and the bacteria, endotoxins and debris contained within it could contribute to ongoing periapical inflammation. Moreover, smear layer prevent medicaments from adequately diffusing from the root canal space into the dentinal tubules. For these reasons, complete removal of the smear layer is seen as desirable.[16]

Irrigation is an essential part of root canal debridement because it allows for cleaning beyond what might be achieved by root canal instrumentation alone. In contemporary endodontic practice, dual irrigants such as sodium hypochlorite (NaOCl) with ethylenediamine tetraaceticacid (EDTA) or chlorhexidine (CHX) are often used as initial and final rinses to complement the shortcomings that are associated with the use of a single irrigant. More importantly, these irrigants must be brought into direct contact with the entire canal wall surfaces for effective action particularly for the apical portions of small root canals.[19]

NaOCl is the most commonly employed root canal irrigant.[5]It is an effective antimicrobial agent and an excellent organic solvent for vital and necrotic tissues. Sodium hypochlorite dissolves proteins and forming chloramines residues on the remaining peptide fragments, thus not only aiding in debridement but also contributing to antimicrobial action of the free chlorine. Furthermore, it inactivates the sulfhydryl groups of bacterial enzymes by forming hypochlorous acid. However, it is highly irritating to periapical tissues especially at high concentrations,[36] but no general agreement exists regarding its optimal concentration, which ranges from 0.5% to 5.25%.[5]

Chlorhexidine (CHX) has been recommended as a root canal irrigant and medicament. It is a potent antimicrobial agent and has a low grade of toxicity. CHX seems to act by adsorbing onto the cell wall of microorganisms and causing leakage of intracellular components. However, CHX is unable to dissolve pulp tissue and may remain on canal walls, obstructing the dentinal tubules.[36]

EDTA a chelating agent used to remove smear layer. The complete cleaning of the root canal system requires the use of irrigants that dissolve organic and inorganic material. As hypochlorite is active only against the former, other substances must be used to complete the removal of the smear layer and dentin debris. EDTA effectively dissolve inorganic material, including hydroxyapatite. They have little or no effect on organic tissue and alone they do not have antibacterial activity. EDTA is most commonly used as a 17% neutralized solution (disodium EDTA, pH 7), but a few reports have indicate that solutions with lower concentrations (eg, 10%, 5%, and even 1%) remove the smear layer equally well after NaOCl irrigation. EDTA used for two to three minutes at the end of instrumentation and after NaOCl irrigation. Removal of the smear layer by EDTA improves the antibacterial effect of locally used disinfecting agents in deeper layers of dentin.[20] .A final high volume flush with both NaOCl and EDTA solutions is recommended to remove the smear layer and the organic tissue in the canal.[7]

Canal curvature and apical diameter influence the mechanical efficacy of root canal irrigation. Irrigation is significantly less effective in curved canals with a small apical diameter than in curved canals with a larger apical diameter. Hence, disinfection of curved canals needs further investigation[10].The key role of root canal irrigants is to clean the canal during the enlarging and shaping process. Consequently, one or more irrigants must be used for the complete elimination of smear layer and debris from the root canal system.[30]

Syringe irrigation is the standard procedure[30] but Syringe cannula insertion to the apical region is more difficult in narrow and curved canals. With syringe irrigation, the ability to flush the root canal is limited and primarily depends on the depth and placement of the irrigation cannula[2]. Sonic and ultrasonic instruments likely clean the canal mainly by filing dentin mechanically and also by streaming and cavitation collapse. In pre enlarged root canals, pressure waves are induced by laser irradiation as well as sonic and ultrasonic vibration. However, in the narrow canals, file vibration is restricted by wall contact and cavitation does not occur.[28]

