Ministry of Higher Education and
Scientific Research/Baghdad University
Institute of Laser for Postgraduate Studies

Effect of Diode Laser 940 nm and LED (450-505)nm on Whitening Efficiency in stained teeth (in vitro and in vivo study)

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

Ali A Hassab Shawkat

B.D.S .H.D.P.P.

Supervisor

Assist. Prof. Basima Mohammed Ali

2020 AB **1442 AH**

بسم الله الرحمن الرحيم

قُلْ هَلْ يَسْتَوِى ٱلَّذِينَ يَعْلَمُونَ وَٱلَّذِينَ لَا يَعْلَمُونَ ۗ
إِنَّمَا يَتَذَكَّرُ أُو۟لُوا۟ ٱلْأَلْبَٰبِ ٩

صدق الله العظيم
سورة الزمر

Certification

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

Signature

Name: Dr. Basima Mohammed Ali Hussien

Title: Assist. Professor

Address: Head of Biomedical applications Department/

Institute of Laser for Postgraduate Studies/

University of Baghdad

Date: / /2020

In view of available recommendation, I forward this thesis for debate by the examination committee.

Signature

Name: Dr. Hanan Jaafar Taher

Title: Assist. Professor

Address: Head of Scientific Committee/

Institute of Laser for Postgraduate Studies/

University of Baghdad

Date: / /2020

Examination Committee Certification

We certify that we have read this thesis " Laser and LED assisted whitening of teeth " , and as an Examination Committee, we examined the student **Ali Abdulameer Hassab** in its content and in our opinion it is adequate with standards as a thesis for the degree of **Master of Science in laser/Dentistry.**

Signature

Name: Dr. Abdulhadi M. Al-Janabi

Title: Professor

Address: Institute of laser for postgraduate studies / Baghdad University

Date: / / 2021

(Chairman)

Signature

Name: Dr. Anas Falah Mahdi

Title: Assist . Professor

Address: College of Dentistry / Baghdad University

Date: / / 201 Date: / / 2021

(Member)

Signature

Name : Dr. Thekra Muhammed Hachim

Title: Assist. Professor

Address: Ashur university

Date: / / 2021

(Member)

Signature

Name: Dr. Basima Mohammed Ali

Title: Assist. Professor

Address: Institute of Laser for Postgraduate Studies/Baghdad Univesity

Date: / / 2021

(Supervisor)

Approval by the deanship of the Institute of Laser for Postgraduate Studies / Baghdad University.

Signature

Name: Dr. Hussein A. Jawad

Title: Professor

Address: Dean of Institute of Laser

for Postgraduate Studies / Baghdad University

Date: / / 2021

Dedication

To everyone who lit a candle of hope

in my way even by simple words

I dedicate this work ..

ALI

Acknowledgment

First of all, I would like to thank **Allah** for inspiring me with the strength and willingness to perform this work.

My highest appreciation to the Dean of the Institute of Laser for Postgraduate Studies **Prof. Dr. Hussain A. Jawad**, whom I was fortunate to be one of his students for his kindness, patience, and encouragement.

I would like to express my sincere appreciation to my supervisor **Assist Prof. Dr. Basima Mohammed Ali Hussein** (Institute of Laser for Postgraduate Studies/ University of Baghdad), whom I was fortunate to be under her supervision, I'm deeply indebted to her for her patience, advices, and scientific support. Also , I would like to thank **Prof. Dr Abdulhadi M. Abed** (Institute of Laser for Postgraduate Studies/ University of Baghdad) one of my best teachers in life whom I am really so lucky to be one of his students for his scientific guidance, help and support.

Also, I like to express my admiration and thanks to **Lecturer Dr. Mohammed G. Rzoqi** (Institute of Laser for Postgraduate Studies/University of Baghdad) for his cooperation , Also I wish to express my thanks to the **Dean Assistant Dr. Mahmood Shaker** (Institute of Laser for Postgraduate Studies / University of Baghdad), for his help and efforts with me in this work.

Also, I like to thank **Assist Prof. Dr. Muhammed K. Dhaher** (Institute of Laser for Postgraduate Studies / University of Baghdad), for his advices and help. Also, I wish to thank **Assist prof. Dr Hanan Jaafer** (Institute of Laser for Postgraduate Studies/ University of Baghdad). For her advices and help and I am grateful to the advices, support and the help of **Assist prof. Dr Zainab Mahdi** (Institute of Laser for Postgraduate Studies/ University of Baghdad).

For all teaching staff members in the Institute of Laser for postgraduate study …thank you very much .

Abstract

Background :

Teeth staining is one of the esthetic problems faced both dentists and patients. Many methods were done to solve the trouble as restorations, crowns, bleaching etc. Dental bleaching may be achieved by use of chemical, thermal or light aids. Among the light assisted procedures is the laser and LED.

Aim :

To test the effect of Diode laser 940 nm and LED (450-505 nm) on whitening efficiency of 32% hydrogen peroxide on extrinsic stained teeth and their effect on pulp temperature, surface topography and roughness, teeth sensitivity and whitening stability measured after one month post operatively.

Materials and methods :

In vitro study included 60 extracted teeth (canines and second premolars) divided into 6 groups: control group (immersed in distal water), already tobacco stained group (immersed in distal water) and other four groups immersed in either tea, coffee, cola, juice. These groups were incubated at 37 ^{o}C for 14 days then subdivided according to bleaching technique into either (laser group) or (LED group). The roots of all teeth were cut off to get 17 mm standard lengths of teeth before debriding their soft tissue contents. A thermocouple thermometers wire was inserted inside each tooth reaching the pulp chambers to measure the pulp temperature changes during bleaching procedure. The root was immersed in a warm water bath at 37 ^{o} C during the lasing procedure to mimic the human body temperature. The bleaching gel was placed on the labial surfaces of the teeth by approximately 2 mm thickness

according to the manufacture recommendations then whitening procedure was performed using either diode laser or LED. Diode laser parameters were 7 W(output power) for 2 min. (total time exposure), while LED parameters were 30 W (output) for 20 min.(total time exposure). The temperature of pulp cores was measured and the shades of teeth were recorded before and after bleaching using VITAPAN shade guide. All specimens were examined under optical microscope before and after the bleaching process beside examining the bleached teeth by both AFM and SEM to study their surface topography. For the in vivo part of study, 15 patients aging 25-40 years diagnosed with extrinsic stained anterior teeth. For comparison, diode laser 940nm was used to accelerate whitening of the right side of the teeth using parameters recommended by the manufacture while LED used to in the other side. Shade of teeth and sensitivity were recorded for each patient before and after whitening procedure before follow up was done after one month.

Results:

All the data of the results of the in vitro study showed significant difference in temperature raise with benefit to laser method. Whitening efficiency showed both techniques has high significance in whitening efficiency. In vivo study showed both LED and laser achieved significant change in shades of bleached teeth. Laser has less teeth sensitivity during and one month after bleaching than LED as well as Laser has more whitening stability than LED.

Conclusion:

Diode laser bleaching achieved safer effect on pulp temperature, less teeth sensitivity and better whitening stability following one month than LED.

List of contents

List of tables

List of Figures

List of Abbreviations

Abbreviations	Term
#	number
ADA	American Dental Association
ANOVA	Analysis of Variance
AFM	Atomic force microscope
A.M	At morning
Abs.	absorption
ATP	Adenosine triphosphate
β	beta
C	Speed of light = $3x10^8$ m/s
CO_2	Carbon dioxide
CP	Carbamide peroxide ($CH_4N_2OH_2O_2$)
CPS	Cycle per second
CW	Continuous wave
df	Degree of freedom
DNA	Deoxyriboneuclic acid
E	Energy
Er:YAG	Erbium-doped:Yttrium, Aluminum, and Gernet
ES	Effect size
ET	Exposure time
eV	Electron volt
FT	Fourier transform
g	gram
G1	Group 1
G2	Group 2
h	Planck's constant = $6.63x10^{-34}$ Js
HP	Hydrogen Peroxide (H_2O_2)
Hz	Hertz (unit of frequency)
H_2O	water
He	Helium gas
Hs	High significance
InGaAs	Indium-Gallium-arsenide
ISO	International Organization for Standardization
IR	infrared
i.e	For example
J	Joule (Energy unit)
KTP	Potassium titanyl phosphate crystal
LED	Light emitted diode
m	Meter

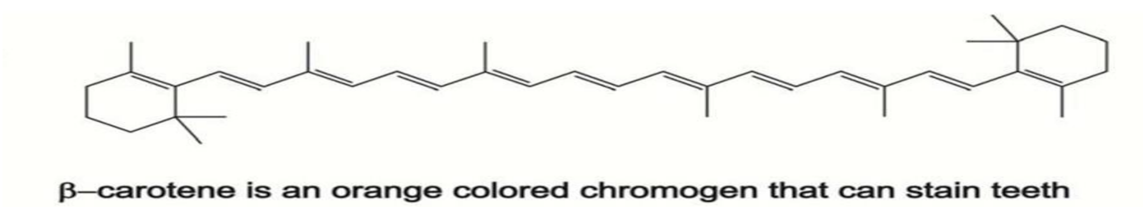
Min.	minimum
mm	Millimeter = 10^{-3} m
Max.	maximum
mW	Mill watt = 10^{-3} W
ml	milliliter
N	Number of samples
Ne	Neon gas
Nd:YAG	Neodymium doped Yttrium –Aluminum Garnet
NIR	Near infrared
nm	nanometer
^oC	Degree Celsius (unit of temperature)
OTC	Over-The-Counter
O_2	oxygen
00	Zero zero
OH	Hydroxyl group
P	Power
PD	Power density
PDT	Photodynamic therapy
pH	Power of hydrogen
pc	Portable computer
s	Second (unit of time)
SD	Standard Deviation
SE	Standard Error
SEM	Scanning electron microscope
Sh	shade
Sig.	significant
Ti	titanium
r	relation
RO	alkoxyl
ROO	peroxyl
VAS	Visual analogue scale
W	Watt (unit of power)
W/cm^2	Watt per centimeter square (unit of power density)
λ	Wavelength sample
μm	Micrometer =10^{-6} m
UV	Ultraviolet light
υ	photon frequency measured in units of Hz
10X	10 times magnification

Chapter one

Introduction

1-1 Introduction

1-1-1 Teeth staining The problem of teeth staining existed in most of world countries for many years, since ancient periods of developing of such countries, and been regarded as one of the aesthetic problems that seeks for the solution (Watts et al 2001). Many studies regarded the aesthetic appearance of teeth is more important than any trouble in their position (Pretty et al 2006). The stain usually occurs due to accumulation of the organic complex molecules which occur due to either intrinsic or extrinsic factors leading to classifying these stains into intrinsic or extrinsic stain. The organic complex molecules of such stain called (The chromogens) which are usually accumulated either within the structure of the teeth to give the intrinsic staining or accumulated on the outer surface of the teeth giving the extrinsic staining. These chromogens can be bound into large organic compounds where they are connected to each other by double bonds as shown (figure 1-1) (Clifton 2014).



Figure(1-1) Chemical composition of chromogen (Clifton 2014)

Dental practitioners have an enough illustrating information of the causes of the discoloration of the teeth color to make an efficient diagnosis and then to present the appropriate treatment or correction for that discoloration (Aryan 2005).Teeth staining varies in etiology, composition, severity, appearances, adherence degree and location. Therefore, the attraction of tooth surface to the materials has great effect in deposition of any extrinsic stains but anyhow the mechanism of this attachment strength of the stains to the tooth surface is not completely clear (Tirth et al 2009).

1-1-1-I Classification of stain :

A- The intrinsic staining:

This type of stain can be attributed to some factors that lead to accumulation of the coloring stain within the structure of the teeth which may be due to genetic causes, age (wearing of enamel layer expose the more darker underlying layer of dentin), high absorption of fluoride, drug poisoning like tetracycline drug discoloration of teeth, amalgam filling of teeth, endodontic treated teeth, traumatized teeth which may be due to internal hyperemia or bleeding inside the teeth (Aryan et al 2005).

B- The extrinsic teeth staining: This type of staining occurs because of acquired causes like smoking, special stained drinks and foods, drugs, and metal poisoning like copper and iron where such stains by time and frequency, being adsorbed by the acquired outer layer on the surface of the teeth (acquired pellicle) which then give the pigmented color of the teeth with varying degree according to many factors like:

1- Type of staining which affect greatly on the degree of staining of the teeth.

