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Er,Cr:YSGG Laser Induced Photoacoustic Streaming irrigation technique for root canal treatment

A Thesis Submitted to the Institute of Laser for Postgraduate Studies, University of Baghdad in Partial Fulfillment of the Requirements for the Degree of Master of Science in Laser / Dentistry

By

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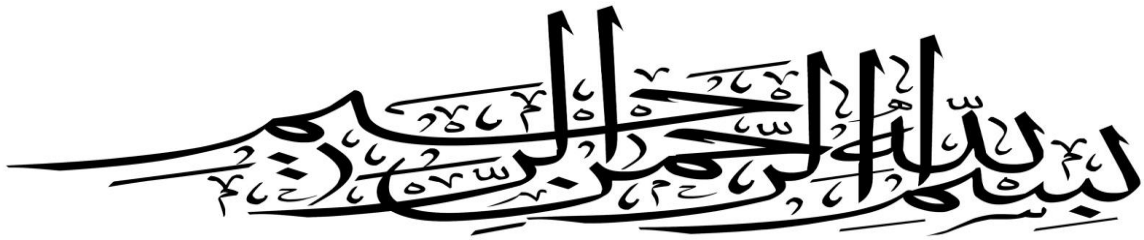

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صدق الله العلي العظيم

﴿ سورة الإسراءالاية 85 ﴾

Certification

I certify that this thesis was prepared under my supervision at the Institute of Laser for Postgraduate Studies, University of Baghdad, in a partial fulfilment of requirements for the degree of "Master of Science in Laser/ Dentistry".

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Dedication

This thesis is dedicated to my wonderful and supportive family especially my mother for her love, patience, support and encouragement.

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*First, I present my thanks to almighty **"ALLAH"** the most merciful and generous for granting me the will, patience and strength through which this study accomplished.*

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Abstract

Background: The smear layer can prevent the penetration of root canal irrigation solutions and medications into the dentinal tubules. As a result, several studies have recommended the removal of the smear layer.

Aim of study: The objective of this research is to study the influence of Er,Cr:YSGG 2780 nm on smear layer removal of the apical third using photo induced photoacoustic streaming technique at short pulse duration alone and with irrigant comparing with ultrasonic activation.

Materials and Methods: Sixty-six mandibular premolars with single-root were used. The roots length was uniform to 14 mm from the anatomic apex and instrumented using the rotary system to size 40/0.06. Er,Cr:YSGG laser was used at 60 µs, 5 Hz, water and air off. Twelve teeth were used to investigate the effect of 17% EDTA (Ethylene Diamine Tetra-acetic Acid) and 5.25% NaOCl on smear layer removal using scanning electron microscope. For pilot study, thirty samples were used. The samples were divided into two groups (n=15) as follows: a) Er,Cr:YSGG induced photoacoustic streaming with 17%EDTA at (0.25 W,0.5 W, 0.75 W,1 W,1.25 W) (b)Er,Cr:YSGG induced photoacoustic streaming with 5.25% NaOCl at different laser powers 0.25 W ,0.5 W, 0.75 W,1 W,1.25 W. Twenty-four samples are used for current study. The samples were arbitrarily divided to four groups (n=6) as follows : (A) conventional irrigation with 5 ml of 17% EDTA, (B) passive ultrasonic irrigation with 5 ml of 17% EDTA, (C) Er,Cr:YSGG induced photoacoustic streaming with 5 ml of 17% EDTA, and (D) Er,Cr:YSGG induced photoacoustic streaming with 5 ml 5.25% NaOCl. After final irrigation 2% methylene blue dye injected into canal. The tooth was splitted transversally at the fourth millimeters from root apex with a diamond disc representing the apical third. The dye penetration measured using analytical software (measure

picture CAD-KAS Kessler Germany). ANOVA unstacked and Dunnttes test was used to analyze the result.

Results: The mean values of the percentage of dye penetration area in pilot study are :- group (a) resulted in (0.25 W= 70.60±0.33, 0.5 W=89.62±0.27, 0.75 W=79.42±0.35, 1 W=73.19±0.16, 1.25 W=28.05±0.04), while group (b) resulted in (0.25 W=53.19±0.1, 0.5 W=66.55±0.2, 0.75 W=69.77±0.2, 1 W=25.94±0.11, 1.25 W=19.01±0.05). The result of pilot study showed that the optimum power for Er,Cr:YSGG laser with 17% EDTA was 0.5 W, while with 5.25% NaOCl was 0.75 W. The obtained result of the study groups (A) 20.79±0.47, (B) 34.54±0.18, (C) 85.98±1.09, (D) 69.78±0.55. The Percentage of dye penetration in Er,Cr:YSGG laser with 17%EDTA was significantly high at 0.5 W power followed by Er,Cr:YSGG laser with 5.25% NaOCl at 0.75 W which also showed a distinct Percentage of dye penetration while ultrasonic activated group result in less Percentage of dye penetration than both Erbium groups.

Conclusion:

Short pulsed Er,Cr:YSGG (60 µs , 5 Hz , air and water off) with 17% EDTA using photo induce photoacaustic streaming technique proved effectively for activation of irrigant in endodontic treatment in smear layer removal at 0.5 W.

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List of Abbreviations

Abbreviations	**Term**
ANSI	American National Standards Institute (ANSI)
CO_2	Carbon dioxide
CW	Continuous wave
ºC	Degree Celsius (unit of temperature)
Er,Cr,:YSGG	Erbium, chromium:yttrium–scandium–gallium–garnet
E	Energy
Er:YAG	Erbium-doped:Yttrium, Aluminum, and Gernet
EDTA	ethylene diamine tetraacetic acid
FDA	Food and Drug Administration
Hz	Hertz (unit of frequency)
HA	Hydroxyapatite
J/cm²	Joule per square centimeter (unit of energy density)
KTP	Potassium titanyl phosphate
KHz	Kilo hertz
LITT	Laser interstitial thermotherapy

LLLT	Low Level Laser Therapy
mJ	Milli Joule (unit of energy)
mW	Milli Watt (unit of power)
MIE	minimally invasive endodontics
µJ	Micro joule (unit of energy)
µm	Micrometer (=10^{-6} m)
µW	Micro Watt (unit of power)
ns	Nanosecond
nm	Nanometer (= 10^{-9} m)
Nd:YAG	Neodymium doped Yttrium –Aluminum Garnet
NiTi	Nickel Titanium
NaOCl	Sodium hypochlorite

Nd:YAP	Neodymium: yttrium, aluminum, and perovskite
PRR	Pulse Repetition Rate
PS	Photosensitizer
PUI	Passive Ultrasonic Irrigation
PIPS	photo-induced photoacoustic streaming
PAD	photo activated disinfection
SEM	Scanning electron microscope
W/cm²	Watt per square centimeter (unit of power density)

CHAPTER ONE

INTRODUCTION AND BASIC CONCEPT

Chapter one Introduction and basic concept

1.1 Introduction

The main goal in endodontic treatment is suppression of microorganisms of infected root canal systems using combination of biomechanical procedure with an antibacterial treatment to reach healing of the periapical tissue[1]. The achievement of the root canal management determined by an efficient chemical-mechanical preparation with a three-dimensional blocking of the system of root canal [2, 3]. After the chemical-mechanical preparation, a smear layer forms on the walls of the root canal consists of microorganisms and by-products and necrotic tissue [4]. Root canal irrigation solutions and medications are prevented from accessing the dentinal tubules by the smear layer [5]. Furthermore, the smear layer inhibits root canal sealer penetration into the dentinal tubules[6]. During mechanical chemical preparation, endodontic tools may not be able to reach the entire root canal system, particularly the irregular and accessory canals [7]. Along with this complex root canal system, the efficient removal of organic and inorganic tissue remnants elevates the success rate of endodontic treatment. These tissue remnants can be considered as a port of bacteria and reduce the entrance of intracanal medicaments into the dentinal tubules. Irrigation is the single way to access parts of the root canal wall that not be reached with mechanical equipment. Irrigation is a critical part of successful endodontic treatment as it perform numerous important chemical, mechanical and (micro) biological functions. The effect of irrigation on the smear layer attracted by most of the research on endodontic irrigation [8]. Ideal chemical irrigant should have bactericidal factor and act as a tissue solvent and lubricant in addition to physical flush for debris exclusion [9].

A mixture of two or more irrigant is vital for safe and effective irrigation because no single solution has totally desired effects [10].

Ethylene Diamine Tetra-acetic Acid (EDTA) was irrigant of choice for smear layer removal, assisted in the removal of the smear layer inorganic constituents , acting as an aide to irrigation [11]. EDTA decalcifies dentine to a distance of 20–30 µm in 5 min [12].

Sodium hypochlorite has a strong proteolysis activity, so it acts as a good aid during instrumentation. Debris and necrotic tissue dissolved by a complex biochemical procedure. Depend on the percentage of free chlorine the breakdown of the proteins into amino Groups will occur [13]. The unique concentration suggested by Dakin was 0.5%, but the concentration used in dentistry has been as high as 5.25% [14, 15].

Numerous progressions have been existing in endodontics field like hand- and engine-determined instruments and altered irrigating solutions [16]. Before the introduction of passive ultrasonic irrigation, syringe irrigation recognized as an active way of irrigation [17]. Endodontists and general practitioners are both familiar with this approach. The method involves injecting an irrigant into a canal through various gauge needles or cannulas, either passively or actively by moving the needle up and down in the canal space. Various studies have shown that irrigants have only inadequate effect beyond needle tip because of the dead water zone or air bubble in the root canal apical part, which prevent penetration of the irrigant apically [18, 19].

An ultrasonic unit for endodontic use for debridement of root canals, which intended by **Martin et al.** [20]developed and become available commercially. In contrast with sonic energy, the ultrasonic energy yields higher frequencies but with lower amplitudes [21]. Although studies on endosonic systems have indicated that root canals prepared ultrasonically

with UI devices are cleaner than canals made with a traditional root canal system alone, other studies have failed to establish the superiority of UI in cleaning and shaping procedure. These results recognized to the limitation in cleaning efficacy of the ultrasonic tip and the vibration motion inside the non-widening root canal space [22, 23]. Moreover, it is very hard during UI to control dentin cutting, and the shape of the prepared canal. Extremely irregular-shaped root canals as well as strip perforations were often produced [24]. UI not supposed as a substitute technique to conventional hand instrumentation. On the other hand, endodontic research suggests that using ultrasonics following root canal preparation is more promising [25].

Agitation or activation of root canal irrigants by lasers is a quite new conception in endodontic. The mechanism of interaction between dental hard tissue (enamel, dentine) and Erbium lasers family is explosive thermo-mechanical ablation or water-mediated ablation. The procedure that occurs with wavelengths between 2.7 and 3 μm and leads to expulsion of mineral particles with conservation of their mineral structure [26]. The laser energy absorbs by water within the dental hard tissues (hydroxyapatite crystal) water quickly expands and vaporizes. The pressure produced by the water expansion is extremely high (pressure stress) and overcomes the strength of the mineral matrix. This pressure stress origins Microexplosions that remove the hard tissue [27]. Recently, researchers have concentrated on irrigant activation by laser devices [28-32].

The newly introduced LAI method, PIPS (photon-induced photoacoustic streaming) pulses the laser light energy absorbed by the irrigants molecules using a very low power source (subablative). This energy transfer generates a series of forceful shock waves able to driving the irrigant across the whole system of root canal [33].

Previous experiments have found that PIPS helps to increase the cleanliness of the canal with a larger amount of open dentinal tubules than if the same irrigants used without PIPS [33]. The deep photoacoustic shock wave facilitates the three-dimensional movement of irrigation solutions. Unlike other agitation methods, the tip is just placed into the canal orifice without reaching the root apex [28]. Thus, the smear layer was removed by means of photomechanical flowing of the liquids where laser activation in coronal access of the root and not by thermal vaporization.

The effect of many components employed in distinct procedures could be one explanation for variances in laser effectiveness in endodontic therapy. comprising the delivery method, tip design, period of application inside the canal, the existence of an aqueous solution that would alter the laser beam's absorption and strength, and finally, the energy density transmitted [34].

1.2 Endodontic treatment

A. Root canal preparation

The key to successful root canal therapy is to obtain an accurate diagnosis followed by a detailed treatment plan; understand the morphology and architecture of the teeth; and completely debride, disinfect, and obturate the radicular space. Endodontic failure has been linked to the absence of one of these concurrent variables, according to previous study [35]. Root canal instrumentation allows for the exclusion of inflamed and necrotic pulpal tissues from the root canal, as well as shaping and widening the root canal to allow for adequate irrigation and obturation. Using hand or rotary files for instrumentation will result in the production of mineralized debris[36]. Variety of nickel-titanium (NiTi) endodontic tools have emerged in recent decades to allow effective and quick root canal preparation. Manufacturers

prefer to emphasis on developing an instrument with good safety and efficiency [37]. The goal of shaping was to maintain and develop a consistent funnel shape of the canal system from the coronal to the apical parts. It can refer to a procedural facility, particularly in the context of apical instrumentation. Despite individual tooth variations, a general understanding of dental anatomy and teeth morphology might aid in assessing the degree of apical expansion [38-40]. In this case, other parameters such as canal form and diameter play a role. Enlargement cannot be controlled specifically in the apical portion due to morphological differences. The use of minimal apical instrumentation lowers procedural mistakes as well as the adequacy of cleaning procedures [40-43]. If the apical size is less than 0.35mm, one of the consequences of poor apical cleaning is that irrigants solutions cannot be delivered apically[44]. According to certain studies, the increase in size of the canal apical portion denotes the irrigation technique as well as appropriate debris removal [45].

B. Irrigation

An essential part of effective chemomechanical preparation is the use of irrigating solutions. The main goal of irrigation solutions is disinfection, dissolve the pulp tissue, and to promote mechanical debridement of the canal by rinsing debris but there is no single irrigation that achieves all of these goals [25]. And therefore a widely used method is the successive use of sodium Hypochlorite and polyethylene solution bi-Amin four-acetic acid (EDTA) [46]. Despite its widespread use, traditional irrigation has proven insufficiently effective in eliminating smear layer and debris from canal irregularities [47], that is why there are so many irrigation systems has developed [48]. Canal anatomy and the system used in its delivery of irrigation solution determine if the irrigant reached to the apical part of root

canal [49]. Irrigation solution should be close contact the whole root canal dentin wall for optimum outcomes [46]. An important aspect of successful treatment is the irrigation chosen and how it is delivered and activated [48].

The primary goals of irrigation of root canal can be summarized as the following [50]:

• Irrigant flow to the root canal system as a whole and then to the canal orifice to come into direct touch with microorganisms/biofilm, waste, and tissue remnants, remove them, and lubricate the instruments. (This is the flow.)

• Irrigant refreshment on a regular basis to maintain a high concentration of its active component(s) at critical areas and compensate for their quick depletion (applied only to chemically active irrigants). (This is a chemical effect.)

• Detaching/disrupting microorganisms/biofilm, dirt, and tissue remains by applying force to the root canal wall (wall shear stress). (This is a mechanical effect.)

• Controlling the stream of irrigant within the boundaries of the root canal system and preventing it from extruding into the periapical tissues. (Safety) [51].

1.2.1 Root Canal Irrigants

There are different types of root canal irrigant [52]:

•Saline

•Distilled Water

•Sodium Hypochlorite (NaOCl)

•Chlorhexidine (CHX)

•Hydrogen Peroxide (H_2O_2)

•Chelator Solutions

o Ethylene di-amine tetra-acetic Acid (EDTA)

o Citric Acid

• Antiseptic Solutions

o BioPure MTAD (Mixture of Tetracycline, Acid, and Detergent)

o Tetraclean

• QMix (Combination of CHX, EDTA and a Surfactant).

• Herbal Irrigants

o Triphala

o Green Tea

o Morinda Citrifolia

1.2.1.1 Sodium Hypochlorite (NaOCl)

Sodium hypochlorite (NaOCl) is broadly utilized as the principal irrigant for root canals [53]. Due to its unprecedented activity against microorganisms

[54] and biofilm [55] and its special capacity to remove pulp tissue [56] and organic elements of the smear layer [57].When administered within the root canal, The organic substance in the root canal reacts with NaOCl. Pulp, dentin (canal wall, smear layer or debris) or biofilm all contribute to the loss of accessible free chlorine [58], causing in temperature increase, protein degradation [58], and variations in pH [59].

Despite its low therapeutic toxicity [59], NaOCl was highly caustic in vitro interaction with organic tissue [60] and at concentrations below 0.1% [61]. Selecting the concentration of NaOCl is commonly perceived as a trade-off between tissue injury in the event of accidental extrusion and cleaning effectiveness [62]. Clinically, concentrations ranging from 0.5 to 6% are recommended, although the clinical optimal concentration is quiet being debated [25]. NaOCl's cleaning performance (antimicrobial potential and tissue dissolution effect) increases with its concentration [63]. Higher concentrations, on the other hand, aid in the removal of further dental structures [64]; or it can be more injurious if accidentally distributed to the periapical tissues [65].

Refreshment recommended as an active way to prevent chemical materials from loss effectiveness of lower concentrations of NaOCl solutions [63], but this never proven. Refreshment also aid in preservation of the concentration of irrigant at the root canal wall boundary, optimizing NaOCl diffusion into tubules and lateral canals [66]. Intermittent Flush Form (IntFM) [67] occur in In a multiple refresh/activation interval procedure, in which refreshment combined with ultrasonic triggered irrigation (UAI).

The PH value of NaOCl ranging from 11-12, its toxicity, antimicrobial properties, and its ability to dissolve tissues decrease when the concentration of hypochlorite is reduced [68]. Studies exposed by Hülsmann and Hahn in

2000 [69] showed that the symptoms that patient experiencing from after extrusion of Sodium Hypochlorite outside the canal, which are severe pain with rapidly exaggerated swelling. Other studies had described the location where patients were admitted with a swelling in the area between the angle of the mandible and periorbital region with the formation of hematoma in the infra-orbital region [70]. Hypochlorite accident occurs typically due to false determination of working length, iatrogenic widening of apical constriction, lateral perforation, or wedging of the needle inside the canal during irrigation, so protections should be followed to prevent happening of such accidents [69].

1.2.1.2 Chelating agent/ EDTA

Ethylene diamine tetra acetic acid (EDTA) is one of the Chelating agents that are used to the smear layer removal from the root canal dentin walls of a fully prepared canal and to negotiate canals with small diameter [22]. The purpose of the aqueous chelating agent is to remove the smear layer during the root canal preparation protocol. EDTA is the one surfactant, which helps to reduce surface tension by increasing irrigation Potential for circulation and penetration [22]. The aqueous solution of 17% EDTA submerged into a prepared canal for one minute, shown to be removed the smear layer [71, 72]. Studies have been show that, interchanging between solutions of NaOCl and EDTA during root canal preparation reduces the accumulation of debris and results in cleaner canals [73, 74].

The removal of the smear layer, which believed to obstruct the dentinal tubules and lateral anatomy, is possible with an aqueous solution of (EDTA). If the smear layer removed, a strong compatibility between the obturation materials and the canal's dentin walls is possible [75].

1.3 Irrigation Devices and Techniques

Irrigants must come into direct touch with the whole surfaces of canal wall, particularly in small root canals apical portions. Many techniques used to ensure successful distribution[46]. In the history of endodontics, continuous attempts made to produce more active irrigation and activation systems for root canal irrigation [48]. These devices classified into two different groups, manual activation techniques and machine-assisted activation mechanism as seen in (Figure 1-1).

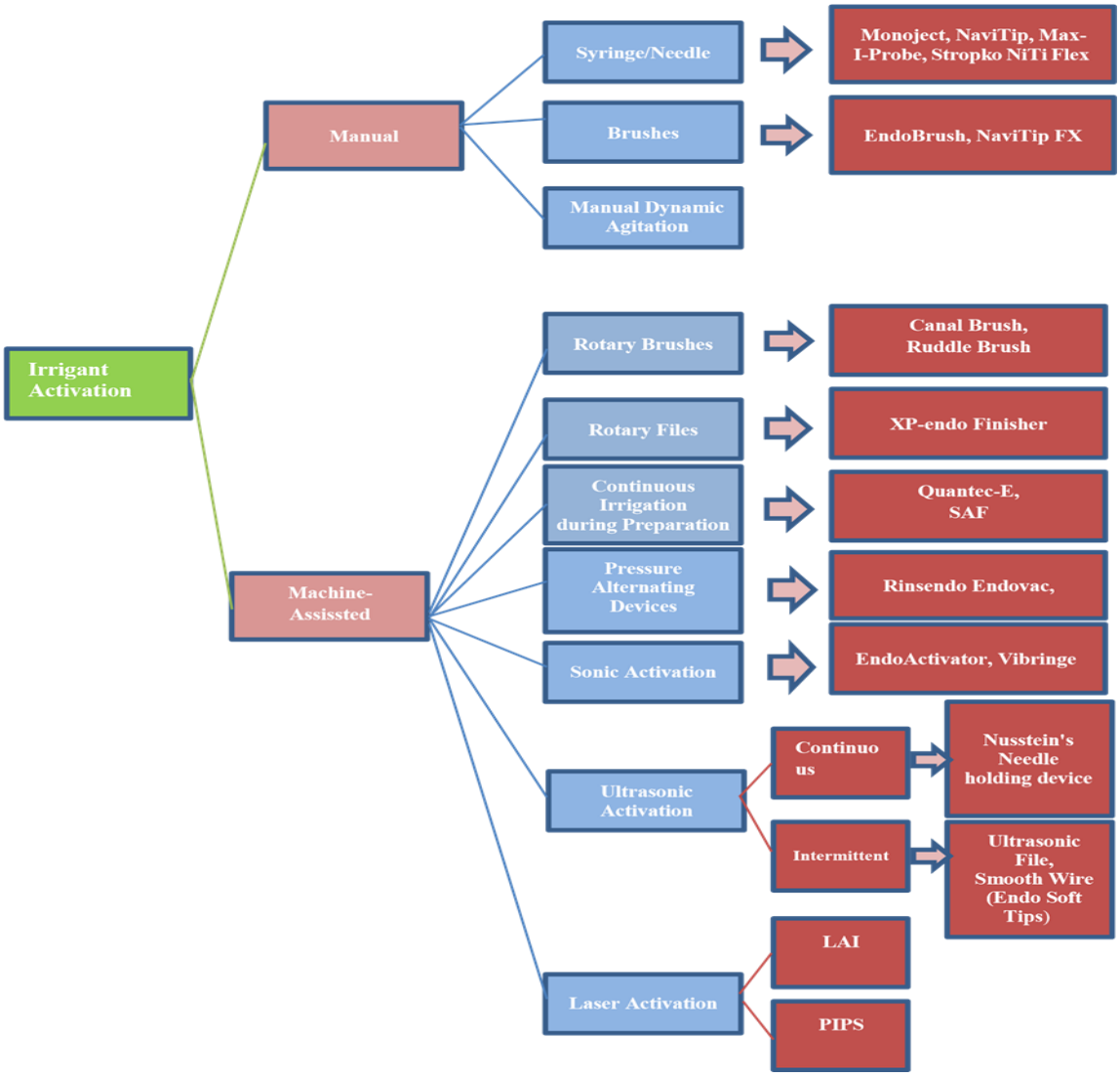


Fig 1-1 Simple diagram of the types of endodontic irrigant activation techniques [48].