Laser is the acronym of the words ‘Light Amplification by Stimulated Emission of Radiation’. Albert Einstein first postulated Stimulated Emission in 1917, it was not until 1960 that the first laser was invented by Theodore Maimam, a synthetic ruby laser. Initially most of the research in the field of laser was restricted to this laser, with Stern and Sognnaes in 1964 reporting that glass like fusion and catering of enamel when subjected to 500- 200J/cm2 of laser energy, they also observe charring of dentine. In 1965 Goldman et al for the first time subjected a vital tooth to laser energy, the patient has experienced no pain and had only minor superficial damage to the crown. Ruby lasers lost favour soon as it needed far too much energy to effectively dental hard tissue was reported to cause severe thermal to the pulp and collateral damage to adjacent hard and soft tissue due to scattered radiation.[34]

The Nd:YAG laser was developed in 1964 by Bell Telephone Laboratories. Though Nd:YAG Lasers where discovered a year after the ruby laser it was largely over shadowed for a long time by the ruby laser and other lasers of the era (Carbon Dioxide Laser). It was not until 1990 that this laser was available for dental use. Early studies with this laser was in its application for soft tissue procedure as well as inhibition of caries.[34]

The carbon dioxide laser was invented by Kumar N Patel in 1964 when working at Bell Telephone Laboratories. Carbon dioxide laser was perhaps the first laser that had truly hard tissue and soft tissue application. Weichman & Johnson in 1971 was one of the first to use lasers in Endodontics, they unsuccessfully attempted to seal the apical foramen in vitro by means of a high power infrared (CO_2) laser. Carbon dioxide lasers are well absorbed by water and is the laser of choice for various dental soft tissue and hard tissue application. However, this gas based lasers could not be delivered through optic fiber due to its large wave length that will not fit into the crystalline molecules of the conducting glass and has to be conducted either by a hollow wave guide or an articulate arm delivery system. Also being well absorbed by water they cannot be delivered by fibers or fiber tips that contain water like the quartz fiber tips, as this would disintegrate the fiber.[34]

In 1988, both Hibst and Paghdiwala were the first to describe in detail the effect of the Er:YAG laser on dental hard tissues, however it was not until 1997 that this laser obtained US FDA approval for cavity preparation. One of the earliest companies to release Er:YAG lasers onto the market was KaVo (Germany) in 1992. Subsequently, the second erbium laser hard tissue wavelength (Er:YSGG, 2.78 µm) was developed and marketed by Biolase (USA). The erbium family of laser has an emission wavelength which coincides exactly with the absorption peak of water, giving strong absorption in all biological tissues, including enamel and dentine and hence are the most popular soft tissue and hard tissue lasers.[34]

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. Previous studies have revealed the side effects that can be caused by the use of lasers in the root canal, these include **the creation of ledges up to a canal curvature of <10 , carbonization, cracks , collagen damage, and apical extrusion of the solution** . In order to avoid some of the side effects that are associated with the use of a laser, the laser-driven irrigation was performed by hovering the laser tip around the orifice of the root canal system instead of placing the tip within the canal itself. During laser irradiation, the root canal was irrigated continuously to maintain the hydration level. The pulp chamber served as a reservoir for the irrigant.[30]

The Erbium, chromium: yttrium- scandium- gallium garnet (Er,CrYSGG) laser has a 2790nm wavelength delivered by flexible fiberoptic tips was introduced and this laser wavelength has highest absorption in water and high affinity to hydroxyapatite, which makes it suitable for use in root canal therapy.[10] Water or other irrigants are used during lasing to reduce thermal stress to the radicular dentine and periodontium.[17] Er,Cr:YSGG laser are useful for cutting hard tissues including enamel, dentin, and bone offering the advantage of precise hard tissue cuts by virtue of interaction of the laser energy with water at the interface of tissues and also for etching of enamel surfaces.[1]

Laser cleaning can be performed in two ways. In one method, the root canal wall should be slightly moist to absorb laser irradiation efficiently. Dentin debris is removed and bacteria are eradicated from the wall by laser-induced explosive vaporization directly. In the second method, the root canal should be filled with a liquid such as water or sodium hypochlorite. The laser tip is inserted inside and irradiation is performed with in the liquid. In this second method, collapse shock waves and rapid streaming caused by laser-induced bubbles are thought to be mainly responsible for the cleaning mechanism.[28]