2- Duration of staining where any application of any staining factor for long time will produce more color discoloration.

3- Concentration of staining where for more concentrated staining agent produce more tooth discoloration.

4- Variation of teeth morphology where for thin enameled teeth or thick enamel affect the ability of the teeth to reflect varying tooth discoloration.

5- Modes of cleaning where for more acceptable manner of teeth cleaning decrease the effect of staining agents.

6- Age where older patients can get more precipitated staining on teeth than younger patient (wearing of enamel by time may enhance rough surface that attract any extrinsic stains).

7- Sex where for male gender can get teeth discoloration more than female gender (Joiner et al 2006).

1-1-1-II Causes of the extrinsic stains:

The extrinsic staining can be subdivided into two categories according to their interaction with surface compounds of tooth (Sruthi et al 2013):

a) Direct extrinsic staining*:* These materials are incorporated into the of pellicle layer (on tooth surface) which then produce the stain according to their basic color.

b) Indirect extrinsic staining: These compounds have staining effect that is caused by the chemical inter-action on the tooth surface.

The Direct extrinsic tooth staining has multiple causes with the chromogens that derived from diet sources or habits affected inside the mouth where the chromogens are adsorbed by the pellicle layer and the color created is formed by the natural basic color of the chromogens which then affect the color of the plaque (the complicated acquired layer formed from uncleaned pellicle on the tooth surface) (George et al 2016). The chewing foods, drinks and Tobacco smoking are known to cause staining (figure 1-2). The color that seen on the tooth surface is believed to be derived from the polyphenolic compounds that give the color in food. The indirect extrinsic stain may be associated with metal salts and cationic antiseptic substances produced on the tooth surface (Clifton 2014).

Figure (1-2): Some Extrinsic stains of teeth (Clifton 2014)

Patients with bad oral hygiene with accumulated calculus stained with different habitual staining substances that lead eventually to staining them by the stains from these foods Although other authors believed that there is association between such dark staining of plaque (figure1-3) due to the interaction between its bacteria colonies (chromogenic bacteria) (José 2018).

Figure (1-3) Effect of chromogenic bacteria of bad oral hygiene (Dharti 2015)

The Extrinsic stain of teeth could be due to an occupational exposure to some metal salts and some drugs containing metallic salts. The characteristic black stain of the teeth in people who are using the iron supplements and those who are working in iron factories is well documented (Tirth et al 2009). Copper can cause a green stain in some mouth rinses that contain copper salts (table 1-1) some other metals may have association in colors staining of teeth like potassium permanganate which produce a black to violate color stain when used within mouth rinses (silver nitrate salt) that is used in dentistry (in pastes to prevent arrested caries) can cause greyish discoloration, stannous fluoride can cause a golden-brown stain. The use of chlorhexidine mouth rinse also may give rise to such discoloration. Also The essential oil phenolic mouth rinses as the 'Listerine' with the long usage of phenol Mouth rinses cause the same discoloration. The degree of staining differ from one person to other, this makes the explanation more complicated because it may be due to intrinsic factors or differences in extrinsic factors or may be both (Sruthi et al 2013) (table 1-1).

Table 1-1 Stains types, sources, appearance with common tooth sites (Sruthi 2013

stain type	Source or predisposing factor	Appearance surfaces of tooth	Common tooth sites
Brown stain	Intake of coffee and tea. With insufficient teeth brushing, lead to Chromogenic bacteria	Thin, translucent, acquired bacteria free pigment pellicle	Buccal surface of upper molars. And Lingual surface of lower incisors
Black stain	Coal tar products of smoking. Exposure to iron , silver , manganese.	These are dark brown or black in color	all the teeth surfaces . Common in fissures and pits
Black line stain	Chromogenic bacteria-e.g. Gram positive rods Actimomyces species like Bacteriodes melaninogenicus.	firmly attached on tooth surface.	lingual surface of a tooth.

Green stain	chromogenic bacterial deposits Copper salts in mouth rinse And Exposing to nickel and copper in the factory workers	green or greenish yellow stains	Labial surfaces of Upper anterior teeth.
Metallic stain	metals and metallic salts. penetrated into tooth surfaces and bind with pellicle giving surface stain.		Generalized appearance on all the teeth.
Yellowish brown stains	Chlorhexidine may react with acidic and sulfate groups such as those found within the pellicle, plaque and carious lesions tissues	Yellowish brown to brownish could be removed with proper brushing with dentifrice	Cervical and interproximal area of the teeth, Plaque and around restorations and on dorsal surface of tongue
Golden brown stains	Due to use of stannous fluoride		labial and lingual surfaces of teeth

1-1-2 Evaluation of tooth coloring :

The color of any tooth usually assessed from the color of outer surface of teeth that is to be taken in consideration when to plan for doing filing or any restoration (Joiner et al 2006) and this measurement is facilitated through the graduated color of the various teeth color that obeys the schematic basic coloration combination that is simplified by the color circle or color wheel as illustrated in figure (1-4A) where such diagrams regarded as the base of combining the colors (Sikri 2010) figure(1-4 B)

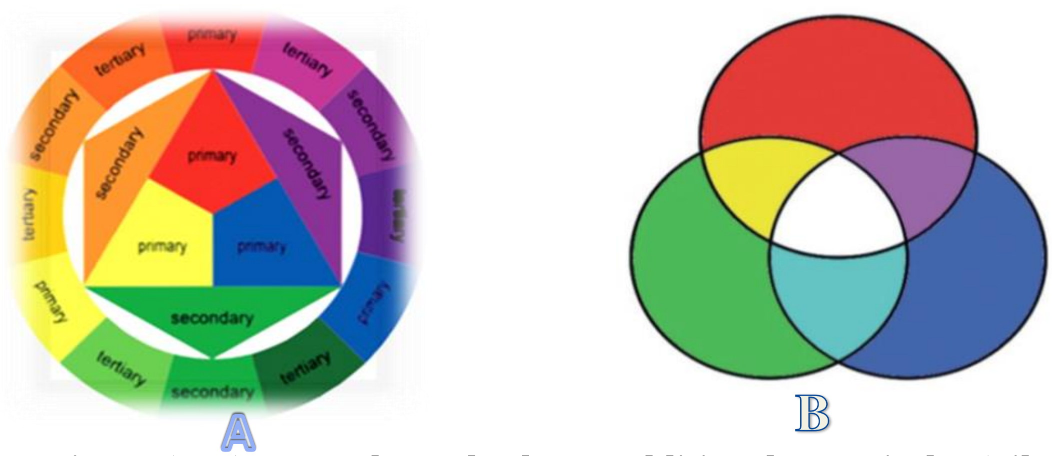


Figure (1-4): A: colors wheel B: additive theory circles (Sikri 2010)

1-1-3 Description of color: The terms **hue** , **value** and **chroma** usually described the colors according to the Munsell system where the color value is determined then the chroma and lastly the hue by comparing the color to a shade tabs of values (Terry 2002).

VALUE: it means the degree of brightness by the reflected light from any object (figure 1-5) (Sikri 2010) it is described by Munsell as white to black gray scale where the higher value objects means they have less amount of gray (brighter) while lower value objects have larger amount of gray (less bright) this brightness comes from either lower chroma or increase in reflectivity of the surface (Boksman 2007).

CHROMA: it means the intensity of any color added to any object which leads to more darker color, this variation in chroma then will have great relation with value (brightness) i.e as the chroma increase then the value decrease with constant hue (the same color) (Boksman, 2007).

HUE: it is an interpretation of a band of colors (wavelengths) represent the quality that distinguish each band from other represented by a shade guide as A,B,C or D (Boksman 2007) .

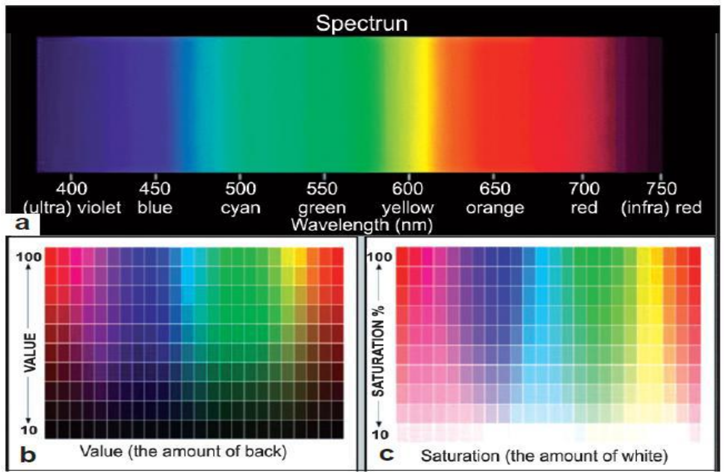


Figure (1-5): Three descriptions of color: Hue ,Value and Chroma (Sikri et al 2010).

1-1-4 Treatment of teeth Staining:

1- Brushing: Effective teeth brushing two times a day with an efficient dentifrice can help to prevent and remove the extrinsic teeth staining.

2- Scaling: Ultrasonic and sonic scalers use the quick small vibrations with a water flow that gives great effectiveness in removal of the deposits with vibrations of frequencies within a range of 25,000–45,000 Hz. The Micro-vibrations crush and removes the calculus combined by a cooling water. sonic and ultrasonic scalars differ in their efficiency to remove calculus from the teeth surfaces. The Sonic scalars are air-turbine devices operated by low frequencies with a range of 3000 - 8000 Cps (American Academy of Pediatric Dentistry 2000).

3- Polishing: polishing the stained areas on the tooth surface using An angle hand piece and rubber cup with a fine abrasive paste, polishing for about 30 sec with a prophylactic paste that contains pumice may remove between 0.6 μm to 4 μm from the outer tooth enamel (American Academy of Pediatric Dentistry 2000).

4- Whitening rinses: the Whitening rinses can prevent the teeth stain and plaque accumulation on the tooth surface. A low concentration of hydrogen peroxide (HP) (1.5 %) is used within the rinse to prevent any accumulation of any new stain (Demarco et al 2009).

5- Whitening strips: The whitening strips contain polyethylene where they are applied for only 30 min and delivered by a tray that can cover only the anterior teeth, the HP within its composition will be liberated from the composition reacting with the stain of the tooth surface (Alqahtani 2014).

6- Microabration: removal of superficial enamel stained Brown, white spots and streaks on the tooth surface by a compound which made of diluted hydrochloric acid and an abrasive powder that is used, in a water soluble silica gel (George 2016).

7- Direct composite filling: by removing the stained spot by a bur then by direct composite filling replace its position to enhance the aesthetic solution for that discoloration problem (George 2016).

8- Direct resin-based composite veneers: by construction a veneer cover the stained tooth that match the original color of the unstained teeth and cover the discolorations as an immediate solution for aesthetic problem (George 2016).

9- Crowns: use crown to cover the stained tooth.The stained tooth prepared from all its surfaces to receive full aesthetic crown to cover the whole tooth with considering the shade of the adjacent teeth .

10- Teeth whitening (bleaching): bleaching can be defined according to The International Organization for Standardization (ISO) as (removal of the intrinsic or acquired discolorations of natural teeth) where this can be done by the chemical action of some chemical compounds with or without light to accelerate the chemical reaction of the bleacher substance (ISO 2011). The bleaching was regarded as the minimally invasive, fast, safe, easy and low cost procedure although some researchers reported concerns about the potential changes of the teeth structure after the bleaching process (Rodrigo et al 2010 ; Luca et al 2019). Main action of teeth bleaching: The basic action of bleaching agent is to break down the complex large long chains of the stain chromogens into simple small short chains that can be then easily degraded. The most commonly active ingredients used in dental bleaching are the hydrogen peroxide which was introduced in 1884 (Shivaprasad et al 2019). Hydrogen peroxide (H_2O_2) is a chemical compound with high oxidative effect. Highly unstable and can dissociated into water, oxygen and free radicals when come into contact with tissues (Jankovic et al 2009). The principle mechanism of the hydrogen peroxide (H_2O_2) is the same where it penetrates through the organic structure of both the enamel and dentin layers of the tooth increasing the permeability of these structures. As this agent is a strong oxidizing agent, it will cause moving the ions within the tooth structure by such operation of oxidation leading to liberation of highly reactive free radicles (Saha et al 2017) which will then react with the organic complex molecules on the enamel surface breaking them into more simple molecules that reflect more light more light(whitening appearance) (Sulieman et al 2005).