1.3.1 Manual Activation Techniques

1. Syringe with Needles irrigation

The use of a syringe and needle to administer irrigant during a root canal operation goes back over a century [76]. It is still recommended for use in spite of its lengthy history and the advancement of new and new refined irrigation systems [77, 78]. The procedure include the use of an irrigant in a canal using variable gauge needles or cannulas, either passively or with activation by pushing the needle up and down in the space of the canal. A syringe with 5-ml recommended as a good cooperation for less recurrent refills and comfort of use. When paired with a fine irrigation needle, this syringe can reach a Flow Rate of at least 0.20– 0.25 mL/s [79]. Because of the high pressures that have built up within the syringe, a Luer Lock threaded fitting is often used to prevent needle detachment during irrigation [79]. Irrigation pattern of flow, rate of flow, depth of penetration and pressure on the walls and apex of the root canal greatly affected by irrigation tip gauge, and tip design [48]. Irrigation tip gauge can mostly assess the depth of the irrigation that has reached the internal of the canal; 27 gauge is the preferred size for regular endodontic procedures. A variety of changes made to the needle-tip design (Figure1-2) to develop efficacy and reduce risk factors. Open-ended tips force the irrigant solution from its end in the direction of the apex, thereby increasing the apical pressure within the root canal. Whereas closed-ended with side-vented tips produce more pressure on the root canal walls, thus generating a hydrodynamic activation of the irrigation and reducing the risk of extrusion of the irrigation solution to the periapical area [80].

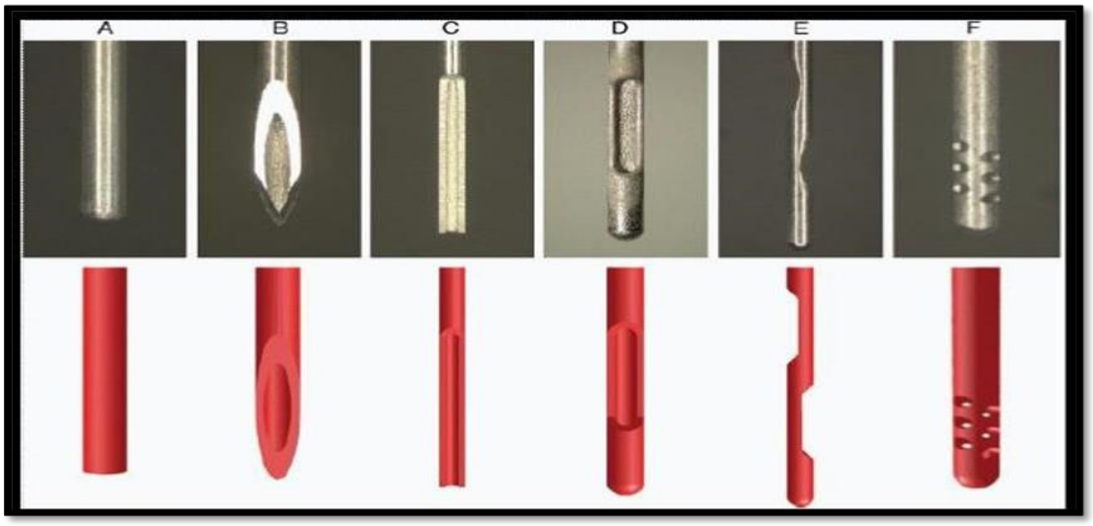


Fig 1-2 Needle-tip designs (A) Flat open-ended needle (B) Beveled open-ended needle. (C) Notched open-ended needle. (D) Closed-ended with side vent needle. (E) Closed-ended with double side vents needle (F) Closed-ended with multivents needle [80].

2. NaviTip Fx

A 30-gauge irrigation needle with a brush is the NaviTip Fx (Figure 1-3). Brush is a tool used to clean the canal walls and agitate the root canal irrigation system. As opposed to brushless NaviTip needle, the coronal third of treated root is cleaner. On the other hand, the variances in the apical and middle thirds were not statistically significant [81]. Because of its radiolucent nature, NaviTip FX brushes can dislodge anomalies in the canal due to friction, making it difficult to distinguish radiographically even with the assistance of a surgical instrument Microscope [48].

Fig 1-3 NaviTip FX needle tip [82].

3. Manual Dynamic activated Irrigation

According to research, moving the master cone gutta-percha (well fitting) to the instrumented canal in brief 2-3 millimeter stroke up and down will cause efficient hydrodynamic motion, which greatly improves endodontic irrigation displacement and exchange. This was done by the research of Huang et al. and McGill et al. in the year 2008 [83, 84]. Manual dynamic irrigation is considerably more effect than automated dynamic irrigation and static irrigation, according to these studies:"RinsEndo; Duerr Dental Co, Bietigheim-Bissingen, Germany's" [85].

1.3.2 Mechanical activation techniques

1. Sonic irrigation

The EndoActivator system is a sonically driven canal irrigation system that developed more recently (Figure1-4). It be made of a movable handpiece and three different styles of interchangeable rubber tips. These tips said to

be strong and flexible, as well as resistant to cracking. They not cut into dentin because they are smooth. The tip vibrates synergistically when used in conjunction with running the tip in short vertical strokes up and down. It results in a controlling hydrodynamic occurrence. This will operate at a rate of 10,000 cycles per minute (cpm). It has shown the ability to debride deep root canal anatomy, remove the smear layer, and dissolve biofilm Clusters inside curved channels [86].

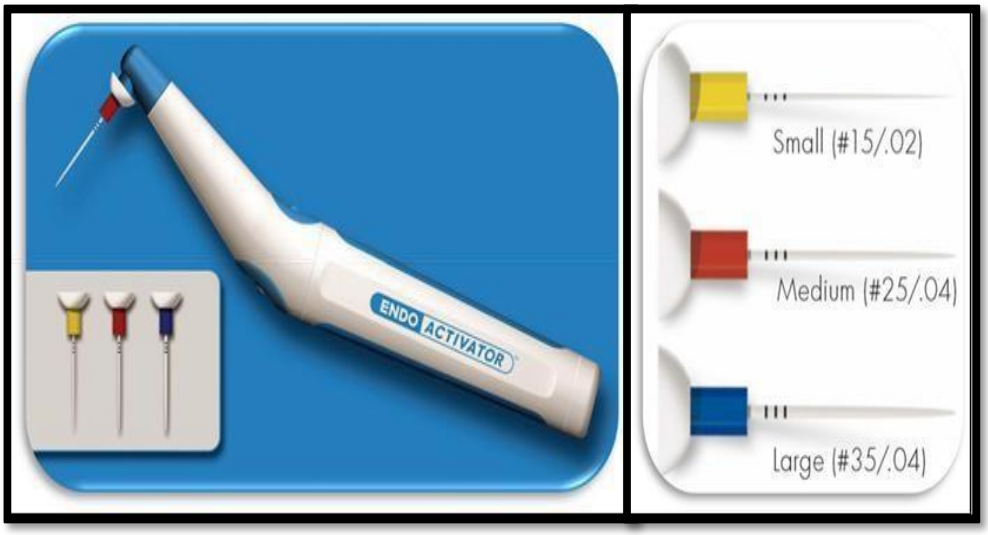
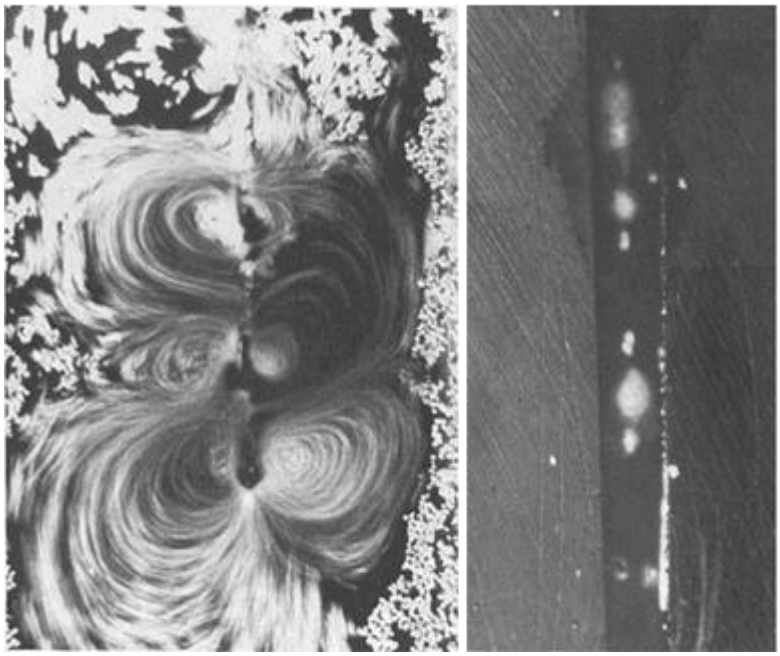


Fig 1-4 EndoActivator handpiece and tips [22].

2. Ultrasonic irrigation

Ultrasonic instruments first introduced in periodontics since 1957 by Richman [87]. In 1980, the endodontic ultrasonic unit was used as a form of debridement of root canals, developed by Martin et al. [20] and became commercially viable. Martin and Cunningham [88]have assigned Ultrasonic instrumentation's success in the relationship between ultrasonic energy and irrigation solution. This mechanism called the "synergistic method" by the researchers. When the irrigating solution is ultrasonated, it achieves its successful biological-chemical effects. The main effects of ultrasound, according to the scientists, are cavitation and acoustic streaming (Figure 1-

5). As ultrasonic energy produces a bubble that expands to a definite size then bursts, it said to be transient cavitation. This collapse causes a vacuum pressure that cleans canal anomalies and destroys microorganisms. Resonant or steady cavitation refers to the oscillatory action of an ultrasonic device that actively agitates the irrigating fluid. Physical energy dispersal that refers to physical acoustic (sound wave) streaming mutual with these effects of cavitation. This acoustic streaming, according to the manufacturer, improves cleaning and decontamination. After an ultrasonic wave introduce into a liquid, it will produce negative pressure, causing the liquid to fracture (cavitation). Cavitation produces bubbles, which oscillated with the projected ultrasonic waves. The bubbles become larger and more brittle as the ultrasonic waves proceed, finally crashing in a powerful implosion. Shockwaves with high-power emitted by the implosions, which dissipate at a rate of 25,000–30,000 times per second (25–30 kHz).



(a) (b)

Fig 1-5 (a) A free-moving file with acoustic streaming generated around it and (b) within simulated root canal hole[89].

3. Rotary instruments

XP-endo Finisher (FKG, La Chaux-de-Fonds, Switzerland) (Figure1-6) is a universal NiTi-based instrument with several properties that make it to enter the walls untouched by the circular files used throughout the canal instrumentation, which is used to scrape the walls. In addition, these files induce turbulence of the irrigant solution, leading to an improvement in its antimicrobial properties [90].

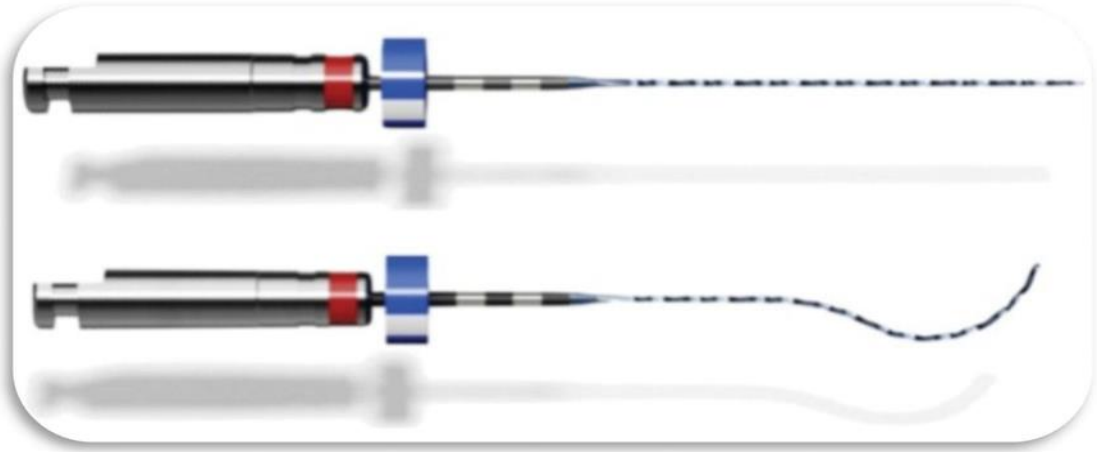


Fig 1-6 XP-endo Finisher [90].

4. Irrigation Pumps from EndoStation/VATEA

The SAF (Self-Adjusting File) has a polyethylene tube attached to a freely rotating hub, permitting the irrigant to pass into the hollow file and into the root canal. EndoStation or VATEA irrigation pumps used to inject the irrigant into the tube. The VATEA is a self-contained pump with a 500 ml fixed irrigant pool that runs on a rechargeable battery. The EndoStation is a complex all-in-one system which can used in rotary or reciprocating file techniques with a standard handpiece, or in the SAF style with a distinctive isolated handpiece with an RDT head (Figure 1-7) that allows for continuous irrigation. The EndoStation's irrigant container is an external bottle from

which the irrigant is drawn into the tube and into the connected file by a peristaltic pump [50].

Fig 1-7 three heads of RDT handpiece. (a) Handpiece head RDT3 which can used on a variety of handpieces. (b) A 1:1 NSK gear/adaptor connects the RDT3-NX handpiece head to the X-smart endomotor. (c) Rotating hub on the SAF that connected an irrigation tube. The SAF has a rotating hub that connects to the irrigation tube, allowing irrigant to flow from the irrigation pump to the hollow file [50].

5. The EndoVac Organization:

The Master Delivery Tip, MacroCannula, and MicroCannula are the three components of the EndoVac apical negative pressure irrigation system (Figure 1-8). The Master Delivery Tip supplies the irrigant and evacuates it instantaneously. The MacroCannula used to suction irrigant from the chamber to the coronal and middle regions of the canal. Tubing connects the MacroCannula or MicroCannula to a dental unit's high-speed suction. The

irrigant syringe is connected to the Master Delivery Tip, and the evacuation hood is connected to a dental unit's high-speed suction by tubing [91].

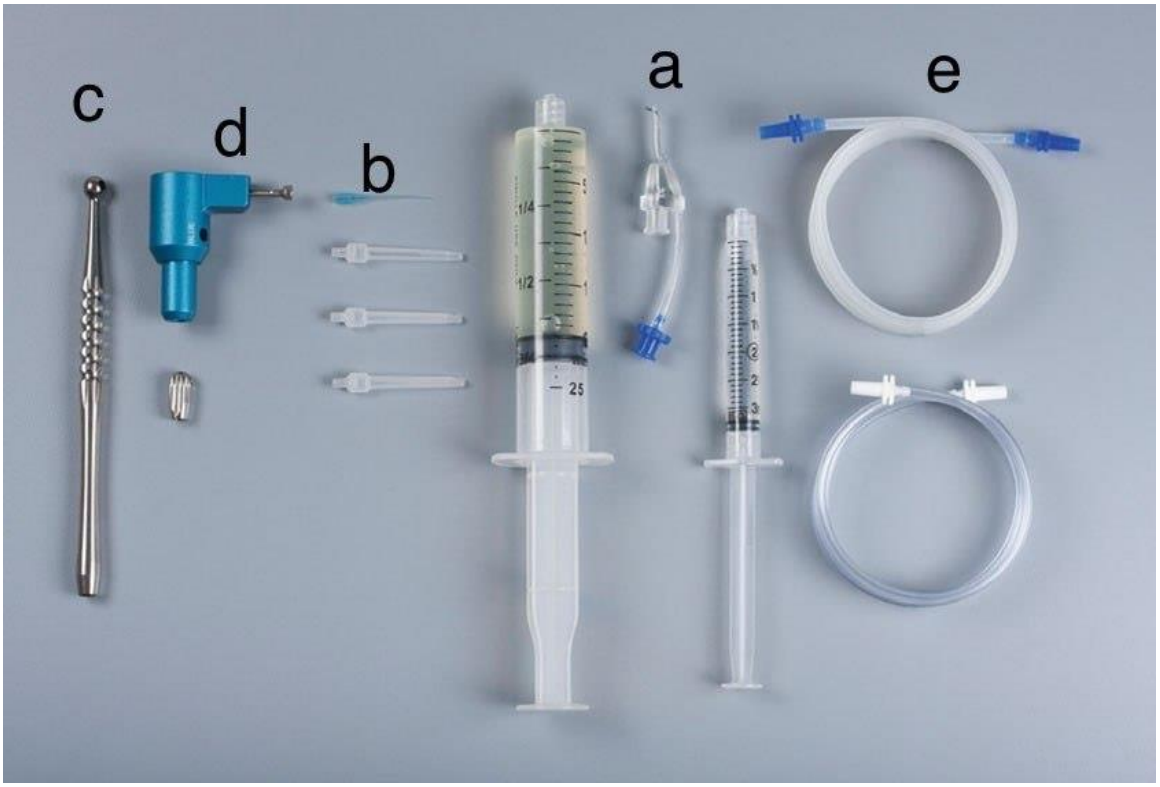


Fig 1-8 The EndoVac device consists of three parts: (a) the Master Delivery Tip (MDT), which provide accommodations of various sizes irrigant-full syringes, (b) the macrocannula, which is connected to (c) the autoclavable aluminium handpiece, and (d)Multiple Endovac adaptar. The macrocannula, microcannula, and MDT are all bound by clear plastic tubing (e) [50].

6. The RinsEndo System:

The RinsEndo system using technology of pressure-suction to irrigate the canal (Figure 1-9). Its parts are a handpiece, a 7 mm outlet opening cannula and an irrigant holding syringe. A dental air compressor powers the handpiece, which has a 6.2 ml/min irrigation rate. The unit draws 65 ml of the rinsing fluid from the attached syringe and with an adapted cannula transfers it to the root canal at a frequency of 1.6 Hz. The used solution and air suctioned out of the root canal and immediately combined with a fresh rinse

solution during the suction process. About 100 times per minute, pressure-suction processes change [48].

Fig 1-9 The RinsEndo system [84].

7. Photo Activated Disinfection:

The theory of photoactivated disinfection (PAD) has recently developed in endodontic irrigation to minimize or remove remaining bacteria developed in the root canal. The technique of PAD produces cytotoxic organisms by combining a low-intensity visible light and non-toxic pigment called a photosensitizer (PS) in the presence of oxygen. The PS molecules attached to the bacterial membrane. The release of singlet oxygen, which causes the bacterial cell wall to break down and kills the cell wall bacterium, is aided by irradiation of light at a wavelength equivalent to the PS's maximum absorption [92, 93].

8. Laser activated irrigation (LAI):

The use of lasers in endodontics for agitation or activation of root canal irrigant is a relatively recent phenomenon. Studies have reported that laser activation of widely used irrigants (LAIs) has resulted in statistically more successful elimination of debris and smear layer in root canals relative to conventional techniques (CI) and ultrasound (PUI) [32, 94].

Recently, researchers have concentrated on irrigant activation by laser devices [28-32]. Photon-induced photoacoustic streaming (PIPS), a new LAI process using a very low power source (subablative), pulses the laser light energy which absorbed by the irrigant molecules. This energy transfer generates a sequence of fast and violent shock waves able to pushing the irrigant through the entire root canal structure with great force [33, 95].

PIPS has been shown in previous studies to better clean the canal wall and a larger number of dentinal tubules open than when the same irrigants utilized without PIPS [33]. The three-dimensional flow of irrigation solutions aided by the intense photoacoustic shock wave. Unlike other techniques of agitation, the tip not inserted into the root apex, just placed into the canal orifice (Figure1-10) [28].

The effect of several factors used in different procedures, such as the delivery procedure, the application time in the canal, design of the tip , the presence of an aqueous solution which affect the laser beam absorption and the laser's strength, and, ultimately, the energy density transmitted, could explain variations in laser effectiveness in endodontic therapy [34].