Previously lasers were equipped with short rigid sapphire probes that were unable to access the entire length of the root canal system. Recently, **thinnest small diameter commercially available germanium-doped silica glass optical fiber tips which may either be plain ended and conical ended** are used to negotiate the root canal system to the apical third. In the apical third the persistence of microorganisms is likely to be higher after instrumentation because of anatomic complexities. Hence, the size of the fiber and the shape of the tip influences the ability of the fiber tip to negotiate the root canal space.[24]

George et al showed that there was twice as much dye penetration through the apical constriction with the fiber tip at 4 mm than at 5 mm.[9] Therefore, a distance of 5 mm from the apical stop to the fiber tip was used for the present evaluation.

The plain fiber tip emitted laser beam in which the active cutting energy is directed parallel to the canal walls rather than laterally. This makes it difficult to control the direction of the energy beam inside the canal[10], whereas conical fiber tip emitted laser beam in which the active cutting energy is directed laterally to the canal walls and have lateral collection of light and are used for severely curved canals and canals with multiple curvatures.[24] In case of a flat-end tip, the laser generated an oval-shaped vapor bubble in front of the laser tip and its surface was rough and cloudy and in case of conical end tip, the laser generated an apple-shaped vapor bubble in front of the laser tip, and its surface was smooth and sleek because the cone-shaped tip emitted the laser beam in a lateral direction rather than in the apical direction.[28]

Debriding action of Er,Cr:YSGG laser energy is much better when delivered through conical fibers than plain optical fibers. The divergent laser energy can interact with the canal walls causing ablation by photomechanical effects and has shown that pulsed middle infrared lasers create shock waves in aqueous solutions in root canals. The conical shape influences the configuration of this shock wave, which might further enhance its action on debris.[15]

Laser treatments had the ability to remove the smear layer. This can be attributed to the ability of the laser driven irrigation used in to create cavitation. 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 .[30]

The aim of the present study was to investigate the effectiveness of newer tip design of Er,Cr:YSGG laser in removing the smear layer at the apical third of curved root canals.

In this present study 81 freshly extracted intact human mandibular premolars with 15-30^{o} canal curvature and closed apices were used. Mandibular first premolars were selected as they showed high incidence of single root, with single canal and single foramen and were easily available since they were extracted for orthodontic purpose.

The degree of canal curvature was determined for each tooth using the Schneider method .The teeth were decoronated and root length standardized to 14.0 mm. Teeth were randomly divided into three groups of 27 specimens each which in turn were further divided in to three sub groups each containing 9 specimens according to the types of irrigant used. In all groups Canals were prepared with rotary nickel-titanium (Ni-Ti) instruments to a working length 1 mm short of the apex to size F3 by using Protaper instruments.

. In group I, laser was not activated, where as in Group II, Plain Laser fiber tip was placed 5mm from the apex in the root canal and the appropriate irrigant solution was then activated for 20 seconds and in group III, Conical fiber tip was placed 5mm from the apex in the root canal and the appropriate irrigant solution was then activated for 20 seconds.

The teeth were then grooved longitudinally on their buccal and lingual surfaces and were split into two halves. The split half of the tooth in which apex was most visible used for SEM evaluation.

In the present study the result were tabulated and subjected to statistical analysis to interpret the significant difference for smear layer removal in the apical third of the root canal system between in each groups and also between the groups.