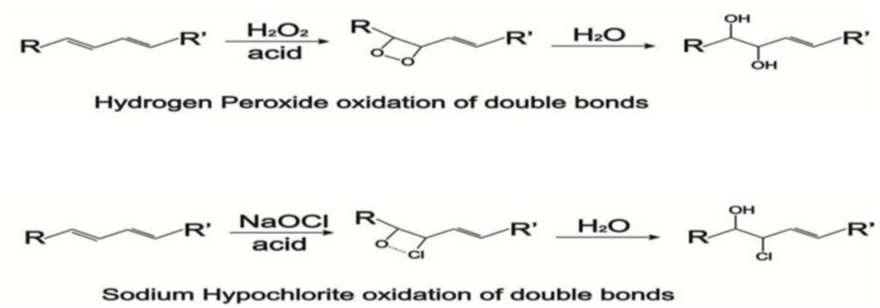


Figure (1-6) Chemical reaction of hydrogen peroxide with a chromogen (Clifton 2014)

1-1-4-I Main bleaching agents used :

The bleaching agents mainly presented as viscous or gels with different vehicles and colors, the most common agents used are :

1- **Hydrogen peroxide:** which has the reactive O_2 beside the hydroxyl (OH^-) , alkoxyl (RO) and peroxyl (ROO) (Tredwin et al 2006).
2- **Sodium Perborate:** 95% perborate acidic, by warm water or air decomposed into metaporate, HP and nascent oxygen , it is safer than concentrated HP**.**
3- **Carbamide Peroxide:** it is urea hydrogen peroxide breakdown to form urea, ammonia, carbon dioxide and HP (Rotstein et al 2002).

1-1-4-II Composition of bleaching gel:

The main bleaching active ingredient is the HP with different concentrations with other major ingredients are: (Alqahtani 2014)

1-Urea: for stabilization the HP and also to rise the pH of the agent (Hegde et al 2012).

2- Thickening agents: mainly Carbopol (carboxypolymethylene) Its concentration is usually between 0.5 % and 1.5 % which give viscosity and also increase the active oxygen releasing time of the bleaching agent by 4 times.

3- Preservative: mainly Methyl, sodium benzoate and propylparaben to preserve components and prevent bacterial growth and also accelerate decomposition of HP.

4- Flavoring: commonly peppermint, wintergreen, spearmint and sweeteners like saccharine to give accepted taste.

5- Carrier: commonly Glycerin and propylene glycol to maintain moisture and also to aid dissolving other components**.**

6- Surfactant and pigment dispersant: which used for wetting and help the active ingredients to diffuse while the pigment dispersant keeps the pigments in suspension.

1-1-4-IV Classification of Bleaching:

A- Home bleaching: this type may be

(**1) Tooth brushing** with bleaching agent contained tooth paste.

(2) Whitening rinse where it contains HP used 2 times a day.

(3) Whitening gels these gels contain hydrogen peroxide which is delivered by special plastic strips twice a day for 30 minutes for two weeks (Jancovic 2009).

B- In Office whitening: It is quick and use higher concentrated HP after protecting the gingiva by special agents. It is more common than the home bleaching due to advantages of short time, less chances of material swallowing, less soft tissue damaging and no need for trays (Ontiveros et al 2009) where this bleaching agent applied directly over the labial surface of teeth and being activated by:

1- Self-chemical reaction: where it depend only on the chemical reaction of the bleaching components that lead to the liberation of the free oxygen radicles by the oxidizing process leading to the bleaching action (Clifton 2014).

2- Light: with wave length ranging from 480 to 520 nm (halogen lamps or light emitting diodes LED) (Niklaus et al 2004). First light used to increase effectiveness of bleaching was introduced in 1937 (Ames 1937).

3-Laser light: Where it depends mainly on the use of laser to activate the bleaching which lead to photothermal effect on the HP that accelerate the release of the strong oxidizing free radicles and it is described by the term “ power bleaching”(Kossatz et al 2011). Where they use long wavelengths (which have low energy photons with high thermal effect) like diode lasers and Er:YAG laser (Abdelfattah 2014) or short wavelengths which have less thermal effect and high energy photons like the Argon laser or second harmonic Nd laser (KTP)(Lagori et al 2014 ; Guptaa et al 2011). There are mainly two procedures of laser bleaching, first, photothermal bleaching which known as the "power bleaching method " Photothermal reaction is a process of Transforming the absorbed energy of light into heat which leads to a local rise in temperature. Photo thermal bleaching is an activation of the gel by using a high intensity light source like laser which gives a control heating of the gel breaking down the peroxide compounds.

Second, the photochemical. The Photochemical interaction activates chemical reactions with the HP leading to dissociate it. Photochemical bleaching uses the visible light energy to activate the oxygen molecule. Therefore, the photothermal bleaching is usually more well known and mostly used now days**.** Figure (1-7) shows the comparison between effectiveness of using the non-laser and the laser light sources (Abdelfattah 2014) the most common laser used in dental bleaching is diode laser (Niklaus et al 2004 ; Guptaa et al et al 2011 ; Shivaprasad2019).

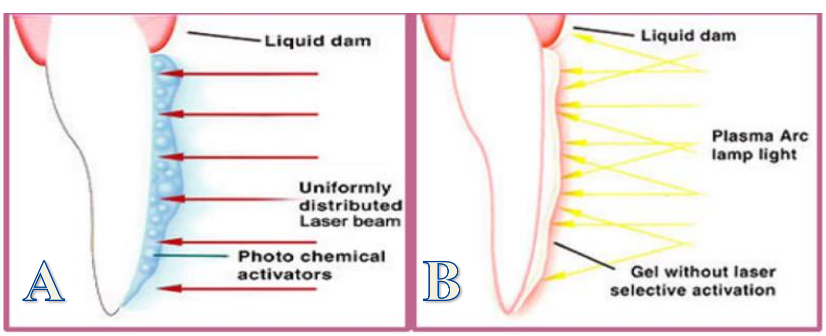


Figure (1-7): Comparison of A using laser and B non-laser system light in bleaching (Abdelfattah 2014)

1-1-5 Diode laser: it is generated from semiconductor crystals by using a combination of gallium, aluminum or indium and Arsenic ranging from 610 to 980 nm (continuous or pulsed modes) (Wetter et al 2004 ; Sulieman 2004). Dostolova et al in 2004 showed in vitro that diode laser used in bleaching require less time without considerable damage to tooth surface under scanning electronmicroscopy (SEM), wide range of wavelengths of diode lasers used in bleaching but the wavelenthgs that are near infrared region are mainly used (Moor et al 2015). Therefore, the diode lasers (780 nm – 980 nm) mainly used (Sulieman 2006).

1-1-6 Advantages of Laser Assisted In-Office Bleaching

(I) Aesthetic where it reports more aesthetic appearance that possess more efficient whitening efficacy for the staining pigments on the surface of teeth ending with more effective results compared to chemical bleaching according to some studies .

(II) Fast where it consume much less time than the conventional chemical bleaching process due to shorter time of accelerating the bleaching agent to liberate the free radicles that bleach the stain molecules.

(III) More comfortable to the patient and dentist as it consume less time consumed during the whitening operation reporting more confidence for both the dentist and patient.

(IV) Less morphological changes of the tooth layers due to the shorter time used for exposing the tooth to the bleaching agent.

(V) Less teeth sensitivity recorded postoperatively compared to other types of bleaching due to shorter time of bleaching beside the occluding action of the dentinal tubules by the action of laser.

(VI) More whitening stability for the bleached teeth for many months compared to other types of bleaching, with taking in consideration that final color change will not be evident before 2 to 4weeks after the bleaching therapy. The average visit times of of in-office bleaching for maximum whitening is 3 ranging from 1-6 visits, patient must be prepared for additional more in-office treatments (Das et al 2014).

1-1-7 Adverse effects :

A- Sensitivity of teeth which occur due to unclear mechanism after penetration of bleaching agents inside the dentinal tubules (Gokai et al 2005 ; He et al 2012 ; **Gaurav et al 2013**), some authors attribute that for the following causes:

1. High concentration of HP lead to diffusion of the bleaching agent into the pulp chamber (Camarga et al 2007).
2. High enamel permeability:-which may be due to decreased thickness of enamel layer due to many factors like wearing up or erosion or congenital anomalies in formation of it (Roeland et al 2015; Turssi et al 2006).
3. Heat generation during irradiation of intense light (Ozyilmaz et al 2015;David et al 2008).

Therefore, according to that, some manufactures tried to solve or lessen this problem by presenting low concentration of HP and addition of desensitizing agents (like potassium nitrate) (Polydorou et al 2013), besides that, there is also physiological dental protector in the pulp (Jankovic et al 2009 ; Dixit 2016).

B-Erosion of teeth after bleaching which occur due to weakening of the outer surface of the tooth because of dissociation of some of the bleached enamel crystals that expose it to any outer stimulus (Guptaa et al 2011).

C- Pulpal damage and increased pulp temperature Any increase in intrapulpal temperature more than 5.5^0 C will lead to irreversible damage of pulp (Kabbach et al 2010 ; Roche et al 2012). Therefore, authors recommended to use special laser hand pieces with large applied area of laser to lessen the heat generation that is created with any small spot application on the tooth surface that is transferred to the pulp causing thermal irritation of it (Niklaus et al 2004 ; Shi et al 2012). It is of important to know that the thermal conductivity of the tooth structure (table 1-2) where the heat transferred through the tooth structure which will be decreased gradually as the light passes from the enamel surface toward the pulp (Kabbach et al 2010). Suggestions recommended use of thick bleaching gel, decrease the exposure of laser application and accelerate the absorption of the laser by the bleaching agent by adding some substances to the gel (Can et al 2011).

Table 1-2: Tooth thermal properties (Kabbach et al 2010)

structure	Diffusivity (m^2/s)	Specific heat ($J/g\ ^oc$)	Thermal Conductivity (W/cm^0C)
Enamel	$2.27*10^{-7}$	0.71	$9.34*10^{-3}$
Dentin	$1.92*10^{-7}$	1.59	$5.69*10^{-3}$
Water	$1.3*10^{-7}$	4.18	$5.61*10^{-3}$

D- Mineral degradation the minerals within the enamel and dentin structure affected by the effect of bleaching gel leading to breaking up their bonds causing dissociation of them, such issue is regarded as relative problem dependently that may lead to weakening of the tooth to some degree (Berger et al 2010).

Therefore, the main effective factor for accelerating the bleaching process is heating the bleaching agent whether by direct heating or by light used in irradiation. The presence of special photosensitizers within the bleaching agent has very good effect in accelerating the bleaching and reducing time for that and then reducing heat generated (Niklaus et al 2004 ; Patrica et al 2000). Average number of visits for in office bleaching is 3 visits, with a range of 1 to 6 visits, the 35% H_2O_2 is preferred for good results (Jancovic 2009).

1-1-8 Laser

Professor Theodor Maiman in 1961 was firstly demonstrated a practical laser using Ruby crystal to demonstrate the optical pumping by flash lamp to generate pink pulsed laser of 694 nm. Javan and Bennet in 1960 produced the gas laser by using He –Ne gas mixture. in 1962 R. Hall demonstrated the first diode laser from gallium arsenide (GaAs) by 850 nm also at the same year, Nick Holoneyak in 1963 demonstrated more developed semiconductor for visible-light-emitting laser, then later on, in 1963 Chandra Kumar was the first user of CO_2 laser (Kaung 2009; Subhash et al 2012; Orazio e2010; Emilly 2012).

In 1969, Geusic, Marcos and Van demonstrated the neodymium doped Yttrium aluminium –garnet (Nd:YAG) laser at Bell Labs (Geusic 1964) also in the same year Bridges of Hughes Research Laboratories demonstrated the Argon laser production (Bridges1964).

In 1974 Zharikov et al introduced the Er: YAG as solid state laser which produce laser with 2940 nm **.** In 1990 Myers introduced the Nd: YAG laser in united states regarding it the first laser for clinical use in dentistry (Myers 1990).