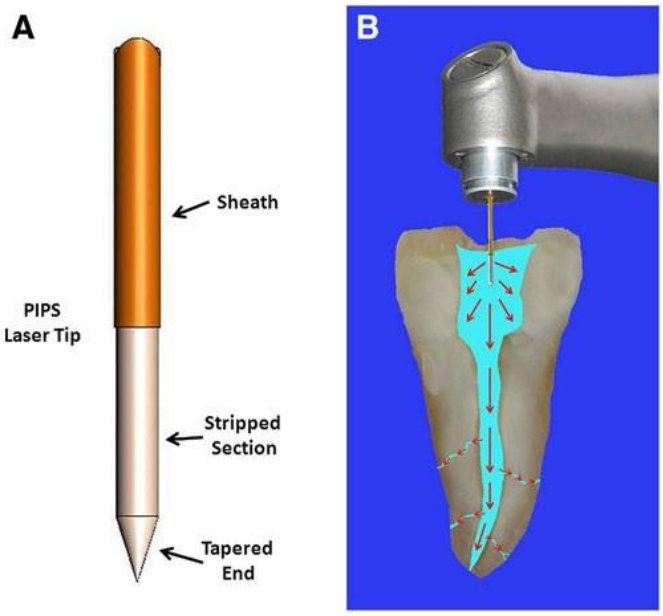


Fig 1-10 A picture view of the photo-induced photoacoustic streaming (PIPS) tip and its arrangement, with a stripped sheath to further disperse shockwaves across the root canal system (A) The PIPS is only used in the coronal part of entry, not in the canal, and it is responsible for supplying shock waves (B)[29].

1.4 Laser fundamentals

LASER: is an abbreviation of Light Amplification by Stimulated Emission of Radiation". Light is a type of electromagnetic energy that exists in the form of waves at a constant speed. A photon is the fundamental unit of radiant energy [96]. Amplification means increasing the intensity of light [97]. The electomagntic spectrum (Figure1-11) is extended from radio waves thousands of meters to gamma rays with wavelengths of 1×10^{-12} m [98].

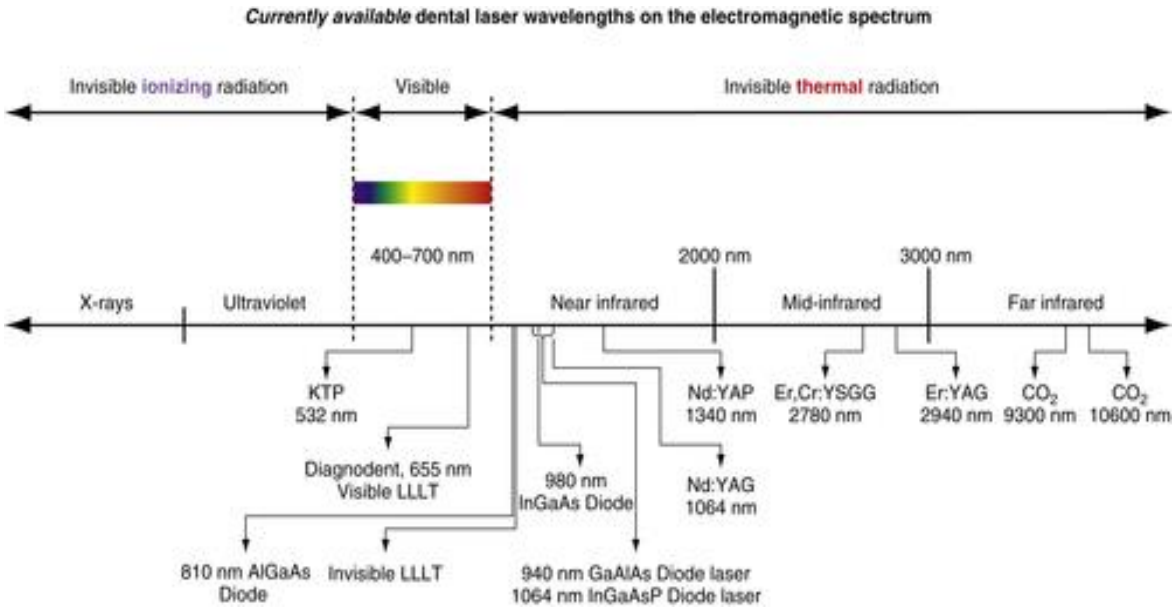


Fig 1-11 Part of electromagnetic spectrum separating the ionizing, measurable component from the nonionizing portion [98].

1.4.1 Components of the Laser System

Every LASER involves three basic components (Figure 1-12) these are:

1. Lasing material or active medium.

2. External energy source or pumping mechanism.

3. Optical resonator.

The active medium consists of molecules, or compounds,

The active medium of a laser can be: (1) a container of gas, such as carbon dioxide (CO2) gas in a CO2 laser,(2) a solid crystal, such as a crystal of yttrium, aluminium, and garnet (YAG) in an erbium (Er) YAG or a neodymium (Nd) YAG laser; 3) a solid-state semiconductor, such as the semiconductors used in diode lasers [98]. The active medium surrounds by a flashy bulb strobe unit, electrical circuit, electrical coil, or other like source of

electricity used as an excitation source, and pumps energy into it. As this pumping process injects energy into the active medium, the energy absorbed by the electrons in the active medium's outermost shells. These electrons expended a certain amount of energy in order to enter the next shell, that is at a higher energy level[98]. A "population inversion" happens if there are additional electrons from the active medium in the higher energy density shell further away from the nucleus than in the ground state. The energy released in the form of a photon when the electrons in this excited state coming back to their resting state. This known as spontaneous (rather than stimulated) emission. The laser cavity completed by two parallel mirrors, one at each end of the optical cavity, or in the case of a semiconductor diode laser, two polished surfaces at each end. These polished surfaces or mirrors act as optical resonators, bouncing waves back and forth and aiding in collimatization and amplification of the generating beam. A focusing lenses, cooling system, and other coordinating mechanisms round out the mechanical constituents[98].

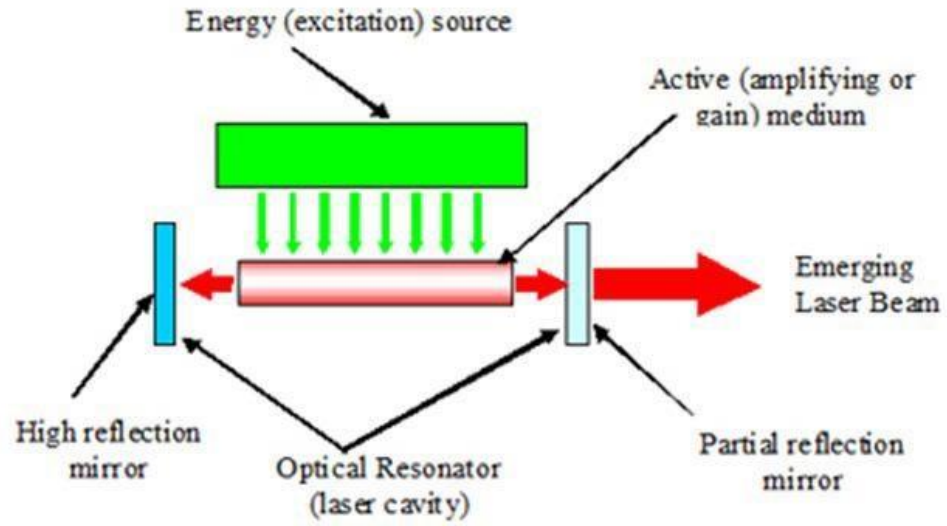


Fig 1-12 Basic components of the Laser System [99].

1.4.2 Properties of laser light

1. Coherence: It mean that all the photons coming out of laser system are in the same phase, i.e. they are coordinated in time and space. This property produces a form of specific focused electromagnetic energy. This property measures the capacity of the waves to interfere with each other, so two coherent waves can combine to yield destructive or constructive interference, depending on their phases and meeting points [100].

2. Collimation: All the light rays or waves are traveling in specific direction, parallel to each other. So laser can travel to long distances with smallest divergence [100].

3. Monochromaticity: Laser beam usually has a single wavelength (may be visible or invisible). This property shows the specificity of the wavelength of laser beam [100].

4. Focusability: The laser has precise focusing beam that can be in a very small spot size [100].

5. Brightness (intensity): it is the power of the laser beam divided by the cross section area of the beam, given in watt per square centimeter (W/cm^2). It measures the amount of energy that is applied to a specific region within a specific duration[100].

1.4.3 Mode of operation

As a function of time, there are two ways that dental lasers devices can emit light energy: (1) constant on or (2) pulsed on and off [101]. For supplying energy to the target tissue, pulsed lasers may further separated into gated and free-running modes. As a result, three distinct emission modes defined:

1. Continuous-wave mode: The beam emitted at a single power level for the duration of the operator's foot turn depressing.

2. Gated-pulse mode, this type of laser characterized by brief fluctuations in laser energy, like blinking light. By opening and closing a mechanical shutter in front of the continuous-wave emission's beam direction, this mode formed. Surgical devices that function in continuous-wave mode have this gated-pulse capability. Some instruments can generate pulses as short as microseconds (μsec) or milliseconds (ms). Peak powers of 10 to 50 times those of continuous-wave intensity measures can attained, with minimal tissue charring. These ultra-short pulses are possible because to computer-controlled shutters in more recent systems. Manufacturers have developed the terms "super pulse" and "ultraspeed" to designate these short pulse durations. [98].

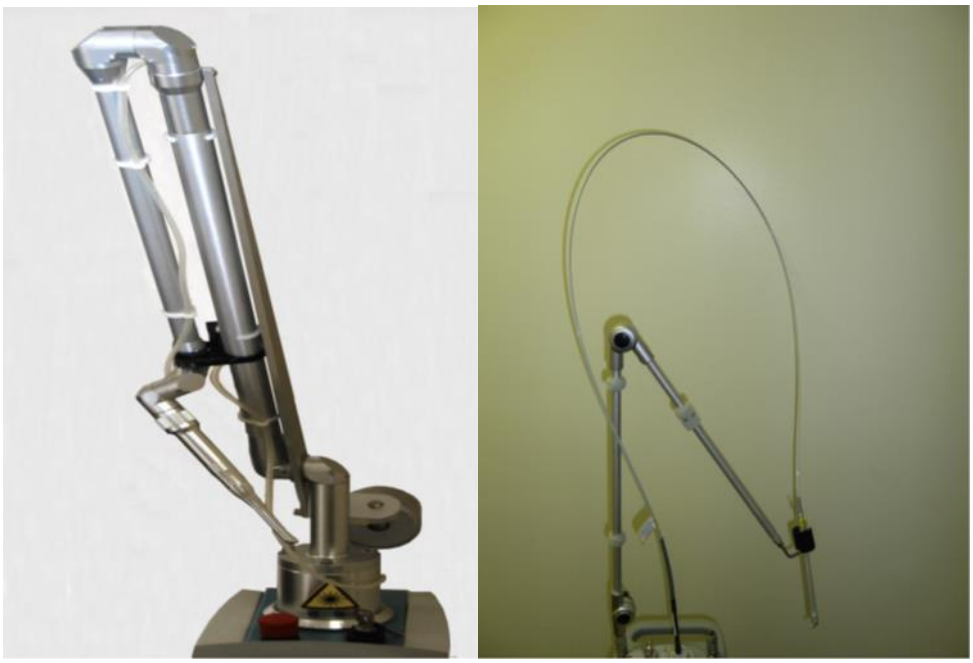
3. True pulsed mode, which is also known as free-running pulsed mode. Laser light with high peak energies normally released for microseconds, after that a considerable period of time when the laser switched off. For example, in a free-running pulsed laser with a pulse length of 100 seconds and pulses emitted at 10 per second (10 Hz), the energy at the surgical site is present for 0.01 percent of a second and absent for the other 99.99 percent of the time. In free running pulsed systems, the active medium pumped by a fast strobing flash bulb. With each pulse, high peak outputs in the hundreds or thousands of watts delivered. Because the pulse length is limited, the tissue's average power is limited. Continuous-wave or gated-pulse outputs are not possible on free-running pulsed machines. The pumping system inside the laser cavity prevents the laser from working [98]. A shutter outside the laser cavity causes gated-pulse lasers to pulse. Pulse durations in the nanosecond (one billionth of a second) and picosecond (one-trillionth of a second) ranges used in medical and science laser instruments. Although large peak powers can

generated, typical pulse energies measured to be low, allowing for more surgical precision. Certain instruments may generate a single pulse [98].

1.4.4 Laser Delivery Systems

The delivery of laser energy to the surgical site should be ergonomic and accurate [101]. Small, flexible fiberoptic systems with bare glass fibers transfer laser energy to the target tissue in KTP, diode, and Nd:YAG lasers, for example (Figure1-14). Water, a main constituent of conventional glass fibers, absorbs erbium and CO_2 laser photons, preventing them from passing through. As a result, erbium and CO_2 systems constructed with wavelength-transmitting fibers, semiflexible hollow waveguides, or articulated arms are becoming more common (Figure1-15A, B). In some of these devices, small quartz or sapphire tips connected to the laser device for interaction with target tissue employed, whereas noncontact tips used in others. Water spray is included with the erbium lasers to keep hard tissues cool [98].

Fig 1-14 the bare fiber, a handpiece, and a disposable tip used to create an accumulating fiberoptic delivery system [98].



A. B.

Fig 1-15 A, CO_2 lasers and some erbium devices represented by an articulated-arm delivery mechanism. B, A CO_2 laser's hollow waveguide delivery method [98].

1.4.5 Contact and out of contact method

All traditional dental instruments, whether hand or rotary, must physically contact the tissue handled, providing immediate guidance to the user. In and out of touch with the patient, dental lasers can employed. To scrape small quantities of granulomatous tissue or cure an aphthous ulcer, merely put the fiber tip into a periodontal pocket. The beam aimed at a point that is some distance away in noncontact mode. This modality is suitable for a variety of tissue contours, but since tactile sensitivity is lost, the interaction of the laser energy with the tissue must be carefully monitored by the surgeon. Nd:YAG, CO_2, diode, and erbium dental lasers all have a distinct focusing beam that can be either a laser or a regular light. The focusing beam travels coaxially through the fiber or waveguide, allowing the user to see exactly where the laser energy will arrive. [98].

1.5 Laser tissue interaction

The principal oral tissue elements include water, pigment, blood contents, and minerals, and different laser wavelengths have varying absorption coefficients. Based on the structure of the target tissue, laser energy may reflected, absorbed, transferred, or dispersed. Chromophores are the main absorbers of specific laser radiation [102, 103]. Water, which found in all biologic tissue, absorbs the two-erbium wavelengths mostly, followed by the two CO_2 wavelengths. Water, on the other hand, permits the transmission of shorter-wavelength lasers (e.g., diode, Nd:YAG). Water and carbonated hydroxyapatite make up tooth enamel. The CO_2 wavelength readily absorbed by the apatite crystal, while the erbium wavelengths are absorbed to a lesser extent. The shorter wavelengths have little impact on it. Hemoglobin and other blood elements, as well as pigments like melanin, absorb various amounts of diode and Nd:YAG laser wavelengths.

The following aspects must be considered when determining the tissue interactions caused by a specific laser system [104]:

1. Each laser wavelength affects the target tissue's integrated constituents: water content, tissue color, chemical composition, and vascularity.

2. Whether transmitted in contact or noncontact with the tissue, the diameter of the laser spot on the tissue, or spot size, can emit a given amount of energy per square millimetre of tissue. This stated as energy density or fluence. Spot size and fluence have an inverse relationship: the smaller the spot size, the higher fluence. The energy density more than doubled when a beam diameter of 200 μm compared to a beam diameter of 300 μm at the similar performance setting. Thermal transfer from the laser to the tissue would greatly increase due to the reduced spot size, resulting in a proportional increase in heat absorption in that smaller region. If the beam has divergence,

shifting it away from the tissue reduces energy density by increasing the diameter of the beam.

3. The rate of tissue temperature rise affected by the length of time the beam allowed striking the target tissue. As a result, two distinct features of laser operation must observed:

a. The number of pulses per second is the repetition rate of the pulsed-laser emission mode. The frequency of repetition expressed in Hz.

b. Hand speed: the speed with which the laser ripped through tissue. Rapid passage of the laser through the surgical field can cause the tissue to absorb insufficient energy. On the other side, moving the laser through the surgical zone too slowly can cause too much heat damage to the tissue.

4. The rate of vaporization can also influenced by cooling the tissue with a water or air spray. The laser practitioner must be aware of these variables before beginning therapy. At this point, you can choose the wavelength, beam diameter (spot size), focused or defocused width, Hz frequency, as well as the amount and technique of tissue cooling. All of these criteria should combined in the same way to ensure a smooth operation and a positive result.

1.5.1 Tissue effect on light

The light energy from a laser will interact with the target tissue in four different ways, depending on the optical properties of the tissue (Figure 1-16) [105].

1) Reflection: This is essentially the beam diverted away from the target tissue by reflecting off the surface. In a narrow beam, the reflected light can keep its collimation or become more diffuse. If the distance between the handpiece and the laser beam extends, the laser beam becomes more divergent. At wavelengths greater than 3 m, certain lasers' beams will still

provide enough energy. Since the energy can diverted to an unexpected target, such as the eyes, this reflection may be harmful. This risk of mistargeting is a large distress in laser activity; As a result, everyone in the dental management room needs to wear wavelength-specific protection glasses with side shields. The association of a CO_2 laser with a patient's titanium implants is an example of reflection. The reflected CO_2 laser energy from the implants could transferred to the dentist's eyes.

2) Absorption is the second interaction with tissue. The most favorable result is where the laser energy absorbed by the desired target tissue. The quantity of energy absorbed by a tissue determined by its properties, such as water content and pigmentation, as well as the wavelength of the laser. Absorption of laser light by the planned biologic tissue is therefore the main and favorable target of laser energy.

3) The third effect is that the laser energy transmitted directly through the tissue without affecting the target tissue. The wavelength of laser light has a significant impact on this effect. Water, for example, is comparatively “transparent” to diode and Nd:YAG wavelengths (does not absorb them), While the water in tissue fluids absorbs erbium and CO_2 wavelengths readily at the surface, energy transmission to surrounding tissues is restricted. Diode and Nd:YAG wavelengths pass through the sclera, lens, iris, cornea, vitreous humor, and aqueous humour of the eye before being absorbed on the retina.

4) Scattering of laser radiation, which reduces the expected energy, is the fourth tissue interaction. When using near-infrared lasers on healthy soft tissue, scattering is the most common occurrence. Scattering allows photons to change paths, resulting in greater absorption and, as a result, a higher likelihood of interfering with the dominant chromophore at certain wavelengths. The scattering of the laser beam may induce heat transfer to

tissue near the surgical site, raising the risk of damage from unintended laser effects. A beam that dispersed or deflected in various directions, on the other hand, may be useful for laser curing composite resin.

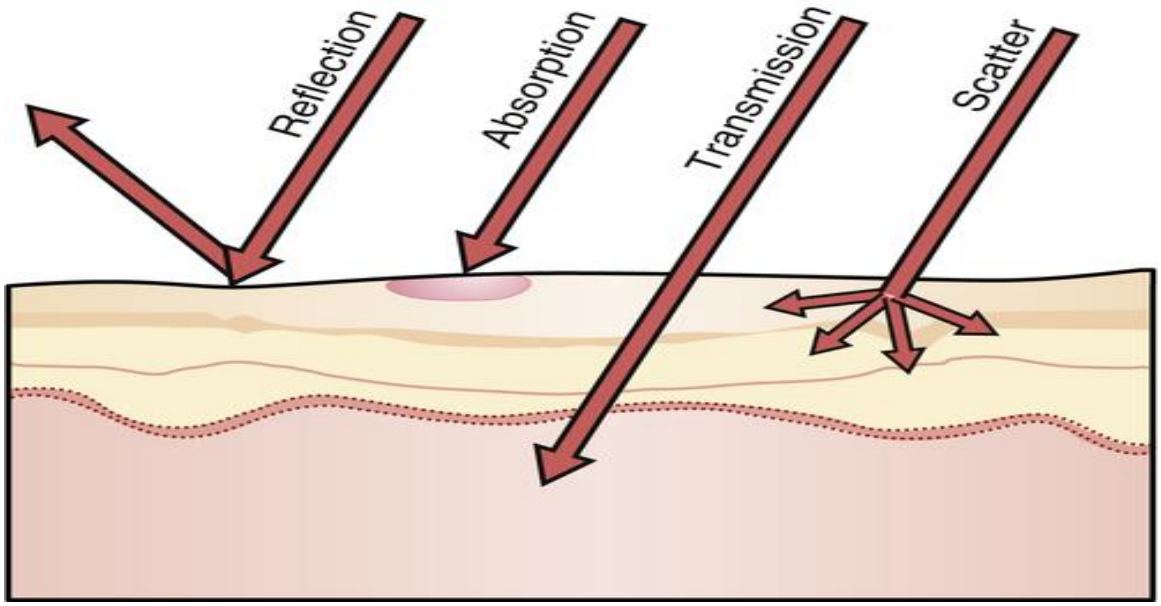


Fig 1-16 Four potential laser-tissue interactions [98].

1.5.2 Light effect on tissue

Generally Light effect on tissue is divided into (Figure 1-18) [106]:

A. Wavelength dependent interactions.

B. Wavelength independent interactions.

Further subdivisions explained for more details.

1.5.2.1 Wavelength dependent mechanisms

A. Photochemical Interaction

The photochemical interactions category based on scientific evidence that light can cause chemical effects and reactions within macromolecules and tissues. One of the most well-known instances is the energy release caused by photosynthesis. Photochemical reaction pathways play an important part in

photodynamic therapy (PDT) in the area of medical laser physics. Biostimulation often linked to photochemical interactions, though this not proven scientifically. Photochemical reactions occur at low power densities (usually $1W/cm^2$) and over extended exposure times extending from seconds to continuous waves. Suspicious laser parameter selection results in a scattering-determined radiation distribution within the tissue. Owing to their performance and great optical penetration distances, visible wavelengths (e.g. Rhodamine dye lasers at 630 nm) used in the majority of situations. The latter require if deeper tissue structures need to reach [107].