The result of the present study evaluated by SEM revealed that all the laser treated groups had the ability to remove the smear layer from the apical third of the root canal system when compared to the non lased groups. The findings of this study were in agreement with Peeters Harry Huiz et al, who concluded that the laser-driven irrigation have the ability to create cavitation.[30]

According to the present study, EDTA activated by Er,Cr:YSGG laser with conical tip showed better smear layer removal when compared to EDTA activated by Er,Cr:YSGG laser with the plain tip and the non lased group I (Table-2). The result of present study are in accordance with previous study by Roy George et al who reported that laser activation of EDTA and better performance of conical fiber tip compared to plain fiber tip for improving the action of EDTA in dissolving smear layer.[13]The results of the present study also corroborate with previous study which indicated that Er,Cr:YSGG laser create shock waves with the irrigants in root canal. The conical design of the conical fiber tip influences the configuration of the shock waves, which might further enhance its action on smear layer removal.[15]

The mean rank scores for the smear layer were highest in the Non lased Group I which indicated that removal of the smear layer was poor in the absence of laser irradiation (Table-1). Blanken and Verdaasdonk showed that when an Er,Cr:YSGG laser is used within the root canal with a 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.[30]

According to the present study Group II showed no significant improvement for smear layer removal in the apical third of the root canal. The result of present study are in accordance with Dewsnup et al who have reported that the plain fiber tip emitted laser beam in which the active cutting energy is directed parallel to the canal walls rather than laterally. This makes it difficult to control the direction of the energy beam inside the canal as described above.[10]

Group III showed an improvement for the smear layer removal in the apical third of the root canal when compared with the Group II. These results corroborate with previous study which indicated that conical fiber tip emitted laser beam in which the active cutting energy is directed laterally to the canal walls and have lateral collection of light and are used for severely curved canals and canals with multiple curvatures.[24]

The present study revealed that the irrigants activated by Er,Cr:YSGG laser - conical tip performed better in the smear layer removal compared to plain tip activation of irrigants. Among the irrigants used EDTA showed better effectiveness in smear layer removal followed by CHX and NaOCl in the apical third of the curved root canal system.

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SUMMARY

The purpose of this ex vivo study was to investigate the effectiveness of newer tip design of Er,Cr:YSGG laser in removing the smear layer at the apical third of curved root canals.

A total of 81 freshly extracted single rooted intact human mandibular premolars teeth with 15-30º canal curvature were selected for the study and were decoronated at the level of cemento enamel junction.

The roots were divided in to three main groups with 27 samples each. GROUP I-Irrigants not activated by laser (non lased group) .GROUP II-Irrigants activated by Er,Cr:YSGG laser with plain tip and GROUP III-Irrigants activated by Er,Cr:YSGG laser with conical tip and each group were further divided in to three sub groups of 9 samples each with EDTA, CHX, NaOCl respectively.

In all the three groups, Canals were prepared with rotary nickel-titanium (Ni-Ti) instruments to a working length 1 mm short of the apex to size F3 by using Protaper instruments. In Group I the canal was irrigated with 17% EDTA, 2% Chlorhexidine and 3% NaOCl without laser irradiation, where as in Group II and Group III the canal was

irrigated with 17% EDTA, 2% Chlorhexidine and 3% NaOCl respectively with Plain and conical fiber tips was placed 5mm from the apex in the root canal and the appropriate irrigant solution was then activated for 20 second.

The teeth were then grooved longitudinally with a diamond disc on their buccal and lingual surfaces and were split into two halves with a chisel and mallet. The split half of the tooth in which apex was most visible used for SEM evaluation at 1000 X magnification and smear layer scoring was done using Torabinejad's scoring system,

The result of the present study were subjected to statistical analysis to interpret the smear layer removal in each group and also between the groups.ONE-WAY ANOVA followed by POST HOC TUKEY HSD test was used for statistical analysis in the present study

CONCLUSION

Within the limitations of this ex vivo study it can be concluded that:

1. Er,Cr:YSGG laser with conical fiber tip performed better removal of smear layer in the apical third of the curved root canal system.
2. Conical fiber tip performed better than plain fiber tip for removing smear layer in the apical third of the curved root canal system.
3. Among the irrigants used EDTA showed better effectiveness in smear layer removal followed by CHX and NaOCl in the apical third of the curved root canal system.

This suggests that to ensure complete removal of smear layer from the root canal system it may be prudent to activate EDTA with conical tip design of Er,Cr:YSGG laser during irrigation protocol in the curved root canals.

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