1-1-8-I Properties of laser light (William 2003 ; Robert et al 2011):

Coherence: which means that the beam of the laser has close phase in all its parts of the wave at any temporal or spatial portions giving it constant size and shape along its propagation which represent the focused electromagnetic energy due to identical amplitude and frequency of the wave photons**.**

Monochromacity: It means that all the photons of the laser light have single or very close wavelength band which is relative term more than real term but we can get more monochromatic laser by suppressing all other modes except the central intense mode.

Collimation: It means the laser output travel with parallel beam propagating toward constant direction along its distance of travel as uniform beam with uniform energy but anyhow this is not really to be achieved due to some diffraction occurs to the propagated beam.

Brightness: It means the high intensity of the laser light compared to other light types due to the high power of the laser beam by the cross-sectional area of its beam because of the closeness of the beam.

Focusability: Which means the preciseibilty of focusing of the laser beam to very small smallest diameter forming very small spot size for that the mode of 00 of the transverse electromagnetic wave of the delivered laser beam can be gotten with so close approximated dimension of this laser beam wavelength.

1-1-8-II Laser parameters

There are a number of parameters that are essential to be considered for any laser tissue therapy, they include (Convissar 2015):

1-. Wavelength (λ): it means the distance by which the wave's shape repeats itself, usually measured by meters (m) or its derivatives.

2-. Frequency (υ): it means the number of complete oscillations of the laser wave per unit time and it is measure by hertz (Hz).

3-. Pulse duration: it means the full width at half-maximum of a single pulse of pulsed laser (time required for completing single pulse cycle).

4-. Peak power: means the energy in joul per each pulse duration .

5-. Pulse repetition rate: means the number of pulses per time.

6-. Average power: means the energy in joule * pulse repetition rate.

7-. Spot size: means the minimum diameter of laser beam applied on the targeted tissue.

8-. Power density (Irradiance and intensity): means the peak power in watt per unit area (W/cm^2).

9-. Energy density(fluence): means the energy in joule per unit area (J/cm^2).

1-1-9 Laser tissue interaction

The laser beam when hit the target tissue it will have 4 different interactions according to the optical characteristics of the tissue (Markolf et al 2007):

1-**Reflection** simply means that the beam is redirected from surface, without any effect on the hitted tissue (Luciano et al 2007).

2- Scattering means changing the direction of the propagation of wave without losing its energy. Scattering of light occurs because of variation in density of the target tissue i.e presence of different types of molecules in tissue will cause scattering. these molecules could be macroscopic (large) as muscle fibers or skin layers or microscopic as cells with their intracellular structures. Therefore, the size of these scatters varies from 10 nm to 10 microns which are distributed randomly within the biological target tissue (Luciano et al 2007).

3. Absorption is the attenuation of the electromagnetic wave when passes through the target tissue which is the usual desirable effect as such energy will be taken by the absorber molecule (chromospheres). Depending on the matching between the energy of the incident photons and energy states of the absorbers i.e. the energy $E = hv$, corresponds to the quantized difference of the distance between states of electron transition (ultraviolet or visible spectrum) or a quantized change of vibrational modes of the molecules (vibration transition: near infrared). The ability of a tissue to absorb photons usually is depending on some of factors as the light wavelength, electronic constitution of the atoms and molecules, the thickness of absorbing tissue, and internal parameters like the temperature or concentration of the absorbing agents of the target tissue molecules (Markolf et al 2007).

4.Transmission it means that the laser beam pass through the tissue without any interaction because there is no part of the tissue will absorb it (no chromospheres) which depend on the wavelength of that incident laser. Therefore, only the non-absorbed and no reflected or forward scattered laser photons will be then transmitted (Markolf et al 2007).

1-1-10 Laser Tissue Interaction Mechanism:

Depending on the use of wavelength of incident photons by the tissue molecules, the target tissue can interact with such photons by two main mechanism (Figure1-7) (Markolf et al 2007):

A- Wavelength dependant **B- wavelength independant**

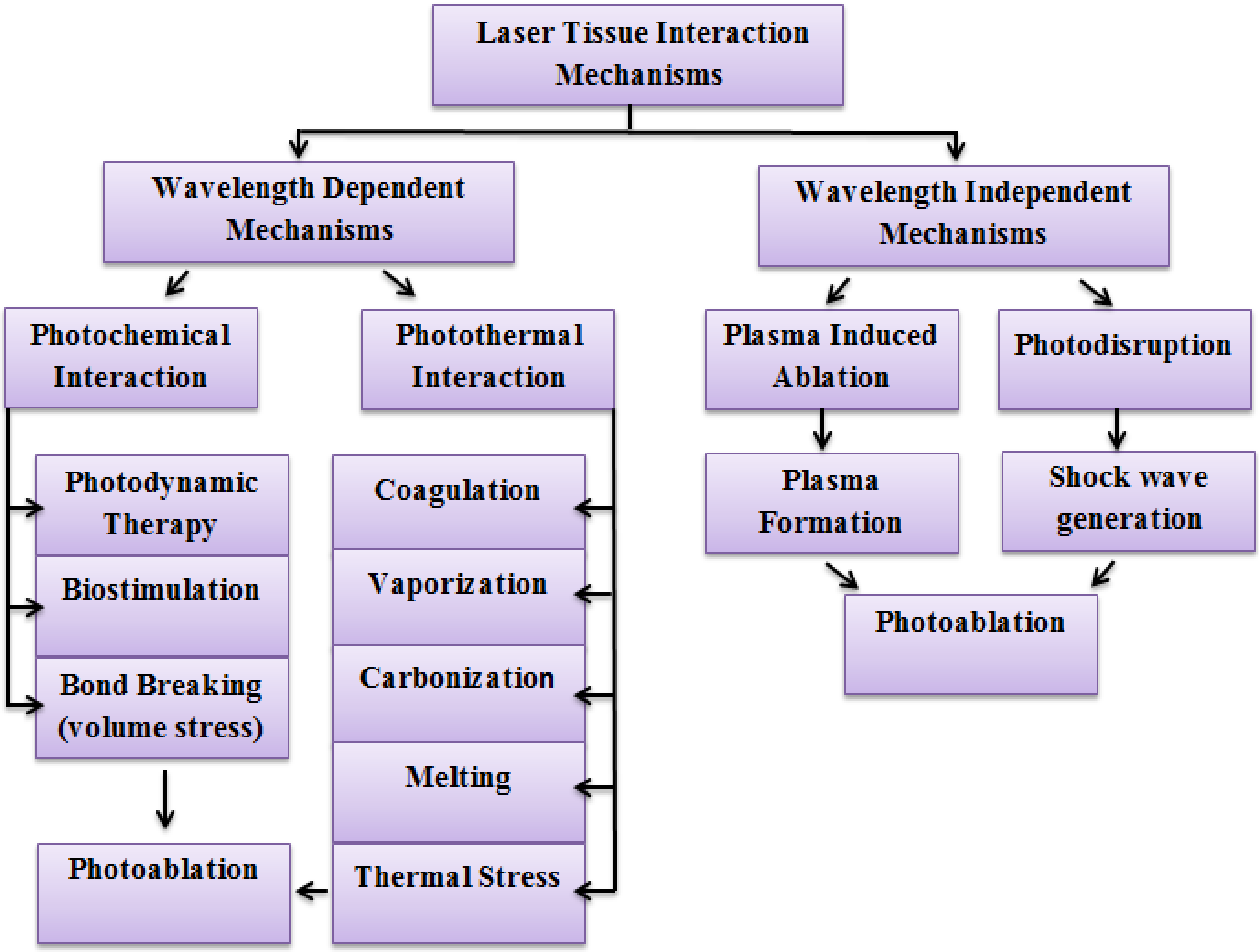


Figure (1-8): Mechanisms of laser-tissue interactions (Markolf et al 2007)

A - Wavelength dependant mechanism (Markolf) which include:

1- photochemical interaction mechanism: The chemical effects and reactions between incident photons and macromolecules or tissues play a great role during the photodynamic therapy (PDT) and bio stimulation. Photochemical interactions which take place by very low power density (1W/cm2) with long exposure times (which range from seconds to continuous wave) depending on the type of wavelength**.**

A) Photodynamic Therapy

The photodynamic therapy reaction usually is mediated by exogenous chromophores which are photosensitizers where the light is used for activating the target molecules or drugs by exposing them to a specific wavelength of the laser irradiation, then The molecule is converted into toxic compound which involve the oxygen free radicals liberation that lead to a cellular death by destructing the DNA molecule, this type of mechanism used in many applications like the treatment of malignant tumors.

B)- Photo biostimulation (Mester 2013)

The principle action of this mechanism is to rise the production of adenosine triphosphate (ATP) which result in:

1) Enhancing the repair of tissues

2) Anti-inflammatory effect

3) Inhibit pain

2- photothermal interaction

It is a large group of interactions of the cellular molecules, the rise in temperature is a significant parameter change, i.e. the photon energy is converted into heat leading to different types of interaction induced by either continuous or pulsed laser radiation start by hyperthermia, coagulation, vaporization, carbonization and melting. The heat generation can be determined by the laser parameters and also the by the optical parameters of the target tissue. Heat transport can be determined by the thermal properties of the tissue as the conductivity and the capacity. Heat is usually transported by three ways which are either conduction, convection (via blood flow)or radiation. Heat effect depends on two parameters which are the value of temperature that achieved inside the tissue and the tissue type. Depending on the duration of temperature, a sequence of changes will occur as illustrated in (table 1-3) (Luciano et al 2007).

Table 1-3: Possible thermal effects of laser light radiation (Markolf et al 2007)

Temperature degree	Biological effect on tissue
37 ◦c	Normal (no effect).
45 ◦c	Hyperthermia
50 ◦c	Reduction in the enzymatic activity
60 ◦c	Denaturation of proteins and collagen with coagulation
80 ◦c	Permeabilization of the membranes
100 ◦c	Tissue Vaporizationwith thermal decomposition (ablation)
>100 ◦c	Tissue Carbonization
> 300 ◦c	Tissue Melting

Thermal relaxation time means the time that is needed for the tissue to lose about 63% of the thermal energy. Thermal relaxation time is affected by the pulse duration, that when pulse duration is less than the thermal relaxation time of the target tissue then the heat will not diffuse further leading to reduce the thermal damage, while if the pulse duration is more than the thermal relaxation time of the target tissue this means that there is no enough time for the tissue to get rid of the excess heat. Therefore, this heat it will diffuse further through the tissue causing thermal damage (Convissar 2015).

3- Photoablation which depends on laser intensity ranging from 10^7 to 10^{10} W/cm2 with short pulse duration (in micro and nanoseconds). The principle mechanism of it is breaking the organic molecular bonds in the proteins and collagen, and that the energy of photon must be higher than the dissociation energy of the bonds which is usually between 3 and 7 eV. The target Tissue will be removed by explosive manner in photoablation by generating a plume (byproduct of ablated tissue contains tissue vapor and toxic substances and microorganisms) from the ablative site. The photoablation in comparison with photothermal interaction is clean ,smooth, high precision, no deep penetration depth and no thermal effects occur (Convissar 2015). Figure (1-8) shows the principle of photoablation.

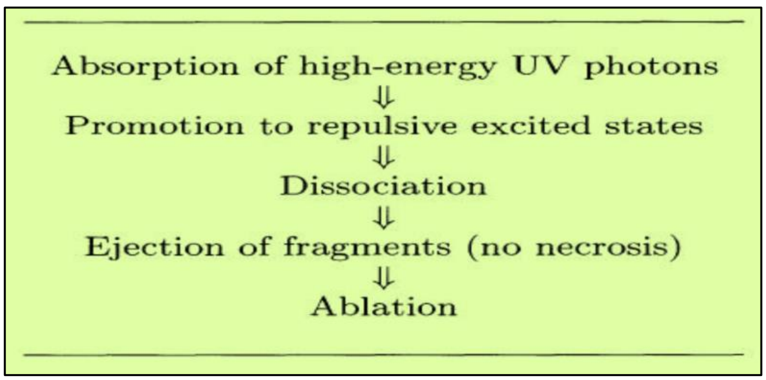


Figure (1- 9): Scheme principles of photoablation (Convissar 2015)

B- wavelength independent mechanism: which include:

I) Plasma-induced photoablation Which is achieved by optical break down phenomenon that occur when the intensity of the laser exceed 10^{11} W/cm2 and short pulse duration. This event is accompanied by plasma formation with sparking noise. The Plasma-induced ablation usually occurs when the pulse duration is in femtosecond, therefore, the interaction is extremely short and thus the tissue is removed (ablated) by thermal vaporization within the volume of the plasma due to the high temperature of the plasma and chemical dissociation by electrons. Therefore, this lead to that the ablated area will be kept confined within optical breakdown region and this is why the Plasma induced ablation produce a very clean and well defined removal of target tissue without any thermal and mechanical damage (Niemz 2013).