1. Photodynamic Therapy (PDT)

In this reaction, an exogenous photosensitizer, which activated by specific laser, is used. Collected with the tissue oxygen, they destroy the target tissue (e.g. malignant tumor). The photosensitizers are drugs, i.e. chemical compounds. They are stimulated only by specific wavelength light and needs an oxygen molecule to work [108]. The Photo-Activated Disinfection (PAD) is an example of this kind of interaction used in endodontic treatments. It activates some irrigants to relief single oxygen radical and rupture the bacteria cell membrane. This type is very effective in disinfecting the root canal system during endodontic therapy. It is also used for caries detection by spread over some pigments on the tooth which fluorescence when irradiated by laser and is also used in composite curing [109].

2. Biostimulation

Biostimulation happen at very low irradiances and belongs to the photochemical interaction group. Unfortunately, until now, the term biostimulation has missed scientific definition. Since the Hungarian surgeon Mester invited them at the end of the 1960s, the possible effects of particularly low laser powers (1–5 mW) on biological tissue have been a source of debate. Red or near-infrared light sources, such as helium–neon lasers or diode lasers, have shown to wound healing and anti-inflammatory effects [107].

This interaction uses very low laser powers, used to enhance the metabolism of the living cells and for that it is named Low Level Laser Therapy (LLLT). Mostly, it is limited to the near IR wavelength lasers in dental applications because of their high penetration depth on living tissues. It can heal the wounds rapidly, relief pain, increase collagen growth, and enhance the immune system[107], Therefore, it was very useful in treatment of TMJ arthritic disease[110].

The photons energy absorbed in cells or tissue and causes several effects on metabolism and signaling pathways within the cells. Molecular target can be cytochrome c oxidase (the absorption is in the near infrared region) or photoactive porphyrin. The cellular target is mitochondria with the effects of increasing adenosine triphosphate production (ATP), reactive oxygen species(ROS) modulation and cellular signaling initiation which may cause increase in both cell proliferation and migration, increase tissue oxygenation, optimize healing of chronic wounds , improve injuries, reduce pain and also affect the nerve injury [111].

B) Photo-thermal Interaction

It is a thermal interaction of the cellular molecule, happens because of laser beam striking a tissue, i.e. the light energy transformed to heat. It has several effects on tissue, produces by hyperthermia, coagulation, vaporization, carbonization, and finally melting (Figure 1-17). Its outcome depends on duration of exposure and the peak value of the temperature collected inside the tissue, it also depends on the cooling factors on the tissue such as the ability of the tissue and the blood circulation all over the area to disperse the heat [108]. The Normal body temperature is 37 º C [108].

Hyperthermia: It refers to the elevation of temperature on tissue directly above the normal level but without any damage or destruction. It occurs at 45 º C. This level might deactivate the non-sporulated bacteria at less than 50º C. At 50 º C, a reduction in enzyme activity happens accompanied with cell immobility [107, 108].

Coagulation: It is the process of protein denaturation at about 60ºC and beginning necrosis of the cells. It used to remove a diseased tissue. It looks as whitening on the tissue surface and is attended by hemostasis due to increase blood viscosity [108].

Vaporization: It starts when temperature of tissue raised to 100º C; the water on tissue vaporizes and causes tissue ablation by its expansion and explosion. This is the chief process in tooth ablation mechanism [108].

Carbonization: It happens when temperature raised to 200º C, a complete dehydration occurs. Carbone, which is the end product that positioned at the surface layer, absorb all the energy if lasing constant and work as heat sink, reason rapid spread to heat and sever collateral injury to the underlying tissue called tissue charring, it prevents ablation[108].

Melting: It happens when heat is raised outside 300º C; it depends on the target material [108].

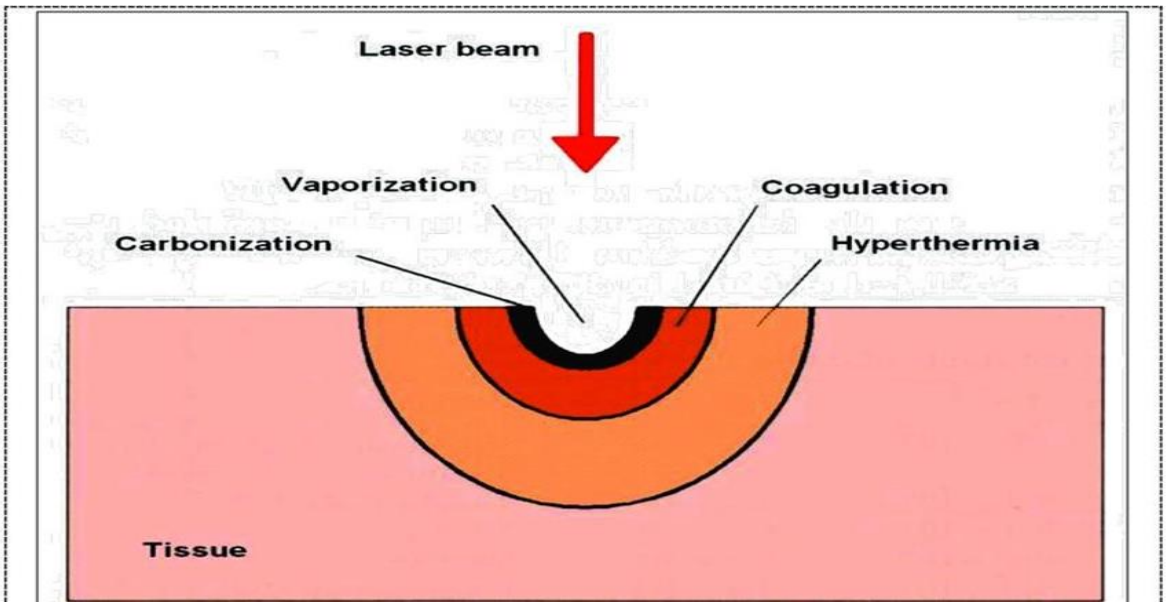


Fig 1-17 laser thermal effect on tissue[112].

C. Photoablation Therapy

It was defined as ablative photodecomposition, which means that when a substance subjected to high-intensity laser irradiation, it disintegrates. The average threshold values for this type of interaction are 10^7–10^8 W/cm^2 for laser pulse durations in the nanosecond range. The pulse energy determines the ablation depth, or the depth of tissue removal per pulse, up to a definite saturation point. The spatial parameters of the laser beam determine the geometry of the ablation pattern. One of the chief benefits of this ablation procedure is the accuracy of the etching method, its tremendous predictability, and the lack of thermal injury to neighboring tissue [107].

1.5.2.2 Wavelength independent mechanisms

I. Plasma – induced ablation

A phenomenon termed optical breakdown happens when obtaining power densities exceeding 10^{11} W/cm^2 in solids and fluids – or 10^{14} W/cm^2 in air. A single 30 ps laser pulse directed on an extracted human tooth using a mode locked and amplified Nd:YLF laser. A bright plasma spark pointed toward the laser source can easily see. When several laser pulses employed, the pulses' repetition rate causes a typical sparking noise [107].

II. Photodisruption

It uses the identical laser parameters of plasma – induced ablation. Plasma forming and shock wave production are two physical effects that typically accompany optical breakdown. Additional cavitation and jet formation occur if this happens within the soft tissue. Cavitation occurs when the laser beam focusing inside the tissue rather than on its surface. A gaseous bubble filled of water vapor diffused against the surrounding tissue. The cavitation collapse or rupture of this bubble due to adjacent solid boundary causes jet formation, and tissue ablation [107].

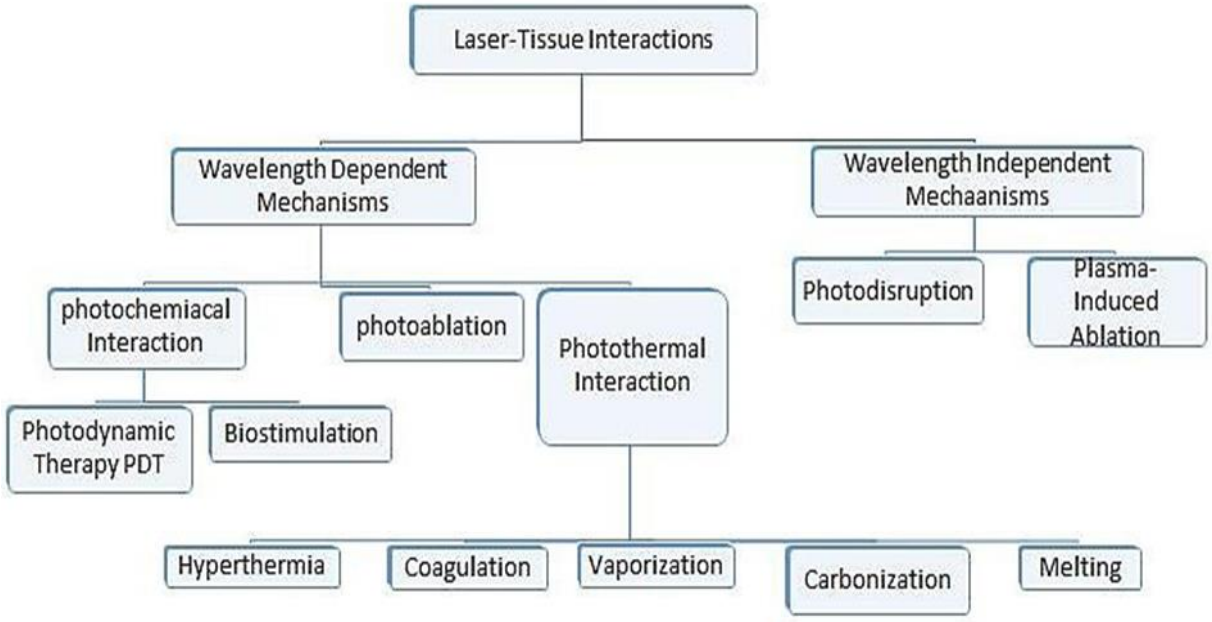


Fig 1-18 simple Diagram summarize the mechanisms of laser-tissue interactions[107].

1.6 Laser Safety Standards and Hazard Classification

Almost all laser safety guidelines taken the method of classifying lasers according to their hazard potential, which is dependent on their optical emission. The following step is to define control steps that are appropriate for the relative danger level. In other words, the laser categorized according to the risk it presents, and a standard series of control measures applied to each classification. In this way, do not need limits on the use of certain lasers that designed to ensure protection. This theory resulted in a variety of classification systems, such as the one used in the ANSI Z136.1 Safe Use of Lasers (1993) standard of the American National Standards Institute (ANSI).

The following are brief summaries of each laser class [107]:

– Lasers or laser devices in Class 1 do not pose a threat under standard operating conditions.

– Class 2 represents visible laser or low-power visible lasers devices that, although not usually posing a danger due to the usual human aversion reflex (i.e. blinking, eye twitch, etc.), If seen directly for an extended period, it may represent a risk (like many conventional light sources). During watching for an extended period is it essential, to wear safety glasses.

– The lowest level of lasers or laser devices, Class 3a, often necessitates the use of protective eyewear. These lasers would not hurt the eye if seen with the naked eye for limited periods (e.g., within the 0.25 s aversion reaction time), but they could be more damaging if seen through collecting optics or without the possibility of an aversion response (as for UV or IR radiation).

– Lasers or laser systems in Class 3b will cause a danger if seen directly. This involves looking at specular reflections within the beam. In most cases, Class 3b lasers do not emit a potentially dangerous diffuse reflection. Eye protection still needed.

– Lasers and laser devices classified as Class 4, which have diffuse reflections, as well as direct or specular reflections. These lasers have the ability to harm the skin and cause fires. Eye protection still needed.

1.7 Dental laser devices that are most widely used

Dental lasers classified as soft tissue lasers or hard tissue lasers based on how well they absorb tissue chromophores (Figure1-19).

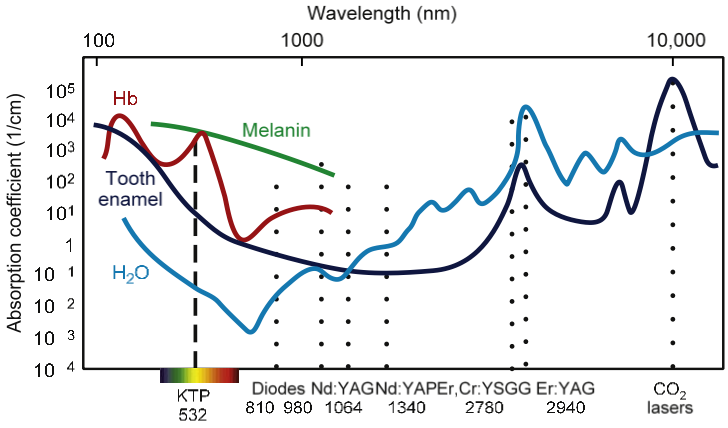


Fig 1-19 The prime oral chromophores' approximate absorption curves [98].

KTP laser

Since the early 1990s, KTP lasers have imported for dental use. It has a strong affinity for haemoglobin, making it suitable for clotting and bleeding control. Nd:YAG and KTiOPO4 crystals make up this laser. The first crystal is in charge of laser generation at a wavelength of 1064 nm, while the second is in charge of frequency repetition, resulting in the output of laser light with a half wavelength of 532 nm. When lasers in the visible-light field are incident on tissue, they exhibit optical phenomena such as absorption and diffusion, which occur in similar proportions. As a result, laser tissue contact will be less dangerous and have a lower penetration depth [112].

Diode Lasers

There are four different wavelengths available for semiconductor diode lasers:

- 810–830 nm
- 940 nm
- 980 nm
- 1064 nm

The wavelengths of 810 to 830 nm and 980-nm can used for nonsurgical periodontal treatment, with positive findings supported by research. Only a few existing studies have looked at the use or benefits of the 940-mn or 1064-nm diode wavelengths.

Diode lasers, like argon lasers, use fiberoptics to deliver energy in both contact and noncontact modes, depending on the process. Energy absorbed in hemoglobin and pigment (e.g., melanin) as diodes in this wavelength range are used. These wavelengths are useful because chromophores, or chemical substances that absorb light at a specific wavelength, are abundant in the infected periodontal pocket. The 980-nm wavelength absorbs more water than the other three-diode wavelengths, which could help with laser interaction inside the pocket. However, no solid evidence yet shown that better water absorption contributes to better clinical outcomes. Diode lasers also provide bactericidal and coagulation treatments [113-115].

With low settings and short application time, diode lasers can be utilized in continuous-wave mode (with energy emitted as a steady beam), or in gated-pulse mode (with energy emitted as a constant but interrupted beam, or pulsed at specific intervals) with higher settings and longer application time.

On some diode lasers, precise pulse length on–off time adjustments offered, allowing for larger pulse lengths, permitting higher power to delivered to the tissue for shorter periods, allowing the tissues to cool before receiving another energy pulse. This energy pattern keeps heat from building up and causing thermal collateral damage. Less collateral damage equals less post-operative pain for the patient.

Nd:YAG and Nd:YAP lasers

The Nd:YAG laser is a free-running, pulsed laser. Instead of a continuous beam, the laser light released in bursts of photonic energy. For contact or noncontact operations, this laser often employs a fiberoptic distribution system. The wavelength 1064 nm absorbed most strongly by melanin, less by haemoglobin, and just marginally by water. The Nd:YAG laser is bactericidal as well [116]. It also aids in hemostasis. Because it is a free-running pulsed laser, the Nd:YAG laser creates large peak power yet permits tissue cooling during the off time. A combination of higher millijoules (mJ) and fewer repetitions per second (i.e., hertz [Hz]) aids coagulation, while a combination of lower mJ and higher Hz aids decontamination. The active medium of the neodymium:YAP laser is an yttrium, aluminum, and perovskite crystal doped with neodymium. The near-IR laser energy is transmitted by bendable optical fibres of varying radius and ends up in a touch hand object[112].

Micropulsed CO_2 Lasers

The micropulsed 10,600 nm CO_2 lasers utilize the most up-to-date CO_2 laser energy production methods. The use of an articulated arm or a waveguide in a noncontact mode makes treatment easier. A 250-µm tip (the diameter of a #25 endodontic file) used to transmit laser energy into the periodontal pocket. Water and hydroxyapatite interact with this wavelength, and has a micrometer-level penetration depth. Inflamed tissue, like crevicular fluids and intracellular fluids, has a higher water content and is thus more sensitive to laser radiation. Fluids are photothermally heated and later vaporized, causing cell membranes to collapse, inactivation of the bacteria [117, 118] and dehydration happens when energy applied. CO_2 lasers previously emitted energy in a continuous-wave mode that could gated with later updates, but only with longer pulses and greater mJ. Such units' less modern equipment caused significant thermal disturbance in surrounding tissue, resulting in charring, and they could not use inside the periodontal pocket. The modern micropulsed CO_2 lasers allow for more precise energy management, allowing application inside the periodontal pocket both safe and efficient. These lasers are capable of higher peak power for ultrashort pulse durations and extended off periods. This enhancement allows for optimum thermal relief, resulting in less collateral damage and pain. In sulcular debridement, the mJ settings are significantly lower than in previous gated-pulse CO_2 technologies. As with any other application of a soft tissue laser, this technique necessitates the same level of caution: The laser should pointed away from the tooth's structure. The FDA recently approved a new CO_2 laser with a wavelength of 9300 nm for clinical use. To date, no research or reports on its usage in periodontal pocket treatment published.

Er:YAG

The Er:YAG laser said to be the first cavity-drilling laser. It has been widely used in dentistry as a substitute for traditional drilling instruments since the last decade of the twentieth century. This laser's active medium is an yttrium, aluminium, and garnet crystal doped with erbium atoms. The active medium's absorption spectrum is in the middle infrared at 2.94 μm, which coincides with the water molecule's absorption peak. It powered by an optical pumping source that looks like free-running flash-lamp bursts. The erbium laser operates in a pulse mode with a pulse width of microseconds. The properties of this device, as well as the program that controls it, provide the erbium laser operate in a pulse mode with a pulse width of microseconds. The properties of this device, in combination with software regulation, result in a thermal interaction with various tissue types that is below the tissue thermal relaxation time. The tissue touch handpiece and sapphire tips attached to optical fiber or articulated arms in this laser's distribution device. Both sensitive and hard tissues can be treated with the erbium laser [112].

Er,Cr:YSGG laser:

Erbium plus chromium–dopped yttrium-scandium-gallium garnet (Er,Cr:YSGG) lasers have wavelengths in the near infrared zone of the spectrum, 2780 to 2790 nm. These wavelengths used preferably on hard tissue but also can used on soft tissue. Erbium lasers family interacts with dental hard tissue (enamel, dentine) by explosive thermo-mechanical ablation or water-mediated ablation, that result to ejection of mineral particles with conservation of their mineral structure [26]. The laser energy absorbs by water within the dental hard tissue, rapidly expands and vaporizes. The water expansion created pressure that is extremely powerful (pressure stress) and

overcomes the power of the mineral matrix. This pressure stress produces Microexplosions that remove the hard tissue [27]. This phenomenon may have a possible impact on the improvement of RCT by removal of debris and smear layer when laser used in combination with the Irrigant [26]. As a result, the Erbium lasers are due to their affinity to water molecules that are present either as part of the dental hard tissue structure or as an irrigant solution can work on hard dental tissue by two different Mechanisms: thermo-mechanical ablation, also referred to as water-mediated ablation or by causing a cavitation reaction.

The Er,Cr:YSGG laser is a one-of-a-kind all-tissue laser that combines laser and water jet operation. The water spray aids in tissue cooling and increases laser absorption within tissue, allowing for clean and efficient cutting, shaving, contouring, and resecting of oral hard-tissue. It also has the capacity to accomplish a range of soft tissue laser techniques, including incision, excision, ablation, and coagulation. The Er,Cr:YSGG laser was useful in dentistry, especially in endodontic and periodontal procedures[112].

This laser system rated as a class 4 system, which means it produces high output power. These lasers have the ability to inflict damage to the operator's eye or skin, as well as a fire threat. It is recommended that extra precautions.

1.8 Laser applications in dentistry

The most Laser applications in dentistry are shown in (table 1-1) [119-121]:

Table 1-1 Most common dental laser applications.

Laser wavelength (nm)	Absorption	Dental use	Advantages	Disadvantages
Argon (488 nm and 514 nm)	Red pigments (melanin and haemoglobin) Camphoroquinon.	Soft tissue surgeries /curing of composite /power bleaching	.Excellent haemostatic ability. .It alter the surface chemistry of both enamel and root surfaces dentine, which reduces the probabilities of recurrent caries.	• Possibility of heat elevation in the pulp and on the adjacent tissues.
Diode * (810 nm,-830 nm and 980)	Pigment (melanin and haemoglobin).	Soft tissue procedures (periodontal and endodontic procedures) /power bleaching	• A reasonable haemostatic ability.	• Poorly absorbed by water and the hydroxyapatite which present in the enamel and dentin.
Nd:YAG * 1064 nm	Pigments (melanin and haemoglobin).	Soft tissue procedures (e.g. periodontal nonsurgical sulcular debridement) and endodontic procedures.	•Highly absorbed by pigmented tissues so effective for cutting and coagulating of oral soft tissues. • Good hemostasis.	• High cost and large size.
Er,Cr:YSGG 2780 nm	Water	Hard tissue procedures / soft	• High affinity for	.High cost.