II) Photodisruption

This interaction differ from the plasma-induced ablation in that the pulse duration is within picosecond or nanosecond, therefore, the optical break down is very high here. Besides that, the formed plasma in the optical break down is accompanied by popping sound that indicates the chemical reactions are occurring which end in photodisruption (Kaschke et al 2014).

1-1-11 Laser Safety Standards and Hazard Classification

Lasers can be classified according to the laser's potential to cause immediate injury to eye or skin and / or potential to cause fires from the direct exposing to the beam or from the reflections of laser beam from reflecting surfaces this classification in fact depend on the physical parameters of the power, wavelength, and the exposure duration. Therefore, as a description for laser, these classes will be as follow: **(Kaung 2009)**

Class 1 laser system: Any laser system which emit laser without causing any injury to the skin or eye during any normal operation.

Class 2 laser system: They are within the visible portion of the spectrum, They can be hazardous if viewed directly for prolonged time.

Class 3 Laser System (medium- power): Which sub classified into subclasses:

a) Class 3a: Normally don't produce injury to eye if viewed by the unaided eye but can cause hazard if it viewed using collecting optics like microscope, telescope or by binoculars. For Example, visible lasers more than 1 mill watt not exceeding 5 mill watts radiant power.

b) Class 3b: that causes severe injury to the eyes by direct viewing the beam or by specular reflections. Example: the visible light CW lasers above 5 mill watts not exceeding 500 mill watts(radiant power).

Class 4 Laser System (high-power): Lasers in this class can cause injury to the eye or to skin by the direct viewing beam, and may cause diffuse reflection or fire hazards.

1-2 Literature review:

1-2-1 Bleaching effect of hydrogen peroxide

Many studies evaluated some effects of HP that subjected to varying intensity and influence. They showed controversial effects on teeth that subjected to the bleaching in general and in light assisted bleaching as particular (whether by laser or other types of lights). Gerlach et al in 2002 reported that Aqueous HP also used clinically with concentration of 30–35% for bleaching teeth. The bleaching mode of bleaching agent include the diffusing of the peroxide through the enamel layer leading to bleaching of the pigment chromogens that are found within the enamel dentin junction and dentin layers which leads to the appearance of whiter teeth and less yellowish appearance. Bernardon et al in 2010 reported that the bleaching degree that is obtained by a home bleaching technique with the use of 10 % HP gel applied by a tray was the same as that obtained by the In office technique which used 35 % hydrogen peroxide. Fornaini et al in 2013 showed a high bleaching efficiency results of KTP 532 nm laser compared to diode laser 810 nm in vitro study regarding lower concentration of bleaching gel, shade change and temperature rise.

Clifton in 2014 reported that the use of HP and carbamide peroxide in tooth whitening is effective and safe, but as with all dental therapy procedure, there were some risks, therefore, treatment must designs for each patient, according to the type and extent of the staining, dietary habits, presence of restorations and the other oral conditions. Roderjan et al in 2015 showed that the use of hydrogen peroxide with concentration ranging from 15% to 40 % gave effective bleaching results in office. Saha et al in 2017 found that Effective whitening results were gained by the correct performance of the bleaching method was the in-office whitening which was one of the most requested methods in many dental clinics, where a significant way to get the fast and immediate color change of their stained teeth by using 35% Hydrogen peroxide **.**

1-2-3 The effect of light in accelerating bleaching of teeth

Hein et al in 2003 showed that activating Energy sources heat, LED, halogen, diode laser and other types of lasers were thought to catalyze the HP decomposition. Therefore, they used to accelerate the liberation of the active radicles from the peroxide bleaching agent leading to efficient teeth whitening. Niklaus et al in 2004 reported diode laser 810 nm gave more efficiency in bleaching than LED, both in luminosity and chroma when associated with the Whiteness hydrogen peroxide bleaching agent while The LED gave best results than the laser regarding the luminosity when associated with Opalescence Xtra whitening agent**.** Wetter et al in 2004 used The diode laser 940 nm in dental bleaching and showed quick and effective results when used to activate the HP bleaching gel, therefore, he concluded that the diode laser assisted bleaching agent gave good results in comparison to the agent that used alone or combined with the xenon source, beside that he found that additional advantage is the less contact time of the whitening agent application, and this reduce the chances of teeth sensitivity and laser irritation. Ziemba et al. in 2005 found that higher significancy in shade change when light activated bleaching methods used compared to non-light bleaching systems with variation in both teeth sensitivity and hetrogencity according to the use of various concentration of the HP.

Some studies found that there is no difference in color between LED- laser-activated whitening with 35% HP and a similar treatment without any light activation i.e use of laser does not yield best efficiency, that high concentrations of HP gel which is used in the whitening protocol may yield such result. For that, the amount of free radicals released by the chemical degradation of hydrogen peroxide will be sufficient to react with the organic pigments and large amount of free radicals will not improve the whitening (Sulieman 2005). Buchalla and Attin in 2007 evaluated the effectiveness of power bleaching with high intensity light by acceleration of the decomposition and oxidant free radical formation for vital tooth bleaching by conducting animal studies, reports and clinical studies and showed that there are some adverse effects on the tooth which were alteration of the surface of enamel and tooth sensitivity**.**

Other studies showed that no preference of use of high power lights to get better bleaching results as the study conducted by Akin et al in 2020, they found that use of a diode laser is not necessary in improving bleaching results and the use of diode laser in whitening led to a reduced bond strength. Marson et al in 2008 concluded that the use of intense light has no difference in the speed of bleaching**.** Domingues et al et al. in 2011 conducted bleaching study using chemical , low power diode laser, halogen lamp and LED activating methods of 35% hydrogen peroxide and found that the LED was the best among them regarding the whitening efficacy and minor increase in pulp temperature**.** Gurgan et al in 2009 found that the use of a laser diode (810 nm) did not give superior efficiency compared to other light sources although it has little better results than them, a 6 months treatment stability was reported for this study.

Klunboot in 2011 conducted a study which evaluated the effectiveness of diode laser on tooth surface in the tooth whitening procedure and found that the diode laser with low power densities was of highly efficiency in tooth bleaching effects with more constant white color change for 2 month assessment. Dominguez in 2011 observed that with the use of KTP, Diode laser, Nd:YAG and Er: YAG resulted high beaching efficiency with no significant effects upon the tooth enamel surface**.** Rafael et al. in 2011 showed the use of both LED and chemical activating systems with 38% hydrogen peroxide led to no difference in results after 24 hours,1,6,12 months evaluation for both the whitening stability and teeth sensitivity.

Roche et al. in 2012 used LED of 450-500 nm for activation of hydrogen peroxide 44% by 3 cycles application of 10 minutes time exposure for each cycle showed insignificant whitening color with insignificant increase in sensitivity. Li-Bang et al in 2012 concluded that light may not improve bleaching efficiency when higher concentrations of HP (25–35%) are used during in office bleaching. As the light-assisted system increases the risk of tooth sensitivity, therefore, the dentists should employ such system with more caution. When low concentration of HP (15–20 %) are employed, there is little evidence that the light can produce better immediate whitening effects. Therefore, they reported the need for more large scale, studies to explore advantages of such light activated system. Rafael et al in 2012 found that in office bleaching of teeth by light and without light assisted bleaching gave similar results. Hahn et al in 2013 conducted an in vitro study where they evaluated the stability of the color of bleached teeth after the light assisted bleaching with either LED, halogen or without light assistance then they reported that all the methods produced good results after three months after bleaching, the authors also showed that the light assisted bleaching was not beneficial in comparison to chemical bleaching beside that there was no difference in the stability of the color up to three months after the bleaching process.

He in 2013 reported (400- 500 nm) halogen assisted source bleaching has a whitening efficiency more than a diode laser (980 nm)and they used 38% HP gel, this may be because of the difference in the wavelength between the two light sources used (980 nm / 400 nm). 6-month post treatment color stability was also reported in this study. Polydorou et al in 2013 concluded that the use of halogen lamp in bleaching led to an efficient whitening effect directly after bleaching compared to the laser assisted bleaching. Halogen assisted bleaching was not of benefit in comparison with the chemical activation of the whitening agent. The bleaching effect with a laser or bleaching without any light assisted mechanism increased within one or three months in comparison to the results directly after bleaching. After three months whitening results were the same for all tested bleaching mechanisms. Therefore, it can be understood that the use of light to activate the process of whitening is so important for better results with consideration to the long term bleaching effects**.** Mathews et al in 2013 reported a study which compared the efficiency in office bleaching system by using titanium dioxide that impregnated in the bleaching gel and conjuncted with an 810nm diode laser as opposed to conventional in office chemical bleaching system. The results showed no difference in the whitening results obtained by both laser bleaching and conventional in office chemical bleaching that didn't use any light**.**

Abdelfattah in 2014 compared the use of laser and non-laser teeth whitening systems. The author concluded that laser assisted tooth bleaching was comparatively better. Among lasers, diode laser 940 nm and Er:YAG 2970 nm laser were evaluated and concluded that Er:YAG was comparatively better.

Clifton et al in 2014 found that light assisted bleaching gave no difference in degree of whitening or tooth sensitivity from other chemical bleaching. Also he found that with use of high concentration of the HP causes roughness of the enamel surface and increase of the demineralization susceptibility and he showed that use of 35%

hydrogen peroxide in all cases will cause sensitivity of teeth and he reported that teeth with restorations have more significant chance to become sensitive resulting in a degree of sensitivity when exposed to bleaching agent**.** Fekrazad et al in 2017 reported that diode laser assisted bleaching gave more efficient results in bleaching of stained teeth than other light assisted bleaching technique**.**

Saha in 2017 conducted a case study of bleaching of stained teeth using 35% HP gel directly on facial surfaces of teeth and irradiated it by LED for 30 min. then let it to cool down for 5 min. led to fast and immediate difference in color of the stained teeth. Shivaprasad et al in 2019 showed that the use of diode laser 810nm 1- 5 W at 5 sec. per each tooth was efficient bleaching activator after 3weeks evaluation of the effect in comparison to conventional methods. Kikly et al in 2019 reported that there is marked change in in color for patients bleached by light activated whitening independently of the bleaching technique but in consideration of the tooth sensitivity the results of different studies were controversial**.**

1-2-4 The effect of the various manners of bleaching on :

I-Tooth structure

II- Influence on hypersensitivity

III-Influence on pulp temperature

I - Tooth structure: The purpose of the bleaching is to whiten the tooth without any morphological and structural chemical changes. Therefore, the post power bleaching side effects which occur in the enamel layer such as changes in microhardness, changes in surface roughness, presence of porosities, erosion, decrease in abrasion resistance, a reduction in fracture toughness, and the alteration in the calcium phosphate ratio were reported. Therefore, This may lead the oxidation of organic or the inorganic elements which end by weakening of enamel structure **(Roeland 2015).**

A- Morphological Analysis. the Morphological analysis show that there were slightly changes by the use of diode laser(970 nm) and the LED/laser (467 nm/790 nm) (Dostalova 2004). Surface changes were unrelated to pH of higher concentration of HP bleaching agent with the laser activation and related more to a lesser or better absorption of the laser by the HP agent. The light Chromophores and the use of TiO_2 seemed to be favorable for preserving the tooth surface (Goharkhay 2009). Therefore, no significant changes in the morphology of the enamel after whitening by diode laser, KTP, Nd:YAG, and Er:YAG were reported by Dominguez (Domingues2011).

B- Mineral Content. Some studies results showed a decrease in the mineral content after bleaching process by chemical or light assistance and with 35% HP whitening gels where the use of LED /laser (470 nm /810nm) lead to results of comparable calcium loss in comparison to the chemical bleaching gels. It was clear that with the use of non-light activated high concentration HP bleaching agents there was a relation to difference in the oxidizing potential (stronger) stronger concentrations with longer time of treatment, and low pH of HP gels (Cesar 2009).

Berger et al in 2010 conducted an in vitro study that showed a decrease in the mineral contents after teeth bleaching procedures with and without light activation and with 35% HP bleaching agents showed use of a LED/laser (470 nm/810–830 nm) resulted in Comparable loss of calcium as in comparison to the non-light activated Bleaching gels (Berger et al 2010). While other studies ,as the study that conducted by Parreiras et al in 2014 which showed that there is no significant differences in the calcium and phosphorus levels were observed after the use of 470/830 nm and LED/laser bleaching (Parreiras et al 2014)**.**

C- Microhardness. The microhardness test is effective to Determine the changes that occur in the enamel layer that exposed to the bleaching procedure. Spalding et al in 2003 conducted in vitro study by which he reported that there was alterations in the morphology of the enamel and dentin (Spalding et al 2003). Lewinstein et al in 2004 showed that there is some deleterious effects on both enamel and dentin for recently in office bleached teeth. Jiang et al in the same year conducted an in vitro study and showed that there was alterations in the morphology of the enamel and dentin. Azer et al in 2009 showed that there was marked deleterious effects occurred to enamel and dentin for recently in office bleached teeth. other study that conducted by Rodrigues in 2005 showed that there is marked deleterious effects on the enamel or dentin layers like the decrease in micro hardness.

Joiner evaluated the side effects of the HP bleaching agent on the enamel and dentin layers of the tooth where he reported no deleterious effects on the surface micro hardness specially with the use of 6 % HP concentration of home bleaching (Joiner 2006). The same results where showed by the study that was conducted by Gotz et al in 2007. Cadenaro et al in 2008 also showed there is no marked alterations in the tooth surface subjected to HP bleaching and also the same results were reported by Magalhaes in 2008 which also showed that there are no alterations in the teeth surface of recently bleached teeth.

Goldberg et al in 2010 Reported the effects of light activated mechanisms that used to activate the in office bleaching gels involving changes in the micro-hardness, changes in enamel roughness, presence of porosities, erosion alteration of the calcium-phosphate ratio, a reduction in fracture toughness, and reduction in abrasion resistance. The enamel surface changes have some variations mostly with the whitening products used, especially with the use of high concentrations of HP, that is, 30–35% HP may cause damaging effect, whereas the use of lower concentrations

10% or 16% HP) was of no effect. In other hand, re-hardening of the porous enamel layer due to saliva ion re precipitation had been reported by the same study. Although re mineralization that occur because of the saliva may be responsible for a gradually mineral rebuilding up, therefore, full repairing of the enamel (by mineral exchange) was not established because of a degradation of the organic matrix, therefore, no clinical adverse effects of power bleaching agent on the enamel recorded.

D- Enamel Permeability. One of the changes that occur to the enamel after bleaching is the Higher permeability of the enamel surface specially by a LED/laser (Turssi et al 2006) while Parreiras et al in 2014 found no significant permeability occurred after LED/laser bleaching**.**

E- Fracture- Strength:- Araujo et al in 2010 showed that the LED /laser (465. 5 nm/ 790 nm) did not affect the fracture strength of enamel structure after the light activated bleaching procedure.

II- influence on Hypersensitivity where there is varying hypersensitivity of the teeth may occur post bleaching procedure, The side effect of Post bleaching sensitivity, even if transient, is a common adverse effect occurred regardless of the whitening technique and type of activation used which is a variable effect. Marson et al in 2015 found that such hypersensitivity of teeth due to pulp irritation that occur due to penetration of the bleaching substance into the dentinal tubules and such irritation vary according to time of application of such material on the tooth surface**.** Li et al in 2012 found that light activated bleaching increase risk of enamel sensitivity. Roche et al in 2004 found that insignificant tooth sensitivity occurred to stained teeth treated by LED assisted bleaching**.** While Mohammed in 2019 found that 940 nm diode laser reduce teeth sensitivity that originate from high concentration of HP bleaching**.** Use of desensitizing agent with the bleaching gel assisted in decreasing the post bleaching teeth sensitivity for some extent (Navarra et al 2014).

III- Influence on pulp temperature

The power and the type of the light source (wavelength) affect the temperature . Many Studies showed that near-infrared lasers can improve the inflammatory response of the pulpal and decrease the pulp damage and relieving sensitivity after the teeth bleaching procedure (Calmon et al 2004) Hein et al in 2003 found that there is dehydration within tooth structure caused by the production of heat by LED /Laser low intensity (200 W). This rapid change in color described as desaturation rather than an effect of lighting itself (Ontiviros et al 2009). The heat factor is so important to accelerate the action of bleaching agent but at the same time has little bad effect on the pulp of teeth (Batista et al 2011). He et al in 2012 found that with the use of LED in bleaching of teeth there is little rise in teeth pulp temperature. Roeland et al in 2015 reported that diode laser can rise pulp temperature by 4.1^{o} C. Moor and Verheyen in 2015 reported that the use of diode laser (785-980) with high power in teeth bleaching rises pulp temperature. Maysa in 2016 reported that the use of hydrogen peroxide in office bleaching of 38% led to increase tooth pulp temperature more than the use of 15% carbamide peroxide in home bleaching. Shendi in 2016 concluded that the intrapulpal temperature of the diode lasers used (940 nm and 980 nm) in bleaching of teeth is considered as noncritical for pulp of teeth, and these types of lasers can be used safely in the considered power settings used in laser power bleaching. Mohammed et al in 2016 found that the bleaching gel decreased (27–29%)of the temperature from reach the pulp during simulated tooth bleaching procedure in vitro where the intrapulpal temperature increases using (940 and 980 nm) diode laser (7 W) in CW mode, The highest color change was gotten with use of 940 nm diode laser.

According to the previous studies, correlation between invitro and invivo studies considering whitening efficiency, temperature change and sensitivity was limited. Therefore, research was planned to estimate the positive or negative effects of different light activated- whitening in bleaching procedure.

1-3 Aims of the study:

1- To study the effect of diode laser 940 nm and LED 450-505 nm on shade change for extrinsic stained teeth using 32% HP external bleaching (in vivo and vitro study).
2- To monitor temperature change in pulp during bleaching by using both diode laser 940 nm wavelength and LED (in vitro study).
3- Evaluating surface roughness and topography of teeth after bleaching by diode laser 940 nm and LED 450-505 nm.
4- Follow up evaluation of whitening stability and teeth sensitivity after one month (In vivo) using diode laser 940 nm and LED 450-505 nm.

Chapter two
Materials
And
Methods

Materials used our study are listed in table (2-1).

2-1 Materials and equipments of in vitro study:

Table 2-1: Materials

Material	Company	Expiry date
Coffee powder	Al Ameed/ Jordan	2021\3\20
Cola	Pepsi Cola/ Iraq	2021\1\1
Composite resin	Competence univers / Germany	2022\4\4
Dental pumice	Perfection plus / UK	2023\5\20
Dental Irrigation syringe	Chanquan / China	2023\6\10
Dental Paper point	ALPHA DENT / USA	2023\5\5
Distilled water	Al -Kafeel / Iraq	2023\5\12
Diamond disc	DF Meisinger / Germany	
Endodontic kit(k files (25-100)	MANI.INK / Japan	2023\7\10
Normal saline 9%	Ahicon / India	2021\10\10
Pomegranate Juice	Rawabi/ Iraq	2021\1\1
Tea leaves	Ahmed / UK	2022\1\1
Thermal conductive paste	BONYX FACTORY/ China	2021\10\10
Toothpaste & toothbrush(soft)	Coalgate / China	2021\2\1

Thymol	MERCK/ USA	2021\1\20
Whitening kit	Light Whitesmile / Germany	2022\2\18
X-ray film	ERGONOM.X/ Italy	2021\9\1

Equipments used in our study listed in table (2-2).

Table 2-2 : Equipments:

Equipment	Company
Atomic Force Microscope(AFM)	PHYSWE / Germany
Dental Scaler	Woodpecker /China
Dental Cement spatula	Denmat.CO /USA
Digital Water bath	Labcompanion BS-11 / South Korea
Diode laser 940nm	Epic Biolase / USA
Incubator	MEMMERT 854 Scawbach / Germany
LED (445-505nm)	POLLILUX/ Italy
Light microscope with its digital camera	OLYMPUS DP72 / Japan OLYMPUS 5000\ JAPAN
Light cure gun	QD spectrum / UK
Low speed hand piece	W&H / Austria
Optical spectrum analyzer(OSA)	Anristu / USA
Power meter	Genetic – EO / Canada

Shade guide	VITAPAN classical, zanfabric/ Italy
Scanning electronic microscope(SEM)	TESCAN MIRA / France
Spectrophotometer	UVD 2950 / USA
Thermocouple thermometer	AmprobeTMD-56 / USA
Vernier Caliper	TOPEX / Poland
X- ray machine	Xgenus oligiateolona / Italy

2-2 In vitro study

2-2-1 Sample collection

Sixty sound upper & lower teeth (second premolars and canines) (from patients 25-45 years old) extracted due to orthodontic or periodontal causes were collected (figure 2-1). All was washed and the attached soft tissue was removed by ultrasonic scaler. The crowns were polished by pumice slury and a disposable rubber cup with a slow speed handpiece. The teeth were kept in freshly prepared 10% thymol solution at $5^{o}C$.

Figure (2-1) Some selected anterior teeth

2-2-2 Baseline shade assessment:

The shade of the teeth was assessed using Vita shade guide as such type used in most common methods of shade assessment (figure 2-2) by two observers separately who stood at half meter from the samples using the sun light source at the morning 11:00 A.M (Collins 2004 et al ; Browning 2003).Gingival third shade was excluded for teeth with more than one shade. Shades of the teeth were categorized according to numbering the shades as illustrated in table (2-3) (Domingues et al 2011).

Table 2-3: Shade range from 1- 16 (brightest color to darkest color) according to VITA shade guide:

Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Shade	B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3.5	B4	C3	A4	C4

Figure (2- 2) VITAPAN classical shade guide

2-2-3 Preparation of staining solutions:

a- Tea solution was prepared by adding 4 gm (Ahmed Brand tea) in 100 ml distilled water then boiled to 100^{o}C for one min. before cooling it to 25^{o}C (room temperature).

b- Coffee staining solution was prepared by adding 50 gm coffee (Al Ameed Brand) to 400 ml distal water and then boiled to 100^{o}C before cooling to 25^{o}C.

c- Cola staining solution by using 100 ml of Iraqi cola beverage .

d- Artificial pomegranate juice staining solution by collecting 100 ml Iraqi artificial red juice (Rawabi Brand) (Patrica and Zeynep 2006; Yan 2012).

Each tooth was stored in a tube contain 10 ml staining solutions which were 10 teeth for each group, the control and tobacco groups were immersed in distilled water tubes (figure 2-3). The tubes were kept inside an incubator at 37^{o}C (figure

2-4) for15 days **(Patricia and Zyenep 2006)**, every day these tubes were shacked well twice to enhance continuous mixing and prevent any precipitation. After incubation period every tooth was removed out of the tube and rinsed profoundly with distilled water then brushed using tooth brush and tooth paste for 30 sec., finally kept in deionized water for 24h.

Figure (2-3) Tubes containing teeth immersed in staining solutions

Figure (2- 4) A: Memmert incubator B: Tubes containing staining solutions and teeth.

2-2-4 Assessment of shade change after staining :

The procedure of shade guide assessment was repeated in the same manner mentioned at (2-2-2).

2-2-5 Examination under optical microscope:

All labial surfaces of the stained teeth were dried and examined under optical microscope (figure 2-5) using different magnification powers 10, 20X and 40X for checking any cracks present to exclude such sample as it may affect stain precipitation beside affecting the bleaching effect and surface topography (David et al 2003 ; John et al 2015 ; Abdulrahman et al 2020).