Er:YAG 2940 nm	Water (highest absortion).	tissue procedures(with specific limitations).	hydroxyapatite and the highest absorption in water.	.Marginally prolonged treatment time but with better results. .Poor haemostatic ability in soft tissue surgeries
Carbon dioxide 10600 nm	Water	Soft tissue procedures (both major and minor surgical procedures).	•Its wavelength have high affinity for water thus rapid removal of soft tissue . . Rapid and excellent hemostasis with shallow penetration depth. .Optimize the mechanical retention of dental sealers.	.Its wavelength is of the highest absorbance than any laser but with greater thermal effect. .High cost and large size, .Greater destruction of hard tissues.

1.9 Literature review

The aim of endodontic treatment is to remove all essential or necrotic tissue in addition to microorganisms from root canal system, as well as to allow for more effective penetration of intracanal drugs, ensure successful obturation, and avoid chronic infection or treatment failure [122]. This can be accomplished by chemomechanical root canal preparation, which combines irrigation and mechanical instrumentation [123, 124].

Martins et al. (2014) investigated the results of Er,Cr:YSGG laser-assisted treatment of teeth with apical periodontitis, finding that for single-rooted and premolar teeth, this laser-assisted protocol would produce predictable endodontic outcomes, comparable to traditional methods, after one year of follow-up [125].

In 2015, Al-karadaghy T. et al. [126] investigated and compared the effects of Er,Cr:YSGG laser and dual wavelength laser (2780 nm & 940 nm) on ultrastructural alterations in dentin morphology and radicular dentin permeability. When radicular dentin irradiation with dual wavelength laser (three rounds, Pave=1.06 W for Er,Cr:YSGG laser, Pave=0.51 W for diode laser, and 162 s irradiation period) compared to Er,Cr:YSGG laser group, it is found to be successful in enhancing dentin permeability with superior statistical results. The technology appears to have potential in laser-assisted root canal therapy, as a smear film and debris successfully removed from root canal walls.

In 2016, Haidary et al combined the alternating pulses of Er,Cr:YSGG and 940-nm diode lasers, emitted from one radial firing tip, to research root surface temperature variations during root canal laser irradiation with dual wavelength laser (940 and 2780 nm) [127]. Martins et al. published two case reports in 2017 using a double-wavelength (940 nm + 2780 nm) laser in endodontics. The findings of both clinical cases indicate rapid symptom remission, no clinical complications, and full radiographic healing. However, the apical region of the canal is disproportionately larger [128].

Paloma et al. conducted a comparison analysis of EDTA and Er,Cr:YSGG lasers for debris and smear layer removal in 2018. They concluded that the Er,Cr:YSGG laser had greater cleanliness in the middle third, with statistically significant variations compared to 17 percent EDTA [129].

The effect of laser radiation in eliminating the smear layer reviewed by Paulina et al in 2019. They believe that using a laser technique to remove the smear layer is a more successful method than using other traditional activation methods [130].

Using confocal laser scanning microscopy, Ayca Yilmaz et al examined the efficacy of various final irrigation procedures on sealer penetration in 2020. With a maximum penetration depth of 652 um, they discovered that both of the study groups had slightly higher penetration rates than the control group [131].

In 2021, Ezatolah et al contrasted the effect(s) of smear layer removal on biodentine push-out bond strength between laser-assisted endodontic preparation and conventional endodontic preparation using sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA). Despite the elimination of the smear layer, the push-out bond strength between Biodentine and the root canal dentinal wall was not affected by 17 percent EDTA+5 percent NaOCl and Er,Cr:YSGG +diod lasers irridation [132].

In comparison to previous study [133] that used Er,Cr:YSGG laser with Radial Firing Tip, the mean value of dye penetration percentage in apical root third was 59.118 while in our study we obtained better result 85.980 by using PIPS technique. The mean value of dye penetration percentage was increased about 27% in our study than previous study.

1.10 Aim of study

The objective of this study is to investigate the influence of Er,Cr:YSGG (2780) nm on smear layer removal of the apical third using photo-induced photoacoustic streaming technique at short pulse duration alone and with irrigant comparing with ultrasonic activation.

CHAPTER TWO

MATERIALS AND METHODS

Chapter two Materials and methods

This chapter contains sample selection, preparation, grouping, irrigation procedure, material, and equipment used in the present study with method(s) used to complete the study and the statistical analysis.

2.1 Materials and equipment

The following are some of the items that used in this study (Figure 2-1):

Fig 2-1 some of items used in the study.

2.1.1 Materials

The materials used in this study:

1. Sodium hypochlorite solution 5.25% (Chloraxid Extra, PPH Cerkamed, Stalwa Wola, Poland).

2. Endodontic ruler (Endo ring rule ,Super,China).
3. EDTA 17% (Disodium edetate, PPH Cerkamed, Stalwa Wola, Poland).

4. Barbed broaches (dentsply, Maillefer, Ballaigues, Switzerland).

5. Stainless steel k- file #10 (dentsply, Maillefer, Ballaigues, Switzerland).

6. Protaper Gold Rotary NiTi files (SX, S1, S2, F1, F2, F3, F4) (Fanta, China).

7. Side-vented irrigation needles 30 Gauge ((SinalDent, China).

8. Diamond disc (22x 0.4) (China).

9. Disposable syringe 5 ml.

10. Thymol crystals (BDH chemical Ltd., Poole, England).

11. Clean stand sponge (china).

12. Clear test tube 5.0 ml (AFCO, Amman, Jordan).

13. Disposable syringe 5 ml (UltraHealth, Changzhou Kangfulai Medical, Jiangsu, China).

14. Ultrasonic activator tip ED98 (25#, 2% taper, 18.5 mm) (Guilin Woodpecker Medical Instrument Co., Ltd.china)

15. Silicon impression material (putty + catalyst gel) (prtesil. Vannini Dental Industry. Florence. Italy).

16. Methylene blue dye powder (India).

17. MD/iplus Glass Tips (MZ6) diameter=600 μm, length=6 mm, calibration factor= 1.00 (Biolase, San Clemente, CA, USA).

18. Distilled water (Al-Mansur Company, Baghdad, Iraq).

19. Disposable face mask (China).

20. Disposable gloves (Bio-touch, Malaysia).

21. Ethyl Alcohol spray 70% (HiClean, Baghdad, Iraq).

22. Paper Points (Diadent, Korea).

23. Stainless steel k- file #20 (dentsply, Maillefer, Ballaigues, Switzerland).

2.1.2 EQUIPMENT

The equipment used in this study:

1. Cordless Endodontic micro motor (OM-T-FINE-II, China).
2. Dental lab electric micro motor (Marathon Champion 3, South Korea).
3. Bench vice (china).
4. Ultrasonic scaler.
5. Black marker.
6. Goggles.
7. CAD-KAS Kassler (measure picture Computer software GbR, V 1.0, Germany).
8. Digital stop watch (China).
9. Ultrasonic activator ENDO1 (Guilin Woodpecker Medical Instrument Co.,Ltd.china)
10. Er,Cr:YSGG laser (waterlase iplus Biolase, CA, USA).
11. Professional Digital SLR camera (Nikon D7100, Nikon Corporation, Thailand).
12. Dental Surveyor.
13. Digital caliper (NSI, China).
14. Scanning electron microscope (Inspect S50, Czech Republic).
15. Mallet.
16. Sputter coater.

2.1.2.1 Er,Cr:YSGG pulsed laser

Er,Cr:YSGG pulsed laser, (Biolase, waterlase, iplus, CA, USA) 2780 nm (Figure 2-2). Its supplied by MD/iplus Glass Tips (MZ6) diameter=600 μm, length=6 mm, calibration factor= 1.00. The fiber tip was inserted just into canal orifice. Each fiber tip was used to clean only one canal just for

uniformity, and then discarded. Waterlase device programme setup was shown in (Figure2-3). The laser device and its specification is depicted in Table (2-1).

Fig 2-2 Er,Cr:YSGG laser equipment (Biolase,waterlase, iplus, CA, USA).

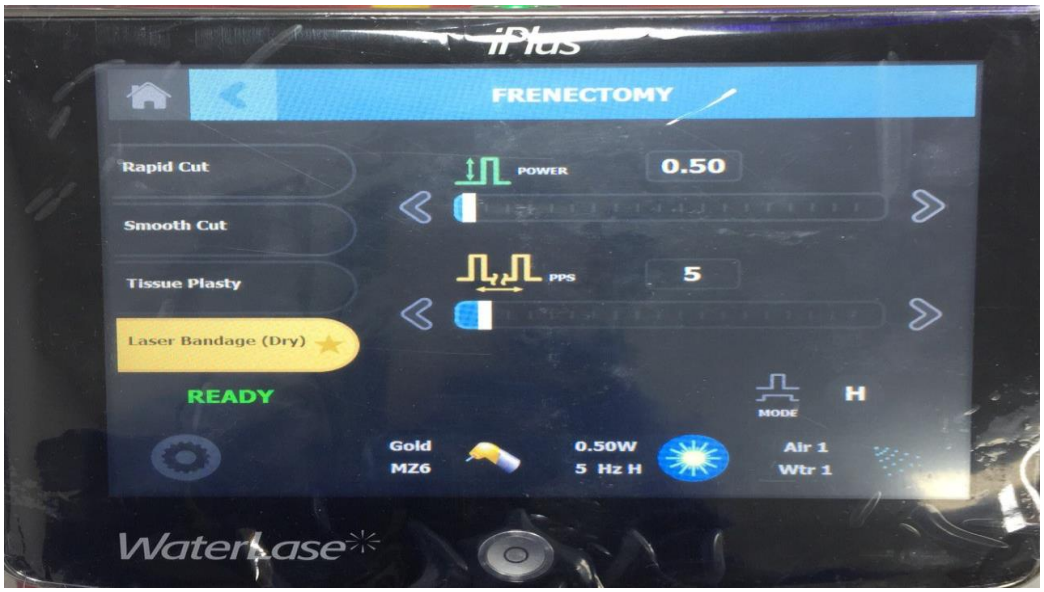


Fig 2-3 Waterlase device programme setup.

Table (2-1) Er,Cr:YSGG (Water-Lase iPlus-Laser) specifications[134].

ELECTRICAL	
Type	(Class I) Medical-Electrical-Equipment
Operating-Voltage	100 VAC ± 10 % // 230 VAC ± 10 %
Frequency,	50/60 Hz
Current-rating	5 A/8 A
Main-control	Circuit-breaker
On/Off control	Key switch
Remote-interruption	Remote-interlock-connector
AIR& WATER-OUTPUT	
Water-type	Distilled-water /Deionized
External-air-source	5.5-8.2bar
Water.	0–100 %
Air,	0–100 %
Interaction-zone	0.5-5mm (Hand piece-tip – target**)**
OPTICAL,	
Laser-classification	Four
Active Medium	Er,Cr:YSGG (Erbium, Chromium :Yttrium, Scandium,Gallium, Garnet)
Wavelengths	2780 nm
Frequency.	5–100Hz
Average-power	0.1–10W
Power-accuracy	±20 %
Pulse-energy	0–600 mJ
Pulse-duration for “H”-mode	60µs
Pulse-duration for “S”-mode	700µs
Hand piece head-angles	70°contraangle
Gold HP Tip diameter-range	200–1200µm
Turbo Tip focal diameter-range	500-1100µm
Output-divergence	≥8°perside
Mode,	Multi mode
Aiming Beam:	635 nm red-laser, 1 mW max

Water-Level Sensor-Beam,	635 nm redlaser, 1mW max
Nominal-Ocular Hazard=Distance	5 cm
Maximum-Permissible-Exposure (MPE):	$3.5x10^5$ W/m^2

2. 2 Methods

2.2.1 Selection and collection of samples

Sixty-six single-rooted, straight human mandibular premolar teeth were removed for orthodontic or periodontic reasons. The teeth were cleaned immediately after collection by distilled water. Soft tissue remains removed with an ultrasonic scaler. The teeth were clinically and radiographically inspected to confirm that no root fracture, open apex, or root resorption existed. They were placed in a plastic container containing a 0.1 percent thymol solution until the experiment done.

2.2.2 Preparation of samples

Using a digital calliper and a permanent black marker, the roots length was uniform to 14 mm from the anatomic apex. The teeth were then mounted on a bench vice, and a double-faced diamond disc was used to split the root perpendicular to the root's long axis, following the marked line (Figure 2-4A). Some root samples after sectioning are presented in (Figure 2-4B).

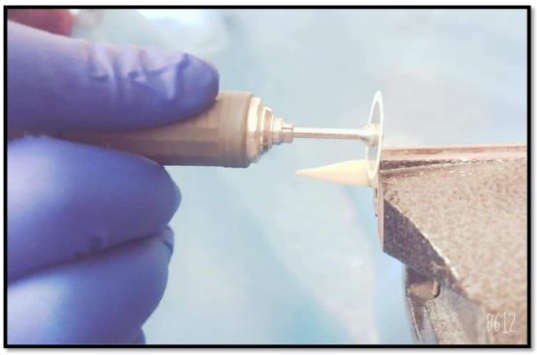
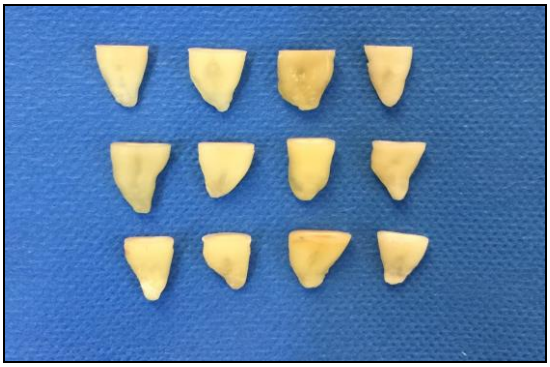
A  **B** 

Fig 2-4 A) splitting of the sample. B) After splitting, some root samples displayed as an example.

Orifices in canals are widened using a small carbide round bur on a standard speed hand piece. Barbed broaches was used to remove pulpal tissues. The patency of the canals and the exact position of the apical foramen were determined using a stainless steel K-file #10 inserted slowly till it was observable at apical foramen by naked view (Figure2-5). The file was removed and measured using an endodontic ruler, and the right working length was calculated by decreasing 1 mm from the previously established length.

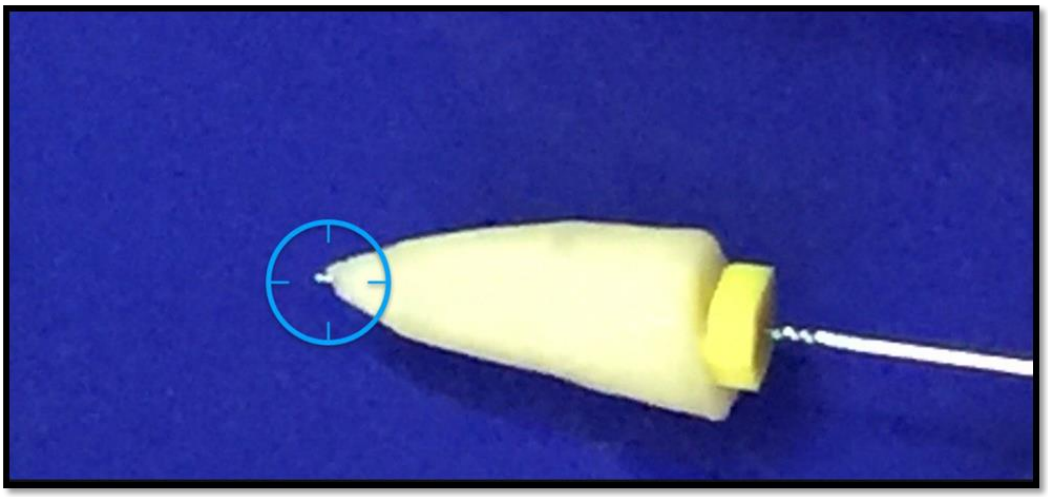


Fig 2-5 Checking for canal patency and determining the operating length.

The samples are inserted in a plastic tube containing putty consistency of silicon rubber base impression material to help handling throughout working processes, with the exception of the coronal 3 millimeters.

During the insertion of the silicon putty, a hole is done in the plastic tube base to allow the air inside plastic tube to escape.

As stated by the manufacturer's instructions the catalyst gel should mixed with the putty, then placed it in a plastic tube, and the sample should be inserted in the silicon putty with help of a surveyor. The canal opening was sealed with Teflon and waxed to the surveyor's arm, and then the sample was gently pushed into the silicon putty to maintain a consistent long axis. After

the silicon material had set, the plastic tubes are moved to a bench vice and fixed to achieve a consistent position for the operation (Figure 2-6).

Fig 2-6 the tube mounting on the bench vice.

2.2.3 Instrumenting of the Root Canal

The working length was calculated as previously stated using a size #10 ISO K file 1 mm from the apex, which was 13 mm, and the canals were mechanically instrumented using a rotary device. We irrigated the root canals with 2.0 ml of 5.25 percent NaOCl solution provided by a 30-gauge side vented needle within a 5.0 ml disposable syringe. The needle was put short of the point where resistance from the canal walls felt during all irrigation phases, with the needle not forced longer than 2 mm shorter than the specified operating length. ProTaper Gold rotary files and an endodontic micro motor were utilized to prepare the canals of root (Figure 2-7).

The sequence of instrumentation was :- SX, S1, S2, F1, F2, F3, F4 (size 40). Apical patency was tested with a #10 stainless steel K-file after each file and before converting to the next file in the instrumentation procedure, and the canal was irrigated with 2.0 ml of 5.25 percent NaOCl. To avoid the sodium hypochlorite action lasting too long, we irrigated the sample with 5 ml distilled water at the end of the procedure. Each set of rotary files was used to prepare five canals and then discarded for standardization. After finishing one canal and before used again, all tools were cleaned using a gauze pad soaked in ethyl alcohol and put on a sponge endodontic stand.

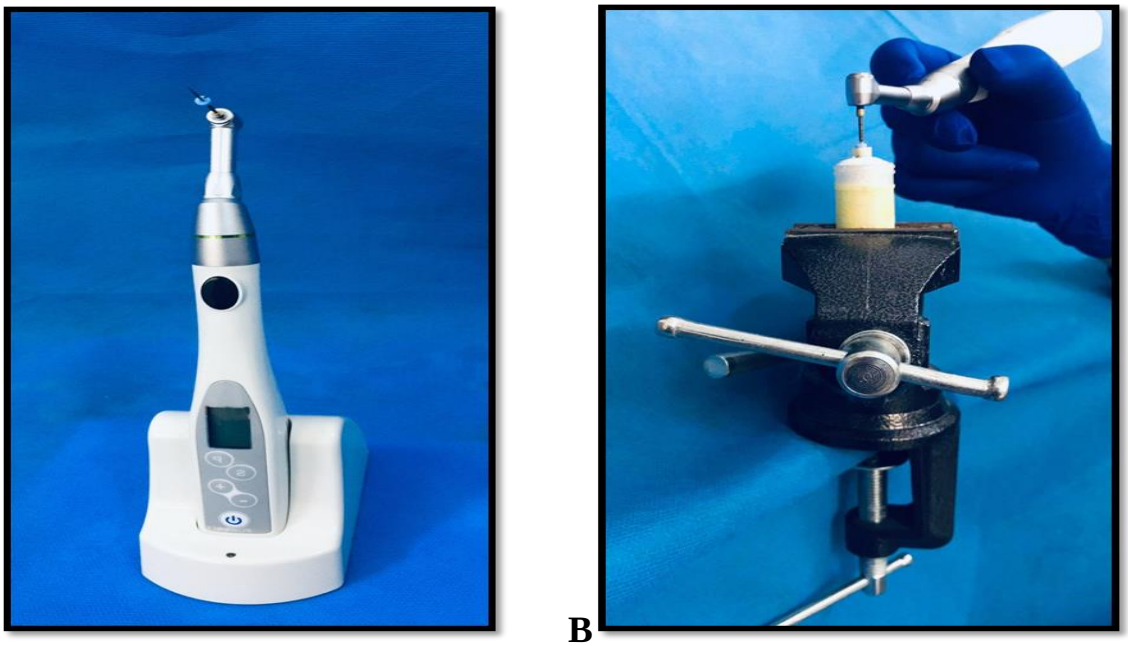


Fig 2-7 A: The endodontic micro motor used in accordance with the manufacturer's recommendations B: Instrumentation of root canal by Protaper GOLD NiTi files.

2.2.4 Grouping of Samples

Sixty-six samples were separated into sub groups as follows:

Two groups, each group has six teeth (n=6) were used to investigate the effect of 17% EDTA and 5.25% NaOCl on removal of smear layer using scanning electronic microscopy.

In pilot study, we have two groups:

G1 (n=15): 17% EDTA+ Er,Cr:YSGG laser 2780 nm. (0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W).

G2 (n=15): 5.25% NaOCl+ Er,Cr:YSGG laser 2780 nm.

(0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W).

After pilot study, we have four study groups:

G1 (n=6): control group (17% EDTA).

G2 (n=6): 17% EDTA+ ultrasonic activation.

G3 (n=6): 17% EDTA+ Er,Cr:YSGG laser 2780 nm

G4 (n=6): 5.25% NaOCl+ Er,Cr:YSGG laser 2780 nm.

2.2.4.1 The protocol of final irrigation

Following biomechanical preparation, each group was received the following final irrigation:

Twelve teeth were used to investigate the effect of 17% EDTA and 5.25% NaOCl on removal of smear layer using scanning electronic microscopy.

Six samples were irrigated with 5 ml 17% EDTA for 1 min then delivering 5 ml of distilled water and with paper point, protaper F4 the canal was dried.

Six samples were irrigated with 5 ml 5.25% NaOCl for 1 min then delivering 5 ml of distilled water and the canal was dried with paper point protaper F4.

Groups of pilot study:

G1:- 17% EDTA+ Er,Cr:YSGG laser 2780 nm (n=15). (0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W). Each power have three samples

Each sample was irrigated as the following procedure with different power (0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W) used:

The samples were irrigate with 5 ml 17% EDTA and agitated with Er,Cr:YSGG 2780 nm pulsed laser for 1 minute (Figure 2-8). Delivery was by MD/iplus Glass Tips (MZ6). Setting was Power=0.25 W or 0.5 W or 0.75 W or 1 W or 1.25 W, pulse duration: 60 μs, repetition rate 5 Hz. Water and air was off. The fiber tip was inserted just into canal orifice. The procedure was followed by delivering the final rinse (5 ml of distilled water) and the canal was dried with paper point F4. Each fiber tip was used for only one canal, after that discarded.

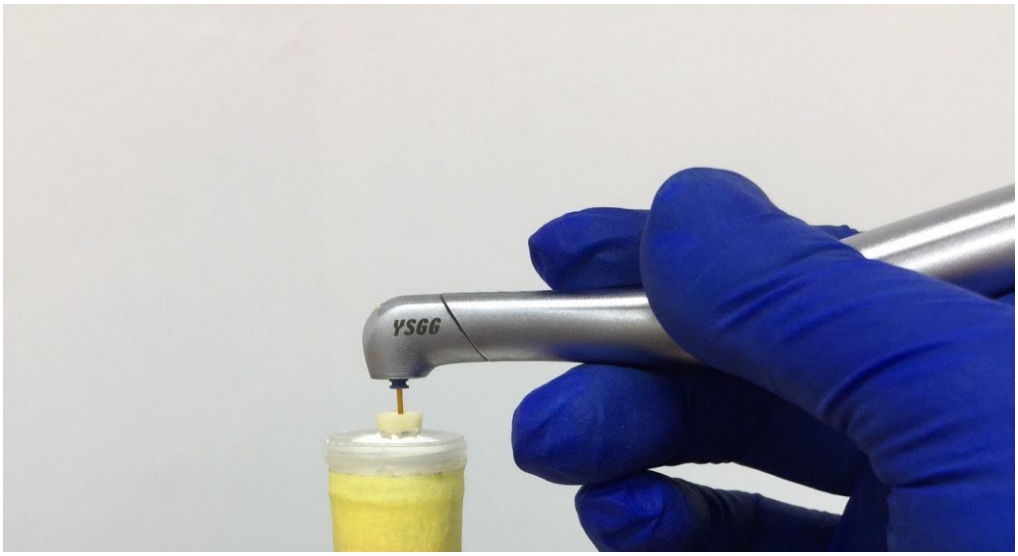


Fig 2-8 Irrigant activation using Er:Cr:YSGG laser.

G2:- 5.25% NaOCl+ Er,Cr:YSGG laser 2780 nm (n=15). (0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W). Each power have three samples

Each sample was irrigated as the following procedure with different powers (0.25 W, 0.5 W, 0.75 W, 1 W, 1.25 W) were used:

Er,Cr:YSGG pulsed laser, 2780 nm was used for 1 minute with 5 ml NaOCl 5.25% for shock wave generation and disinfection. The delivery was by MD/iplus Glass Tips (MZ6). Setting was Power=0.25 W or 0.5 W or 0.75 W or 1 W or 1.25 W, repetition rate: 5 Hz, pulse duration: 60 μs. Water and air was off. The fiber tip was inserted just into canal orifice. The procedure was followed by delivering the final rinse 5 ml of distilled water and the canal was dried with paper point F4. Each fiber tip was used for only one canal, after that discarded.

Study groups:

G1:- control group (n=6) The samples were irrigated with 5 ml of 17% EDTA for 1 min by Side-vented irrigation needle which positioned 2 mm shorter than the working length of the root canal .Then 5 ml of distilled water was delivered and the canal was dried with paper point F4.

G2:-ultrasonic activation (n=6) the samples were irrigated with 5 ml of 17% EDTA for 1 min. The ultrasonic system was used according to the instructions of manufacturer (Figure 2-9). After injection of the solution into the root canal the Ultrasonic activator tip ED98 was fitted passively inside canal, 2 mm shorter than the working length, then the tip was move up and down motion in a small range. After 20 seconds, we stopped to clean the root canal. A root canal was irrigated for 3 times and each time takes 20 seconds. Then 5 ml of distilled water was delivered and the canal was dried with paper point F4.

A  B 

Fig 2-9 A: ultrasonic Activator system, with ED98 tip.

B: Cleaning of root canal by ultrasonic irrigation.

G3:- 17% EDTA+ Er,Cr:YSGG laser 2780 nm (n=6).

The samples were irrigated with 5 ml of 17% EDTA and agitated with Er,Cr:YSGG pulsed laser 2780 nm for 1 minute. The delivery was by MD/iplus Glass Tips (MZ6). Setting was Power= 0.5 W according to pilot study, repetition rate: 5 Hz, pulse duration: 60 µs. Water and air was off. The fiber tip was inserted just into the canal orifice. Then 5 ml of distilled water was delivered and the canal was dried with paper point F4. Each fiber tip was used for only one canal, after that discarded.

G4:- 5.25% NaOCl+ Er,Cr:YSGG laser 2780 nm (n=6). Er,Cr:YSGG 2780 nm pulsed laser was used for 1 minute with 5 ml 5.25% NaOCl for PIPS technique (shock wave generation and disinfection). Delivery was by MD/iplus Glass Tips (MZ6). Setting was Power= 0.75 W according to pilot study, repetition rate: 5 Hz, pulse duration: 60 µs. Water and air was off. The fiber tip was inserted just into canal orifice. Then 5 ml of

distilled water was delivered and the canal was dried with paper point F4. Each fiber tip was used for only one canal, after that discarded.

2.2.5 Sectioning of the root for SEM examination

Twelve samples were chosen for SEM analysis in order to assess ultrastructural changes and smear layer removal. The roots were separated from their tubes, and longitudinal guidelines were drawn with a marker on the buccal and palatal surfaces. The roots were held in a bench vice and the previously marked lines were grooved longitudinally using a diamond disc on handpiece of low-speed that kept cool with water (Figure 2-10A). With a little air blow, the grooves were cleared of any residual debris. Then the roots were divided in two parts using a surgical blade #11 in the groove with a small mallet. One part was analyzed, and the other being discarded (Figure2-10 B).

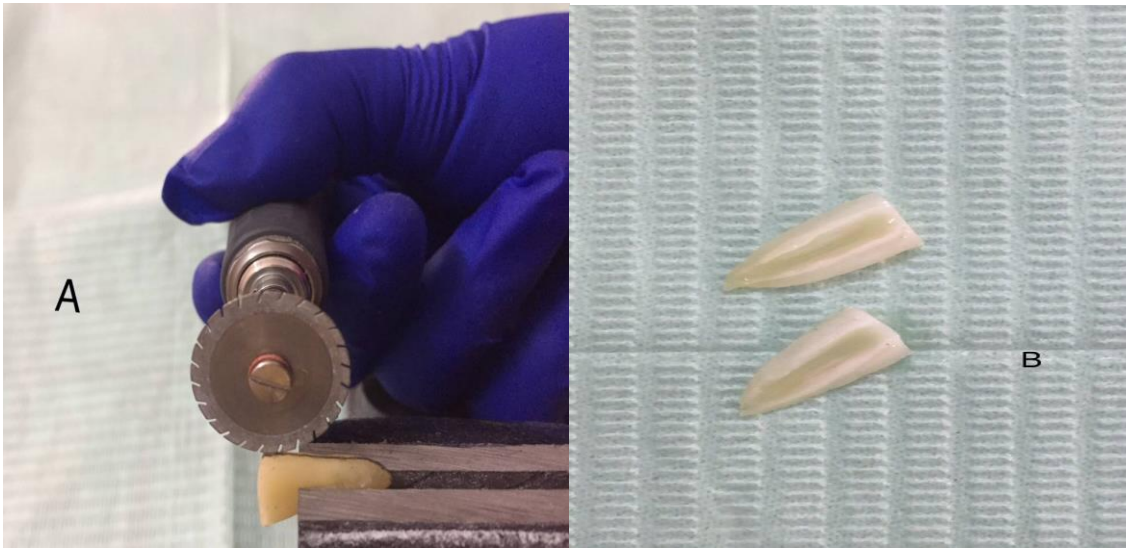


Fig 2-10 A: The root mounting for longitudinal groove location. B: The root longitudinal portion.

2.2.5.1 Preparation protocol for SEM evaluation

The fixation and dehydration of the samples were carried out according to Marchesan et al methodology[135]. At 4 °C, the samples were dipped in 2.5 percent buffered glutaraldehyde (EOBA CHEMIE PVT, India) and 0.1 ml

sodium cacodylate (BDH Chemicals Ltd, England) pH =7.4 for 12 hours before being rinsed in distilled water for 3 minutes. Then left in distilled water for 1 hour (the water was changed every 20 minutes), then dehydrated in an ascending graded ethyl alcohol beginning from 25% for 20 min, 50% for 20 min, 75% for 20 min, 95% for 30 min, and end with 100% for 60 min. The specimens dehydrated, and then dried for 24 hours before placed on aluminium stubs and metallized with a coating of gold using vacuum evaporation. The samples were then investigated using a scanning electron microscope (Inspect S50, Czech Republic) and examined under 1500 and 3000 x magnification.

2.2.6 Permeability test experiment

The test was prepared to assess the dye penetration area in apical third of root canal. The wax was used to seal root apex. The surface of roots was covered by two layers of nail paint and left to dry. Then 2% methylene blue dye was introduced into the canal by hypodermal syringe with needle gauge 23 by placing the needle 2 mm inside the canal, then k-file # 20 was inserted and withdrawn one time to confirm that the dye was reached to the apical root third. After that, the dye was left inside the canal for 20 min. at room temperature (27-29 $_{o}$c). When time had been passed, they were washed comprehensively below running tap water to clean external root surface and with absorbent paper cone the root canal was dried constantly until the cone appears white [136, 137].

2.2.6.1 Root sectioning for permeability test

The tooth was split at the fourth millimeters from root apex with the aid of diamond disc just below the guiding line representing the apical third (Figure2-11). Pictures were taken by Professional Digital SLR camera (Nikon D7100, Nikon Corporation, Thailand) for each sample with 40X magnification.

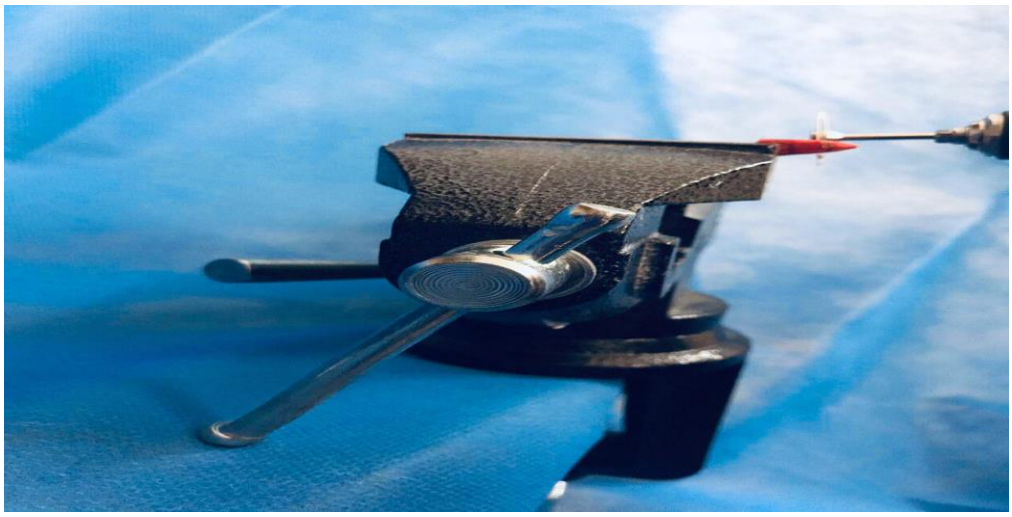


Fig 2-11 Sample cutting for permeability test.

2.2.6.2 Radicular dentin permeability measurements and evaluation

The images were opened with measure pictures V 1.0 software (CAD-KAS Kassler Computer software GbR, Germany), for computing of radicular dentin Permeability. Dye penetration area and total root section area were calculated then subtract the root canal area from both earlier mentioned areas to acquire the real dye penetration area and the real root section area.

First, calibration was by numerical scale to convert pixel unit into millimeter (Figure2-12).

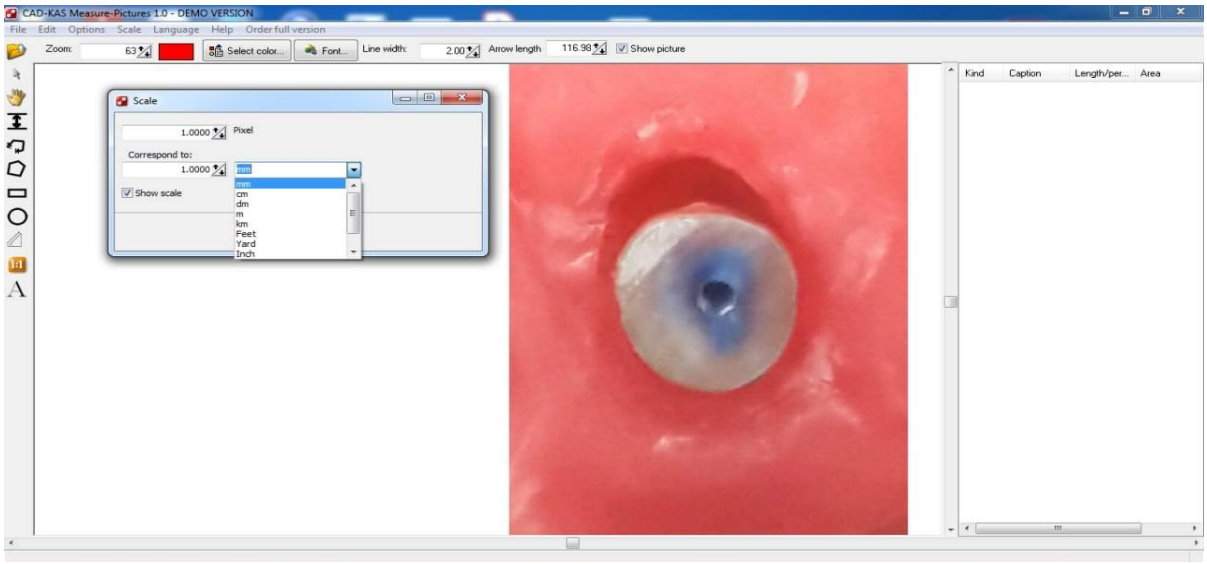


Fig 2-12 Calibration to convert pixel unit into millimeter by using numerical scale.

Consequently, and after completion of measuring areas (Figure2-13), the dye-penetrated area was divided by the root third area giving dye penetration in root third, and multiplied by 100% resulting in dye penetration percentage of root third see the following equation:

Dye Penetration in Root Section = (Net dye penetration area /Net total root third area) × 100.

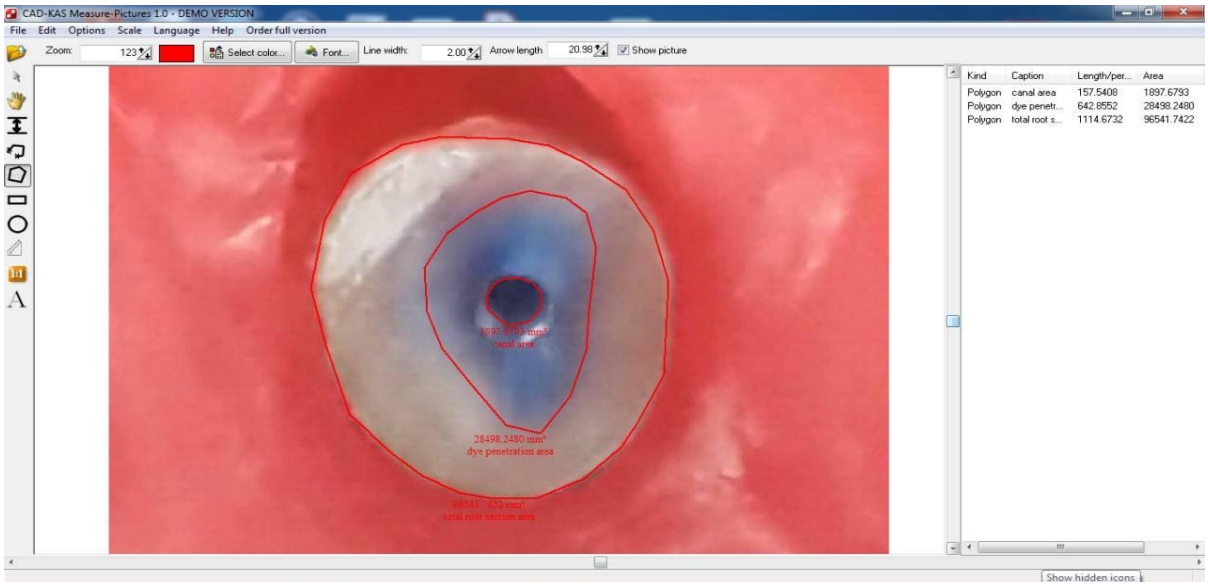
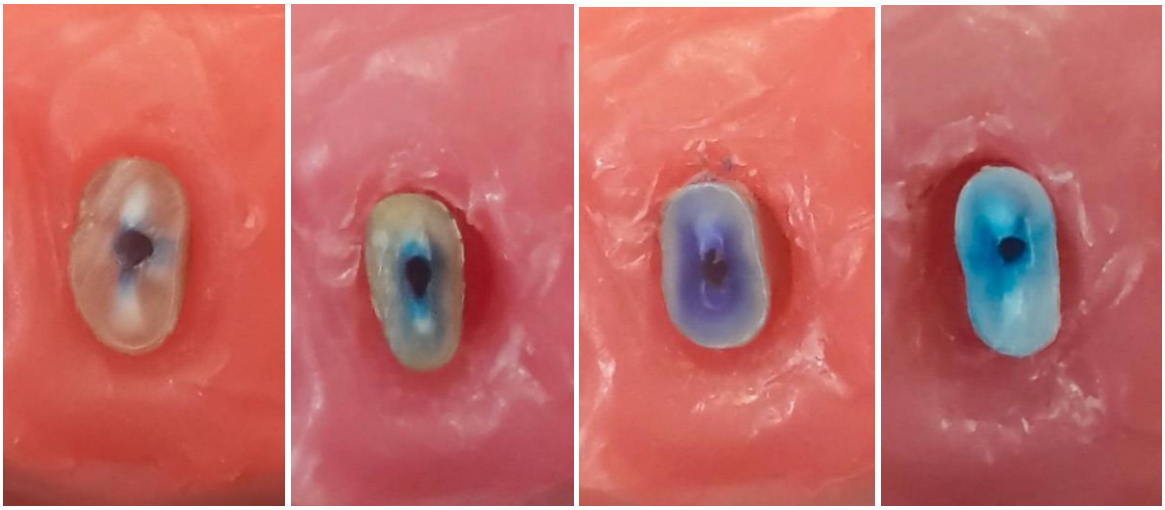


Fig 2-13 measurement of dye penetration area in square millimeter unit.

The dye penetration area after using different technique shown in (Figure 2-14) as follow:



A B C D

Fig 2-14 Image after dye solution penetration and perpendicular cuts for control group (A), 17% EDTA+ultrasonic group (B), 17% EDTA+ Er,Cr.YSGG group (C), 5.25% NaOCl+ Er,Cr.YSGG group (D).

2.2.7 Discussion of methodology

Single root mandibular premolars where used in the current study because they had a more circular canal morphology in cross section than the other teeth. Using a single type of tooth, on the other hand, can improve sample uniformity and decrease factors that might affect the results. Furthermore, the specimens carefully chosen; all teeth had a single canal and orifice, a mature apex, patent apical foramen.

The teeth decoronated to get 14 mm of consistent length and a standard level for employed instruments as a reference point. In addition, any variations in the access preparation should rejected, and a straight-line entry to the canal should create. Furthermore, if the crown was present in every tooth, the

access design for each sample would be different [138]. All specimens were given the same working length by removing 1 mm from the apical foramina. For all samples, root canal instrumentation were performed in the same way for all groups, using ProTaper GOLD NiTi files up to size #40/06 (F4). Hypochlorous acid is antimicrobial and assists in the amputation of the smear layer's organic part. It used in various concentrations ranging from 0.5 to 6% [139]. NaOCl used in our study at 5.25% because the unique concentration suggested by Dakin was 0.5%, but the concentration used in dentistry has been as high as 5.25% [14, 15]. Because the smear layer is largely made up of inorganic materials, root canal treatment with sodium hypochlorite has minimal effect in removing it. Therefore, we used 5.25% NaOCl as assistant for PIPS technique, which require liquid for energy absorption and shock wave generation and cannot occur without presence of liquid in addition to the main function for bacterial disinfection.

Ethylene Diamine Tetra-acetic Acid (EDTA) was used as irrigant of choice for smear layer removal, assisted in the removal of the inorganic constituents of the smear layer, acting as an aide to irrigation [11]. EDTA decalcifies dentine to a distance of 20–30 μm in 5 min [12]. EDTA, an artificial amino acid with a pH of 7, is the most widely used chelating agent. It is utilized as an irrigation solution in primary and secondary teeth [140], Calcium is removed from root dentine at concentrations of 15-17 percent [141] So we used it at 17 percent.