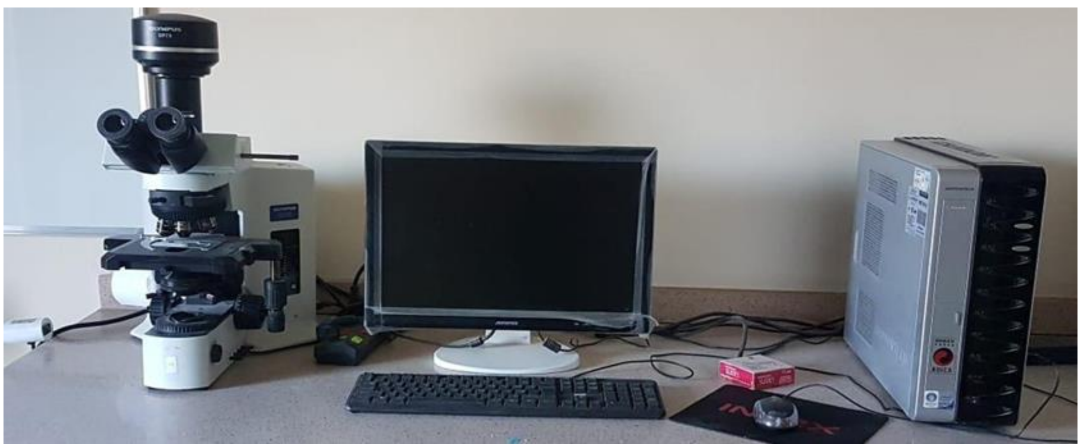


Figure (2-5) Optical microscope connected to a computer

There were different images of stained teeth examined under optical microscope by different magnification powers which showed no cracks within the surface structure of the stained teeth.

Whitening kit:

The Light White smile contain the whitening gel tube, gingival protector and desensitizing agent (figure 2-6). The whitening gel contains the following ingredients :

1- Aqua.

2- Hydrogenperoxide 32%.

3- Glycerol .

4- Organic amines.

5- Polyglycol.

6- chlorophyls .

Figure (2-6) Whitening kit contain the bleaching gel, gingival protector and desensitizing agent

2-2-6 Absorption spectrum analysis:

By using Spectrophotometer (figure 2-7) the absorption spectrum of the bleaching gel was measured within spectrum of 265-1100 nm to investigate the absorption of it for the wavelength of both the LED (450-505nm) and laser 940nm.

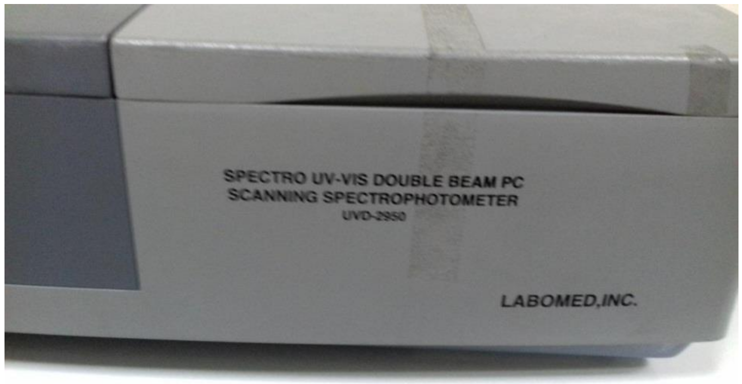


Figure (2-7) Spectrophotometer (200-1100nm)

2-2-7 Laser system and calibration of output power:

(940 nm, 7 W(output power) CW near-infrared diode laser(EPIC™, BIOLASE ,San Clemente, CA, USA) was used (figure 2-8 A &B) to perform the test.

Figure (2-8) A: Diode laser 940 nm B: Whitening head

The output power of the diode laser device was calibrated by monitoring it using the power meter which confirmed the output at 6.9 W (figure 2-9 A & B)

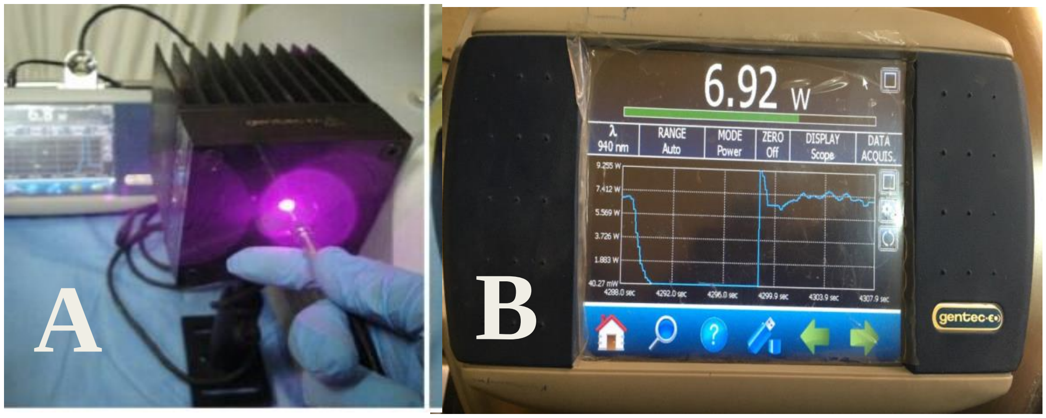


Figure (2-9) A: Laser applied on power sensor   B: Power measurement screen

2-2-8 LED system with analyzing spectrum:

The LED (pollilux Accelerator system, Italy) was used with (450-505nm at 30 W power for 20 min), its manufacture specification was to achieve the second source for irradiation during teeth whitening (figure 2-10).

Figure (2-10) LED Whitening device

By using Anristu optical spectrum analyzer (OSA) the spectrum of the LED was analyzed to confirm its spectrum wavelength within 450-505 nm (figure 2-11) **.**

Figure (2-11) Optical spectrum analyzer (OSA)

2-2-9 Preparation of roots of teeth:

To standardize the length of the teeth up to 17 mm (figure 2-12 A), the roots tips were cut off using disc bur at slow speed handpiece. All the teeth lengths were checked using vernier (figure 2-12 B). Then the apical foramen was enlarged by retrograde technique using Gate Glidden #5 and #6 to enhance the root debridement of all the soft tissues from the pulp chamber and root then washed thoroughly by sodium hypochlorite solution 5%.

Figure (2-12) A: Some of stained teeth B: Vernier

2-2-10 Preparation of teeth for bleaching :

The 40 stained teeth with the 10 teeth of tobacco group were divided randomly into two main groups: laser group (25 teeth) and LED group (25 teeth).

2-2-11 Temperature measurement :

To assess the effect of heat generated during light bleaching, the temperature of the pulp cavity of 10 teeth (from each group) was recorded by using the K -type thermocouple (figure 2-13 A), basic accuracy of ± 0.05%. The procedure was done by inserting the thermocouple wire from the apical foramen to reach the pulp chamber and fixed there by a thermal paste (figure 2-13 B).

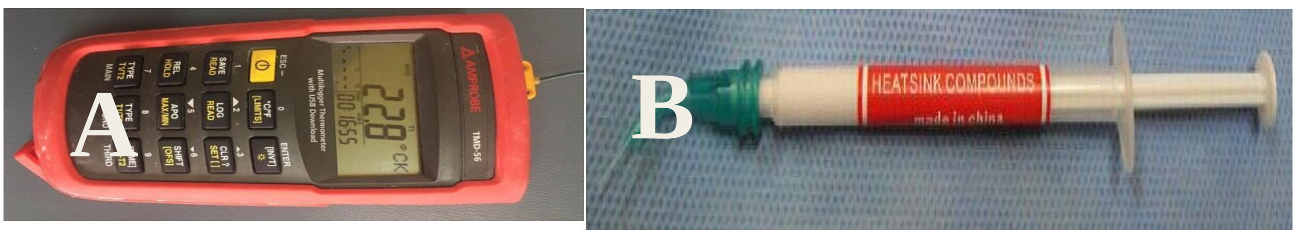


Figure (2-13) A: Thermocouple device B: Thermal paste

A radiograph then taken to assess that the thermocouple tip touches the higher point of the pulp after fixing the wire inside the pulp chamber (figure 2-14 A) and fixed by the thermal paste (to conduct heat) then the apical foramen was sealed by a composite resin.Teeth with their bounded thermocouple wires were hold with their roots immersed in a water bath warmed to make the pulp cores temperature become 37^{o}C to mimic the mouth temperature during the light exposure (laser or LED) by fixing such root within perforated glass plate on the water surface of the bath (figure 2-14 B). The data of thermocouple was transferred to a PC by digital multilogger thermometer (figure 2-14 C) using a computer software (Amprope multiline V3.0).

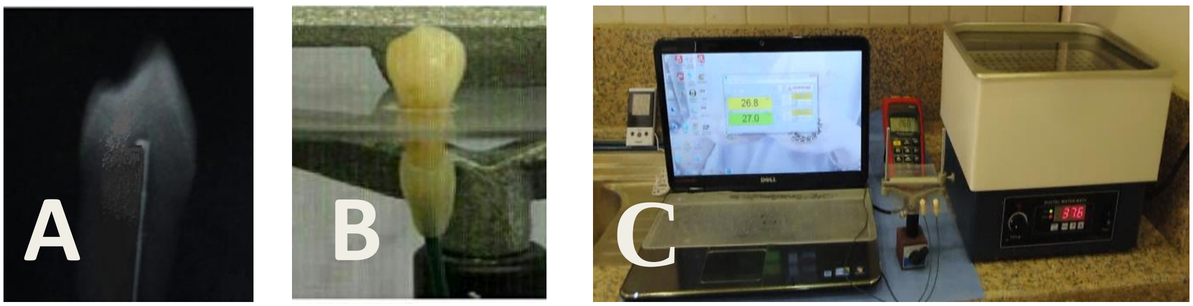


Figure (2-14) A: Radiograph show thermocouple wire inside pulp core, B: Control tooth fixed inside water bath C: Measurement of pulp temperature

2-2-12 Light bleaching systems:

1- Laser group bleaching:

After fixing the teeth roots in the water bath, the bleaching gel applied on the labial surface of 25 stained teeth within approximately 2mm thickness. The whitening handpiece (2.8 cm^2 area) of the diode laser (940 nm, 7 W) positioned 2 mm from the gel, the cycle of whitening started by leaving the gel for 1 minutes before irradiation with power density 2.41 W/cm^2 for 30 sec. then the lasing was switched off for one min. then re irradiating the area again for another 30 sec. Laser system was switching off and leave the gel on the surfaces for 7 min. Therefore, the total cycle will be 10 min, then the gel was sucked by the sucker tip and the bleached surfaces wept by wet gauze and dried after that this cycle of bleaching was repeated again by same manner (figure 2-14 C). Therefore, the two cycles will be of 20 min. total times, The data of thermocouple was transferred to a PC software during these two cycles of bleaching (figure 2-15). The means of the temperature readings were recorded, after completing the second cycle, the bleaching gel was removed by sucking tip and wet gauze then dried. Finally, the teeth washed thoroughly and dried then the shades of bleached teeth was recorded by the VITA PAN classical shade guide as mentioned in 2-2-2.

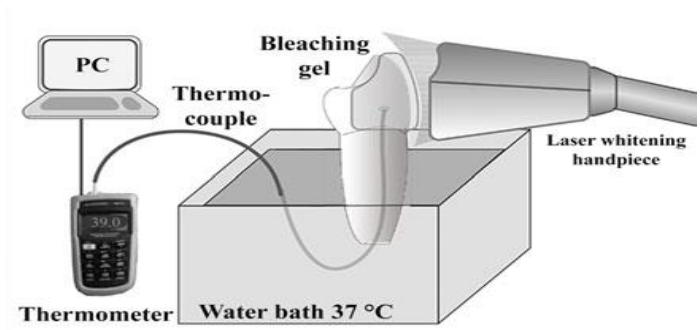


Figure (2-15) Scheme shows the temperature measurement during bleaching (Al Maliky et al 2016)

2- LED group bleaching:

Bleaching procedure using LED was performed by applying the bleaching gel on the labial surfaces of teeth with their roots immersed in the water bath at 37 ^{o}C by approximately 2 mm thickness, 25 teeth was included in this group. The cone of the LED device was applied 2-3 cm from the gel. The teeth were irradiated for 20 minuets with power of 30 W. The pulp temperature was assessed during the procedure by the same technique used in the laser bleaching. Finally, bleaching gel was removed from the teeth surfaces by sucker and wet gauze. The teeth were washed thoroughly to remove the excess of the bleaching gel and the shade of the teeth was assessed as mentioned in (2-2-2).