Numerous progressions have been existing in endodontics field like hand and engine-determined instruments and altered irrigating solutions [16]. In our study, we used ultrasonic activation and laser activation. We used Ultrasonic irrigation activation in our study because its considered as the better technique of activation before the laser used. In contrast with sonic energy, the ultrasonic energy yields higher frequencies but with lower amplitudes [21]. Although studies on endosonic systems have indicated that

root canals prepared ultrasonically with UI devices are cleaner than canals made with a traditional root canal system alone, but other studies have failed to establish that UI is a superior cleaning and shaping procedure. These outcomes can be recognized to the limitation in cleaning efficacy and the vibration motion of the ultrasonic tip inside the non-flared root canal space [22, 23]. Show that, we have to look for another technique to overcome those obstacles.

Recently, researchers have concentrated on irrigant activation by different laser [28-32]. Er,Cr:YSGG laser was used in our study for agitation or activation of root canal irrigants via photo induce photoacoustic streaming technique. This technique is a new LAI approach, pulses the laser light energy which absorbed by the irrigant molecules. This energy transfer generates a series of forceful shock waves capable of driving the irrigant across the whole root canal system [33, 95].

We used PIPS technique in our study because previous experiments have found that PIPS helps to improved canal wall cleanliness and increased the number of open tubules than when the same irrigants were used without it [33]. The deep photoacoustic shock wave simplifies the three-dimensional movement of irrigation solutions [28]. Thus, the smear layer was removed by means of photomechanical flowing of the liquids where laser activation in coronal access of the root and not by thermal vaporization.

2.2.8 Statistical analysis

In pilot study, the ANOVA unstacked test was used to compare the repeated measures of the tested and control concentrations. The data was presented as a mean with standard deviation. The letters (A, B, and C) were reflected the levels of significant, extremely significant start from the letter (A) and decrease with the last one in the LSD test. There are no substantial

distinctions between tests if the letters are similar. Values of $p>0.05$ were reflected statically non-significant while $p\leq0.05$ and <0.01, 0.001 were reflected significantly different, highly significantly different correspondingly. Estimate of correlation coefficient between difference parameters in this study. The statistical analysis was done by SPSS (v 2). In study groups because of the possibility of the statistical analysis program used (ANOVA unstacked) is limited, we have to select another one to know the difference in every group so the Dunnttes the statistical analysis program was our choice.

CHAPTER THREE

RESULTS, DISCUSSION AND CONCLUSIO

Chapter Three Results, Discussion and Conclusion

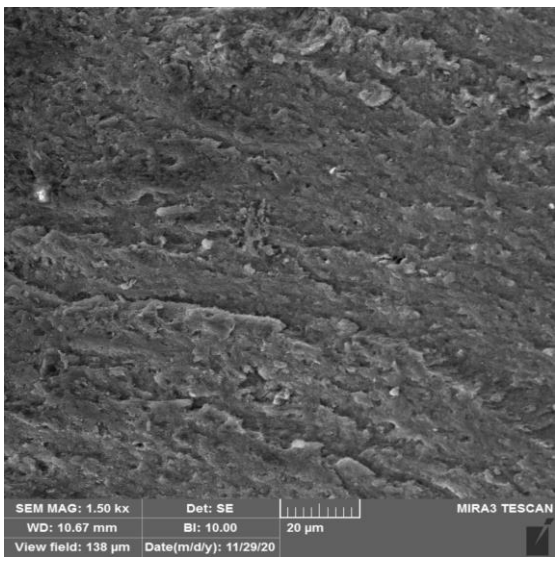
In this chapter, the result are given for pilot and study groups and discussed it to end finally in conclusion:

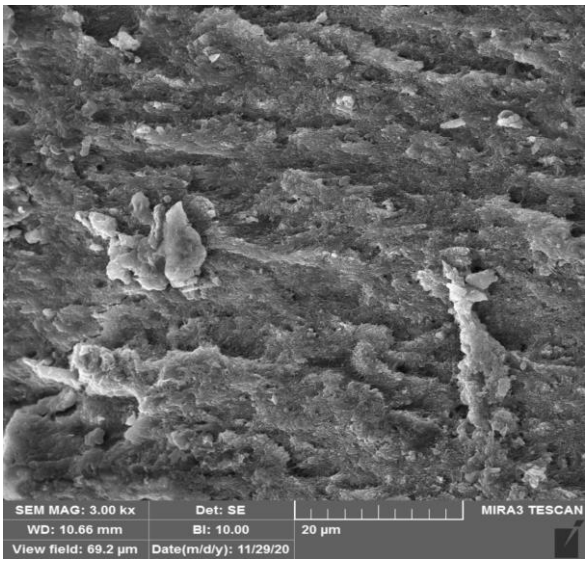
3.1 Results

The results of our study illustrated as the following:

3.2 SEM images

In terms of SEM results, there are two sets of SEM results in the root canal apical third, clusters of debris and smear layer observed in the apical portion of the NaOCl group as shown in (Figure3-1). It is clear that the dentinal tubules were blocked. The EDTA group had a superior clearance of the smear layer and debris, as well as a higher number of opening dentinal tubules, are given in (Figure3-2).





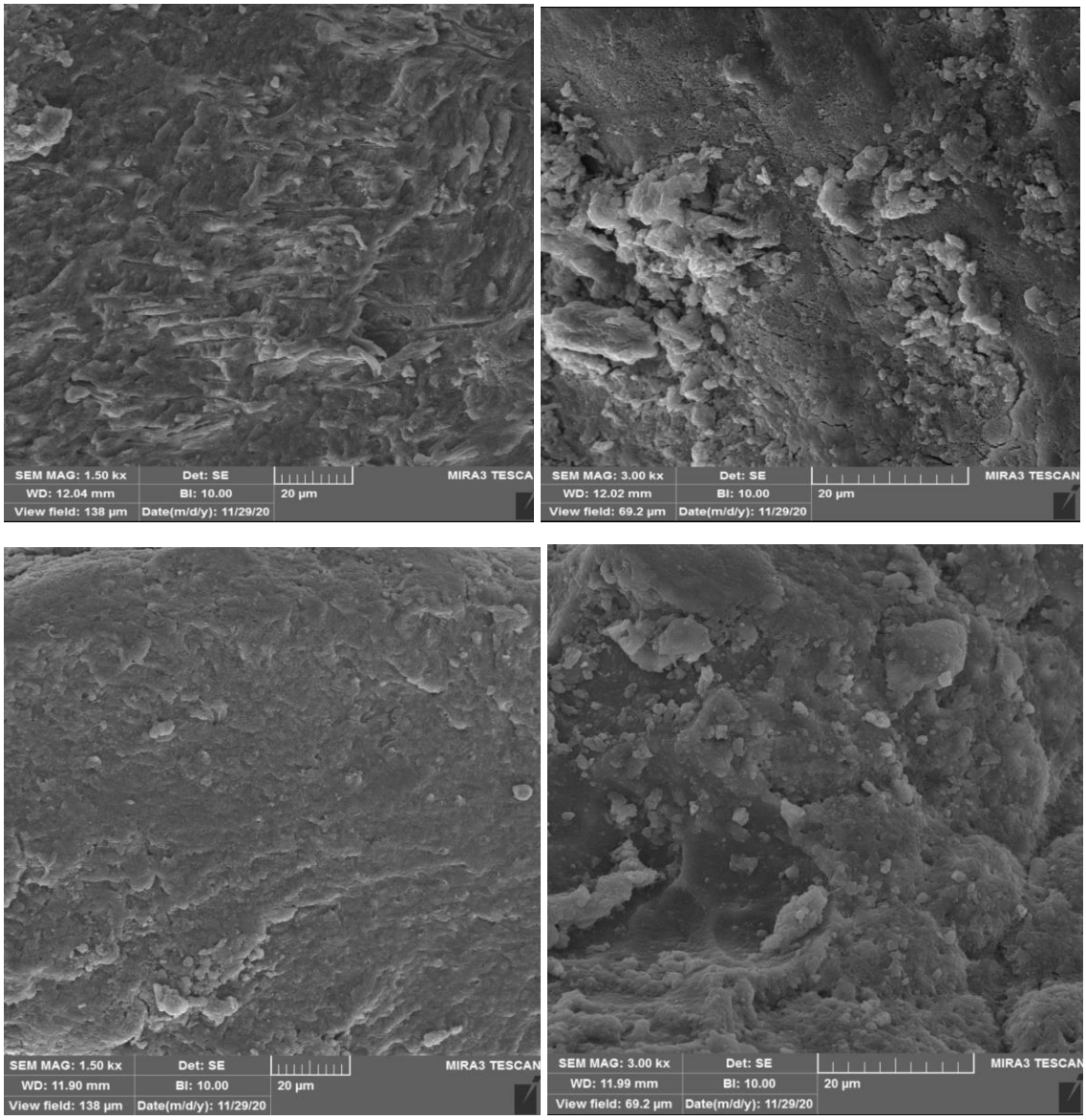


Fig 3-1 SEM images of apical root third for 5,25 % NaOCl group at magnifying power 1500X, 3000X respectively for different samples.

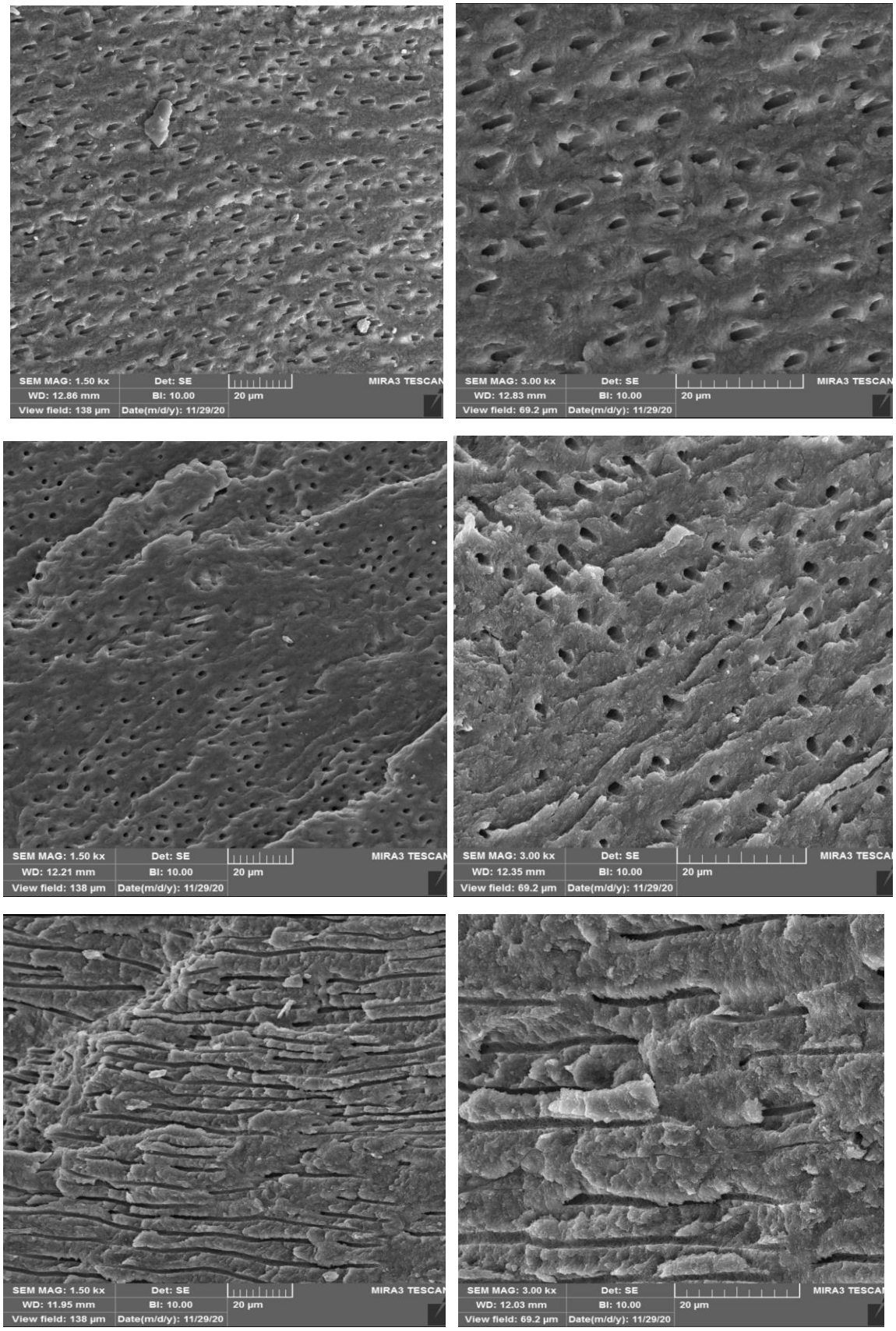


Fig 3-2 SEM images of apical root third for 17% EDTA group at magnifying power 1500X, 3000X respectively for different samples.

3.3 Permeability test

As it was stated in methodology, the roots were sectioned transversely at apical area of the root. The area of dye penetration and the total root section area were computed, and both subtracted from the root canal area to provide the net dye penetration and net root section areas. The dye-penetrated area is divided by the root third area giving dye penetration in root third, and multiplied by 100% resulting in dye penetration percentage of root third as seen in the following equation [47]:

Dye Penetration in Root Section = (Net Dye Penetration Area /Net Total Root Third Area) × 100

Data representing root canal dentin permeability was expressed as dye penetration percentage at the apical root third of the canal.

3.3.1 The results of the pilot study

The comparison of permeability for root canal dentin between control and different groups in apical root third are presented.

The Data of root canal dentin permeability was illustrated in Table (3-1) as dye penetrating percentage area at apical third of root canal. The table showed that the high percentage of dye penetration area was seen in activated laser group with 17% EDTA at 0.5 W followed by Erbium laser group with 5.25 % NaOCl at 0.75 W respectively.

Table 3-1 Dye Penetration of pilot groups (A) Control (B) 17% EDTA+ Er,Cr:YSGG (C) 5.25%NaOCl + Er,Cr:YSGG

(A)Control	Laser Power	(B) 17%EDTA + Er,Cr:YSGG	(C) 5.25%NaOCl + Er,Cr:YSGG
20.56±0.36	0.25 W	70.71098 69.99 71.1	53.2715 53.3 52.99
20.56±0.36	0.5 W	89.76463 89.1 90	66.55742 66.9 66.2
20.56±0.36	0.75 W	79.27453 78.9 80.1	69.40433 70.1 69.8
20.56±0.36	1 W	73.46328 73.2 72.9	25.7323 25.98 26.1
20.56±0.36	1.25 W	28.08477 27.98 28.1	18.93397 19.1 18.99

Table 3-2 shows the results of descriptive and statistical tests for the percentage of dye penetration area in the control and experimental groups. Among groups, the highest mean percentage is observed in activated Erbium laser group with 17% EDTA at 0.5 W while for Erbium laser group assisted by 5.25% NaOCl at 0.75 W, and the lowest mean rank percentage were appeared in Erbium laser group with 5.25% NaOCl at 1.25 W with highly significant difference among groups.

Table 3-2 Permeability of pilot study groups: a descriptive and statistical test

Mean ± SE	**(B) 17%EDTA + Er,Cr:YSGG**	**(C) 5.25%NaOCl + Er,Cr:YSGG**	**p value Between B&C Groups**
Control	20.56±0.36	-------	-----
0.25 W	C 70.60±0.33	C 53.19±0.1	0.001
0.5 W	A 89.62±0.27	B 66.55±0.2	0.001
0.75 W	B 79.42±0.35	A 69.77±0.2	0.05
1 W	C 73.19±0.16	D 25.94±0.11	0.0001
1.25 W	D 28.05±0.04	E 19.01±0.05	0.05
p value within the group	0.01	0.001	------
p value between tested groups and control	0.0001	NON	

(Figure3-3) shows the mean values of the percentage of dye penetration area among five powers in 17%EDTA+ Er,Cr:YSGG where the high percentage is observed at 0.5 W.

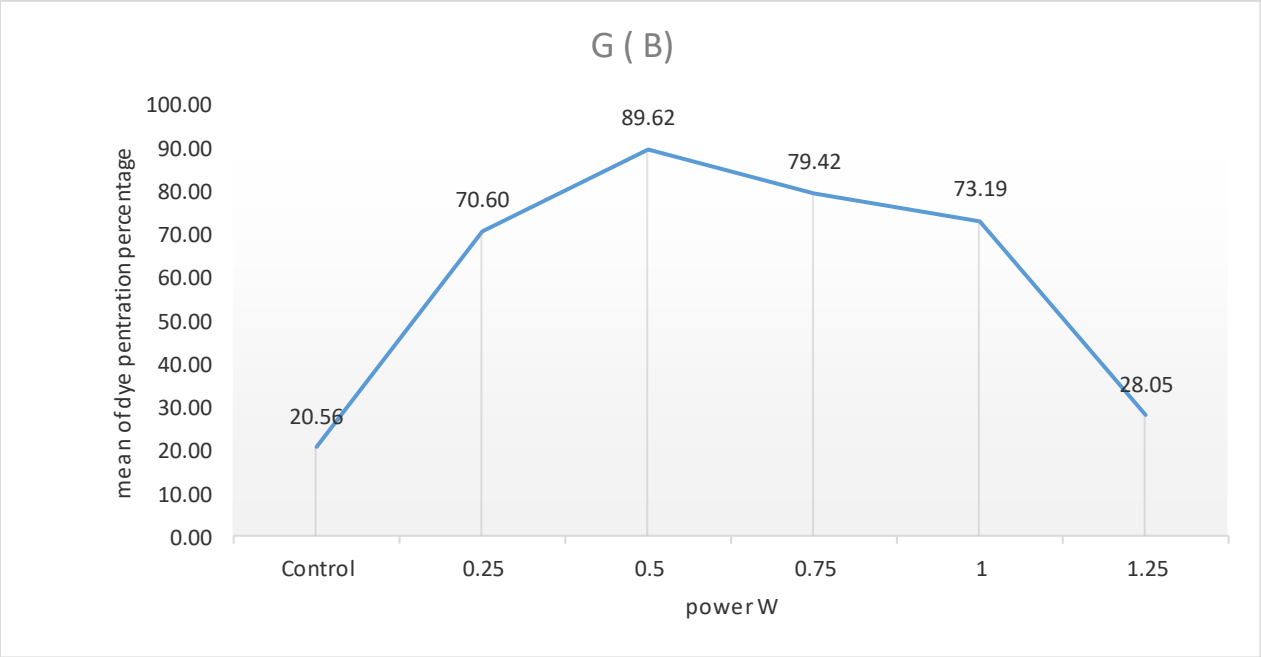


Fig 3-3 The mean values of the percentage of dye penetration area between five powers in 17%EDTA+ Er,Cr:YSGG and the control group.

It is very clear that the dye penetration is depending on the laser power directly where the dye penetrates with increasing the incidence power to a certain limit then starts to decrease what points the relationship between the dye penetration and the incident power on the root canal is not linear.

(Figure3-4) illustrates the mean values of the percentage of dye penetration area between five powers in 5.25 % NaOCl and Er,Cr:YSGG. It is observed that the high percentage of dye penetration area at 0.75 W and the lowest at 1.25 W. The dye penetration area decreases.

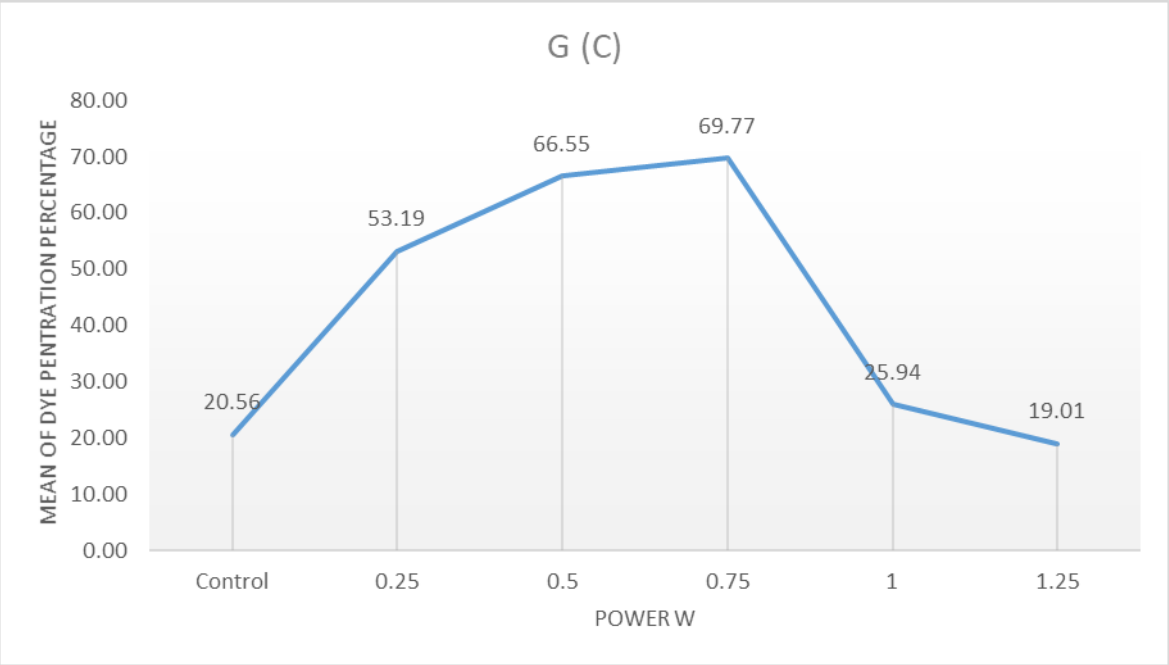


Fig 3-4 The mean values of the percentage of dye penetration area between five powers in 5.25 % NaOCl + Er,Cr:YSGG and the control group.

Similar behavior is observed in this Figure (the relationship is not linear). It noticed that the dye penetration at high incident power (1.25 W) is less than the control group, which means that the NaOCl alone has no effect to remove the smear layer.

The mean values of dye penetration percentage area among five powers in both17% EDTA+ Er,Cr:YSGG and 5.25% NaOCl + Er,Cr:YSGG were shown in (Figure3-5). It is clear that the high dye penetration percentage area was seen in 17%EDTA+ Er,Cr:YSGG at 0.5 W and for 5.25% NaOCl + Er,Cr:YSGG was observed at 0.75 W.

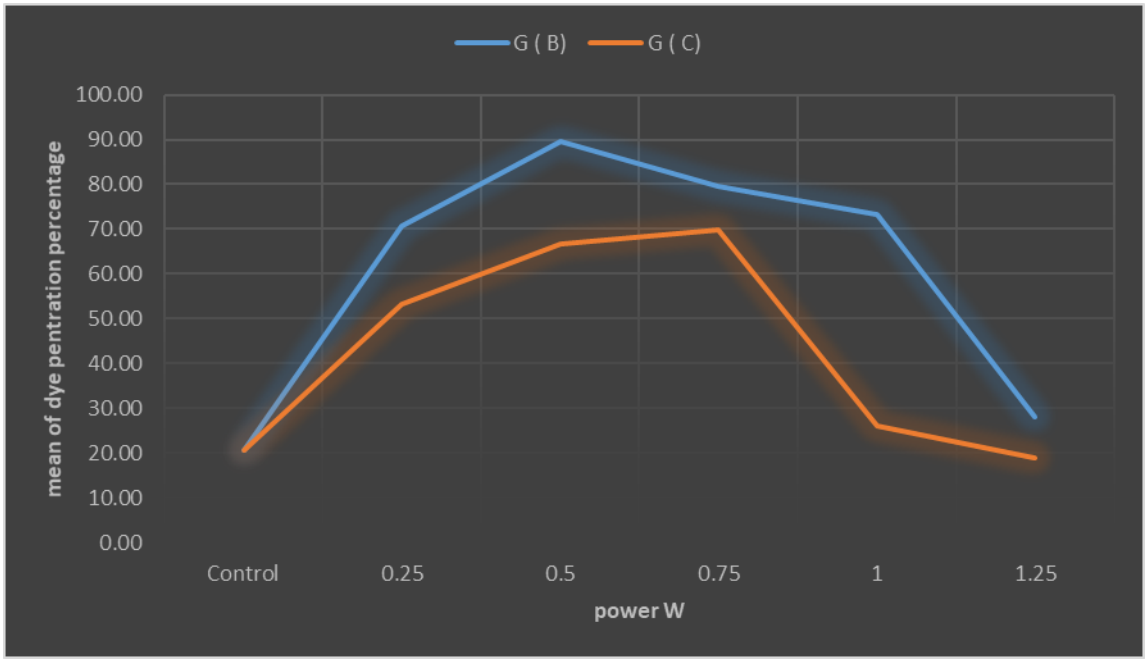


Fig 3-5 The mean values of the percentage of dye penetration area among five power in both17% EDTA+ Er,Cr:YSGG and 5.25 % NaOCl + Er,Cr:YSGG

3.3.2 Permeability of root canal dentin in apical root third for different technique used

The Data of root canal dentin permeability stated as dye Penetrating percentage area at apical root third of canal is shown in Table (3-3).

The table shown that the high percentage of dye penetration area seen in activated laser group with 17%EDTA followed by Erbium laser group with 5.25% NaOCl, and ultrasonic group respectively and the lowest percentage appeared in control group.

Table 3-3 Dye Penetration of four study groups (A) Control (B) 17%EDTA+ Ultrasonic(C) 17%EDTA+ Er,Cr:YSGG (D) 5.25%NaOCl + Er,Cr:YSGG

Groups	**Percentage of dye penetration area**					
	Sample**1**	Sample**2**	Sample**3**	Sample**4**	Sample**5**	Sample**6**
A Control	20.71136	19.88	21.1	22	19.1	21.99
B 17%EDTA+ ULTRASNIC	35.25516	34.05645	34.7	34.8	34.5	34.8
C 17%EDTA+ Er,Cr:YSGG	89.76463	85.87762	83.84926	88.16257	82.42876	82.42876
D 5.25%NaOCl + Er,Cr:YSGG	69.40433	69.37595	71.94869	67.86306	70.50247	69.6

After descriptive and statistical test for the dye penetrating percentage, the highest mean percentage were presented in activate Erbium laser group with 17% EDTA followed by Erbium laser group with 5.25% NaOCl, and ultrasonic group respectively and the lowest mean percentage were appeared in control group with highly significant difference among groups.

Because of the possibility of the statistical analysis program used (ANOVA un stacked) is limited, we have to select another one to know the difference in every group so the Dunnttes the statistical analysis program was our choice.

The summary of descriptive and statistical test for the percentage of dye penetrating area among control and experimental groups are shown in Table 3-4.

From this table we see that the highest mean percentage were presented in activated Erbium laser group with 17%EDTA (Group C) followed by Erbium laser group with 5.25% NaOCl (Group D) and ultrasonic group (Group B).

Table 3-4 Descriptive and statistical test of the percentage of dye penetrating area among control and experimental groups

TESTG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
ControlA	6	20.7969	1.15675	.47224	19.5830	22.0108	19.10	22.00
B	6	34.5453	.45789	.18693	34.0647	35.0258	34.06	35.26
C	6	85.9804	2.69288	1.09937	83.1544	88.8064	82.43	89.76
D	6	69.7817	1.36018	.55529	68.3543	71.2091	67.86	71.95
Total	24	52.7761	26.81153	5.47288	41.4545	64.0976	19.10	89.76

The homogeneity of Variance was shown in Table 3-5

Table 3-5 Test of Homogeneity of Variances

TESTG

Levene Statistic	df1	df2	Sig.
3.070	3	20	.051

ANOVA test was done to analysis of multiple groups of data to determine the variability between groups and within groups as seen in Table 3-6.

Table 3-6 ANOVA test of study groups

TESTG

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	16480.486	3	5493.495	2063.394	.000
Within Groups	53.247	20	2.662		
Total	16533.733	23			

Dunnett's Test was used to compares control group mean against experimental groups mean to see there is a difference as seen in Table 3-7. When an ANOVA test has significant findings, it does not detect which pairs of means are different. Dunnett's can be used after the ANOVA test to detect the pairs with significant differences. From Table 3-7 we observed that high mean difference was between control and activated Erbium laser group with 17%EDTA (Group C) followed by Erbium laser group with 5.25% NaOCl (Group D) and ultrasonic group (Group B) respectively.

Table 3-7 Multiple Comparison between control and experimental groups.

Dependent Variable: TEST Groups

Dunnett t (2-sided)

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
B	control A	13.74838*	.94205	.000	11.3552	16.1415
C	control A	65.18348*	.94205	.000	62.7903	67.5766
D	control A	48.98482*	.94205	.000	46.5917	51.3780

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

The mean values of the dye penetration area percentage among all four groups were shown in (Figure3-6). The percentage of dye penetration area increased in ultrasonic group and became the highest in 17%EDTA+ Er,Cr:YSGG and then there is some reduction in the percentage when the laser is used alone.

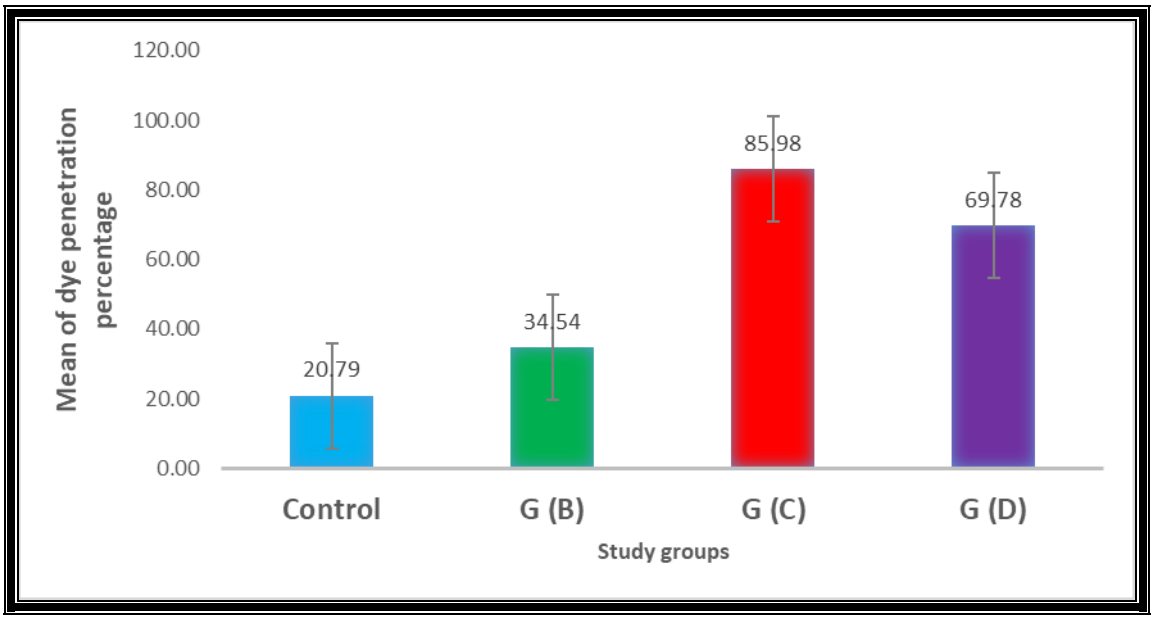


Fig 3-6 Bar chart showing mean of dye penetration percentage of study groups.

3.4 Discussion of results

The present study investigates the effect of Er,Cr:YSGG photon-induced photoacoustic streaming (PIPS) technique at short pulse duration (60 μs) with different powers setting (0.25 W ,0.5 W, 0.75 W,1 W,1.25 W) on removal of smear layer in apical third with and without irrigant. Knowing that the power of 0.25 W represents the threshold of shock wave generation (the irrigant activation). That is obtained from experimental trials. In pilot study, we used ANOVA unstacked statistical test. The mean values of the percentage of dye penetration area are: - group (a) resulted in (0.25 W= 70.60±0.33, 0.5 W=89.62±0.27, 0.75 W=79.42±0.35, 1 W=73.19±0.16, 1.25 W=28.05±0.04), while group (b) resulted in (0.25 W=53.19±0.1, 0.5 W=66.55±0.2, 0.75 W=69.77±0.2, 1 W=25.94±0.11, 1.25 W=19.01±0.05). The result of pilot study showed that the optimum power for Er,Cr:YSGG laser with 17% EDTA was 0.5 W, while with 5.25% NaOCl was 0.75 W. The power consuming in the case of the laser with irrigant (EDTA) is less than the laser

alone, which gives clear indication that the laser activated the irrigant (EDTA) while the laser needs more power complete the irrigation function without irrigant. The parameters of the PIPS approach produce a photomechanical effect, which happens when light energy is absorbed in a fluid, rather than a thermal effect [33]. The creation of bubbles due to the absorption of laser energy incorporates the process of laser-activated irrigation [142]. In front of the laser beams, the vapor bubble begins to expand and create void. As a result, the laser tip, which placed just into the root canal coronal portion, needs not to reach to the end of root canal to ensure that the root canal kept unperforated while the shock wave generated removing the apical smear layer smoothly. Each PIPS impulse interacts with the molecules of fluid, creating expansion and subsequent shock waves, which result in the development of a powerful flowing fluid [33]. Tips of Photon-induced photoacoustic streaming utilized with precise settings at a novel tip structure. The irrigation solutions move three-dimensionally because of the powerful photoacoustic shock wave [28]. We also observed that the dye penetration increased with the power increase until a certain limit, which represent the optimal power. Then it starts to decrease which could be explained as, the high power density causes a multiphoton absorption process resulted in molecular dissociation, which means that the structure of the irrigant is changed and hence it loses its ability of the irrigation function.

Now we will discuss the result obtained from experimental study. We compared the effect of different techniques on smear layer removal using four groups (conventional, passive ultrasonic activation PUI, Er,Cr:YSGG+17%EDTA with PIPS, Er,Cr:YSGG+5.25%NaOCl with PIPS). From statistical analysis, the high mean difference of dye penetration area was observed between control and activated Erbium laser group with 17%EDTA (Group C) (65.18348$^{*)}$ followed by Erbium laser group with

5.25% NaOCl (Group D) (48.98482*) and ultrasonic group (Group B) (13.74838*) respectively.

In comparison to previous study [133] that used Er,Cr:YSGG laser with Radial Firing Tip, the mean value of dye penetration percentage in apical root third was 59.118 while in our study we obtained better result 85.980 by using PIPS technique. The mean value of dye penetration percentage was increased about 27% in our study than previous study.

Using rotary instruments and chemical irrigation in existing instrumentation techniques stay fail of successful removal of the smear layer. This results seen in the control group (group A) in which the conventional method used.

The photomechanical effect may generate shock waves generation which occur after the incidence of pulsed light energy in liquid [34, 143]. The shock wave is generated due to high power density, which perform via short pulse duration. It is worth mentioned that this phenomenon was the main reason for the smear layer elimination in (group D) (the laser alone with 5.25 % NaOCl) that gives better result than conventional and ultrasonic group. Both functions was verified when using NaOCl, liquid media for shock wave transformation in addition to disinfection. This energy transfer results in a series of fast and intense shock waves capable of powerfully propelling the liquid across the entire root canal system [33, 95] while if laser used alone without presence of liquid PIPE technique will not occur. Because of the diminutive volume, the effect can eliminate residual tissue and the smear layer and decline bacterial contents with the tubules and accessory canals [144-146]. In this study the smear layer was removed by means of photomechanical flowing of the liquids where laser activation in coronal access of the root and not by thermal vaporization. In conventional treatment procedures, the tip of the irrigation syringe becomes more active if positioned closer to the working length but in

the laser procedure the laser tip not positioned with the canal, but it is restricted to coronal access beyond the orifice to allow simple access of the photomechanical effects to take place inside the root canal. This can help in cleaning of numerous canals shapes.

Standard laser applications need typical preparing at minimum size 30, with the laser tip reaching the apical root third. The PIPS tip, on other hand, does not require penetrating the canal end and just put in the root canal's coronal reservoir. As a result, this procedure permits for minimally invasive cleaning of the root canal [28].

3.5 Conclusions

From the extracted results, we can conclude that

- Short pulsed Er,Cr:YSGG (60 us , 5 Hz , air and water off) with 17% EDTA using photo induce photoacaustic streaming technique proved effectively for activation of irrigant in endodontic treatment in smear layer removal at 0.5 W.

- Improved result was obtained for smear layer removal using Er,Cr:YSGG alone assisted by 5.25% NaOCl for both functions disinfection and shock wave generation simultaneously at 0.75 W .

- Both applications (with and without irrigants) using Er,Cr:YSGG induce photoacaustic streaming technique are better than ultrasonic activation in smear layer removal. The activation improvements are 85.98% for laser with irrigant, 69.78% for laser alone and 34.54% for ultrasonic.

- Er,Cr:YSGG induce photoacaustic streaming technique is simple, easily used so it is recommended to be used clinically.

3. 6 suggestions for future work

1. Comparing between different irrigant types other than that used in the study with PIPS technique in smear layer removal.
2. Study PIPS technique with other type of laser like Er,YAG laser.
3. Study bactericidal effect of PIPS technique.
4. Study temperature raise inside canal when we use PIPS technique.
5. Study medication injecting things dycal (calcium hydroxide) with PIPS technique.

3.7 References

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تقانة الري بالتدفق الصوتي-الضوئي المحتث بليزر الاربيوم-كروميوم لمعالجة قناة جذر السن

الخلاصة

مقدمة: إعداد قنوات الجذر هو خطوة هامة في علاج قناة الجذر. وبما ان التنظيف الميكانيكي لقنوات الجذر ينتج عنه طبقة غير منتظمة من الحطام ، تعرف باسم طبقة اللطاخة التي تعيق تخلخل مادة السقي الى داخل قنوات السن وبذلك تحد من عملية التعقيم ونتيجة لذلك، ذكرت العديد من الدراسات أن يفضل إزالة طبقة اللطاخة.

الهدف:هدف هذه الدراسة هو لدراسة تاثير ليزر الاربيوم ذو الطول الموجي 2780 نانومتر باستخدام تقنية (الري المتدفق الضوئي الصوتي الناجم عن الفوتون) في مدة النبض القصيرة 60 ميكروثانية مع قدرة مختلفة 0.25 واط,0.5 واط,0.75 واط,1 واط,1.25 واط مع مادة السقي اوبدونها على ازالة الطبقة اللطاخة وبعد ذلك نقوم بمقارنة النتائج مع جهاز الاهتزاز فوق الصوتي.

الطريقة: مجموعة عددها ستة وستون سن احادي الجذر من الضواحك السفلية.تم توحيد طول الجذور إلى 14 ملم من القمة التشريحية . حضرت قنوات جذور الاسنان ميكانيكيا إلى حجم 40. ثم استخدمت 12 عينة لاجل دراسة تاثير المحاليل على الطبقة اللطاخة عن طريق الفحص بواسطة المجهر الالكتروني الماسح. للدراسة التجريبية استخدمت ثلاثين عينة. تم تقسيم هذه العينات الى مجموعتين من طرق الري التالية 1/طريقة التدفق الصوتي الضوئي المستحثة بواسطة اربيوم ليزر مع EDTA%17عند 0.25 واط,0.5 واط,0.75 واط,1واط,1.25 واط. 2/طريقة التدفق الصوتي الضوئي بواسطة اربيوم ليزر مع NaOCl%5.25عند 0.25 واط 0.5 ,واط, 0.75 واط, 1 واط, 1.25 واط. ثم مقارنة هذه المجموعات مع متوسط مجموعة التحكم. بعد الدراسة التجريبية،استخدمت 24عينة. العينات تنقسم إلى أربع مجموعات (n= 6) وتستخدم على النحو التالي: (A) الري التقليدي (CI)) مع 5 مل من 17 ٪ EDTA، (B) الري بالموجات فوق الصوتية (PUI)) مع 5 مل من 17 ٪ EDTA، (C) Er.Cr: YSGGمع تقنية التدفق الصوتية الضوئية المستحثة (PIPS)) مع 5 مل من 17 ٪ EDTA ، و (D) Er,Cr: YSGG مع تقنية التدفق الصوتية الضوئية (PIPS) مع 5 مل 5.25 ٪ l NaOCl. بعد الري النهائي والتجفيف، تصبغ الجذور مع طلاء الأظافر خارجيا، وتحقن 2٪ من صبغة الميثيلين الزرقاء في القناة. يقسم السن بشكل عرضي مع قرص ألماس عند المليمتر الرابع من قمة الجذر الذي يمثل الثلث القمي. الصور تلتقط بالكاميرا SLR الرقمية المهنية (نيكون D7100، نيكون كوربوريشن، تايلاند) لكل عينة مع تكبير X40. اختراق الصبغة يقاس باستخدام

البرمجيات التحليلية (قياس صورة CAD-KAS كيسلر ألمانيا). اختبار ANOVA و Dunntte استخدم لتحليل النتائج.

النتائج: كان متوسط قيم النسبة المئوية لمنطقة اختراق الصبغة في الدراسة التجريبية يتراوح بين (Er,Cr:YSGG ليزر مع EDTA بنسبة 17٪ عند 0.25 واط= 70.60±0.33 ،0.5 واط= 89.62±0.27 ، 0.75 واط= 79.42±0.35، 1 واط= 73.19±0.16، 1.25واط= 28.05±0.04 بينما Er,Cr:YSGG ليزر مع 5.25٪ NaOCl في 0.25واط= 53.19±0.1، 0.5 واط=66.55±0.2, 0.75 واط69.77±0.2، 1واط= 25.94±0.11، 1.25واط= 19.01±0.05). بينما كان في الدراسة المقارنة (20.79±0.47المجموعة التقليدية، 34.54±0.18 مجموعة الموجات فوق الصوتية، 85.98±1.09 Er, Cr.YSGG +17٪ EDTAفي 0.5واط, 69.78±0.55. NaOCl ٪5.25+ Er,Cr:YSGG عند 0.75 واط). كانت النسبة المئوية لاختراق الصبغة في Er,Cr:YSGG laser مع ٪17 EDTA عالية بشكل ملحوظ عند القدرة0.5 ,واط تليها Er,Cr:YSGG laser مع 5.25 ٪ NaOCl في مجموعة ليزر عند 0.75 واط والتي أظهرت أيضا نسبة متميزة من اختراق الصبغة في حين أن المجموعة المنشطة بالموجات فوق الصوتية تؤدي إلى نسبة أقل من اختراق الصبغة من مجموعتي Erbium.

الاستنتاج :أن استخدام الليزر النبضي Er,Cr:YSGG (5 هرتز, الهواء والماء مغلق) في مدة النبض قصيرة (60 ميكروثانية) مع ٪17 EDTA باستخدام تقنية PIPS لتنشيط irrigant في علاج حشوات الجذور فعال في إزالة الطبقة اللطاخة في 0.5 واط. في حين أثبتت PIPS نتيجة مقبولة عندما يتم استخدام الليزر وحده بمساعدة 5.25٪ NaOCl أو مع irrigant هو أفضل من التنشيط بالموجات فوق الصوتية في إزالة الطبقة اللطاخة.

وزارة التعليم العالي والبحث العلمي

جامعة بغداد

معهد الليزر للدراسات العليا

تقانة الري بالتدفق الصوتي-الضوئي المحتث بليزر الاربيوم-كروميوم لمعالجة قناة جذر السن

رسالة مقدمة الى معهد الليزر للدراسات العليا كجزء من متطلبات نيل درجة

ماجستير في الليزر/طب الاسنان

من قبل

صابرين صباح رشيد

بأشراف

الأستاذ الدكتور حسين علي جواد

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