2-2-13 Crack investigation under light microscope:

Assessment of crack due to bleaching was repeated by examining three areas of the labial surface (left, right and central areas) from each bleached tooth .

2- 2-14 Surface roughness and topography assessment :

The surface roughness of 10 samples of control group with 10 samples from laser group and 10 samples from LED group were analyzed using AFM (5 samples from each group) (figure 2- 16 A) while the surface topography for the same teeth was investigated using SEM (5 samples from each group) which were coated by gold coat to prepare them for such examination (figure 2-16 B) .

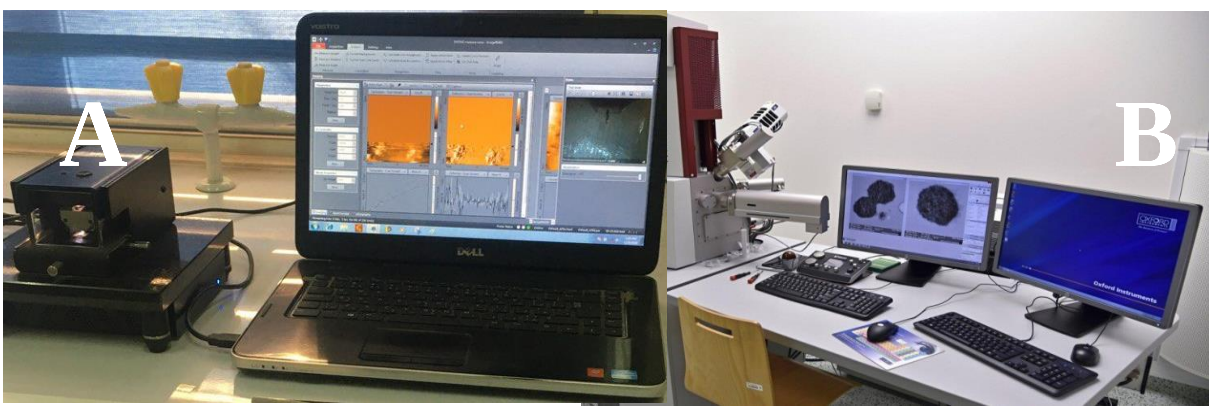


Figure (2- 16) A: Atomic Force Microscope AFM B: Scanning electronic microscope (SEM)

2-2-15 Sample Sectioning for Thickness Measurement

10 crown samples from each group, laser and LED were sectioned buccolingually to measure the effect of thickness of teeth (from labial surface to pulpal surface) on the temperature rise that occurred after bleaching by laser and LED. They were

sectioned using disc bur starting from the incisal surface toward the cervical line labiopalatel . The thickness was measured by the digital vernier caliper from the midpoint of the pulp cavity to the middle portion of labial surface (figure2- 17 A&B) .

Figure (2-17) A: Measurement of thickness of each sample of laser group & LED group B: Sectioned teeth from both laser and LED groups.

2-3 In vivo study materials and methods

2-3-1 Materials of in vivo study:

Table 2-4: Materials and Equipments used in in- vivo study

Material	**Company**
Cotton rolls	MED TEX / India
Case sheet	
Check retractor	VIVADENT / Swiss

Dark glasses	BIOLASE / USA
Dental pumice	Perfection plus / UK
Diagnostic instruments and dental spatula	BK-MEDENT / USA
Gingival protector	Light whitesmile/ Germany
Goggle for diode laser 940 nm	BIOLASE /USA
Red protecting glasses	Healthy Guard / China
Rubber cup	Dental prophy / China
Sucker device	ASPEED 2/ Italy
Saliva ejector	NISCOMED / Indi
Slow speed handpiece	W & H / Austria
Shade guide	VITAPAN classic / Italy
VAS scale	
Whitening kit	Light WhiteSmile / Germany
Whitening Laser system	Epic Biolase / USA
Whitening LED	Polilux Accelerator / Italy
X – ray film	ERGONOMAX / Italy

2-3- 2 Methods:

2-3-3 Selection of patients:

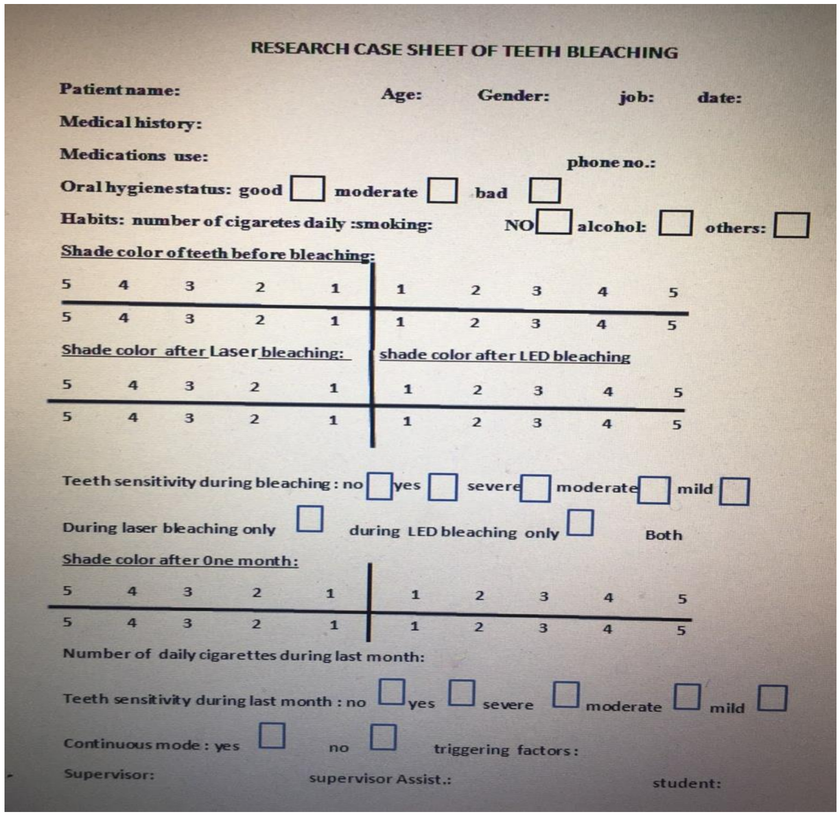
Fifteen patients aged from 25-45 years with extrinsic stained anterior teeth, free from any caries or anterior fillings. The patients included in the study according to specific criteria regarding :

1- Should have extrinsic stained anterior teeth.
2- They should not have history of sensitivity to any of the bleaching gel ingredients.
3- They should not have any bad troubled history with previous bleaching.
4- They should be monitoring for expectations.
5- Their anterior teeth should not be with decay or fillings.
6- They should not have sensitivity or exposed dentin anterior teeth.
7- Should not have gingival recession, periodontal disease or gingival pockets.
8- Should not be pregnant ladies.

The teeth of those patients were scaled to remove any calculus and polished using prophylactic pumice by rubber cup at slow speed handpiece .

2-3-4 Preparation of the patients for bleaching :

Special case sheets were prepared to record the medical history, oral hygiene , habits for every patient before treatment (figure 2-18) and the patient signed on a consent for approval for such dental work. Cheek retractor (figure 2-19 A)was placed with cotton rolls to ensure dry environment and the shades of the teeth were recorded using the same method mentioned in 2-2-2. The gingival protector (figure 2-20) was put on the gingiva around the cervical area of upper and lower anterior teeth then cured by the light cure gun. Using split mouth technique, the laser bleaching technique used for right side while the LED technique used for the left one.



RESEARCH CASE SHEET OF TEETH BLEACHING

Patient name: Age: Gender: job: date:

Medical history:

Medications use: phone no.:

Oral hygiene status: good ☐ moderate ☐ bad ☐

Habits: number of cigaretes daily :smoking: NO☐ alcohol: ☐ others: ☐

Shade color of teeth before bleaching:

5	4	3	2	1	1	2	3	4	5
5	4	3	2	1	1	2	3	4	5

Shade color after Laser bleaching: shade color after LED bleaching

5	4	3	2	1	1	2	3	4	5
5	4	3	2	1	1	2	3	4	5

Teeth sensitivity during bleaching : no ☐ yes ☐ severe ☐ moderate ☐ mild ☐

During laser bleaching only ☐ during LED bleaching only ☐ Both

Shade color after One month:

5	4	3	2	1	1	2	3	4	5
5	4	3	2	1	1	2	3	4	5

Number of daily cigarettes during last month:

Teeth sensitivity during last month : no ☐ yes ☐ severe ☐ moderate ☐ mild ☐

Continuous mode : yes ☐ no ☐ triggering factors :

Supervisor: supervisor Assist.: student:

Figure (2- 18) Case sheet prepared before bleaching procedure

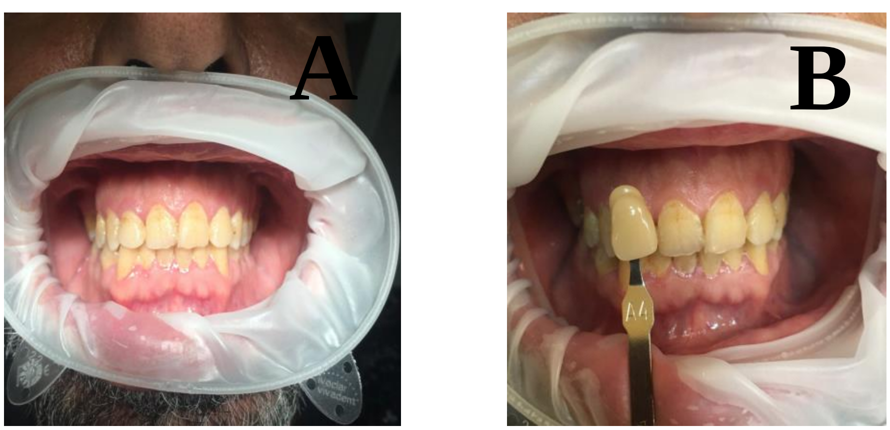


Figure (2-19) A: Cheeck retractor placed B: Shadeguide assessment

Figure (2-20) Placement of gingival protector on gingiva and bleaching gel teeth surfaces

2-3-5 Laser bleaching:

Both dentist and patient was wearing appropriate goggles for protecting eyes (figure 2-23 A & B) Vaseline was applied on upper and lower lips and keeping the mouth dry from any excess saliva by using dental sucker tip (figure 2-24). The bleaching gel was applied on the right side (upper and lower) anterior teeth by approximately 2 mm thickness (according to the manufacture instructions) and left for one minute before starting laser irradiating (figure 2-21) using the diode laser 940 nm as the same manner mentioned in 2-2-1. shades of teeth were taken by same manner mentioned in 2-2-2.

Figure (2-21) Diode laser irradiation on the right half

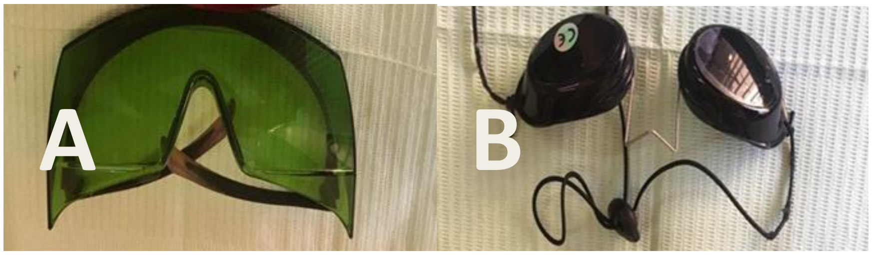


Figure (2-22) A: Goggle used for diode laser 940 nm B: dark eye glass for patient

Figure (2- 23) Medical sucker

2-3-6 LED bleaching :

The bleaching gel was placed on the labial surfaces of the other half by 2 mm thickness according to the manufacture specifications. The LED source was put by 2 cm away from the gel (figure2- 24). The LED bleaching cycle performed as the same manner mentioned in 2-2-13.

Figure (2-24) A: Irradiation by LED B: Protecting the other side by x ray film

Both dentist and patient wear the protecting eye glasses from the LED irradiation, shade of teeth then taken as mentioned in 2-2-2.

Figure (2- 25) Shade assissment A: Before bleaching B: After bleaching

2-3-7 Evaluation of teeth sensitivity :

The sensitivity of teeth during the bleaching procedure was evaluated according to VAS scores (Heft 1984) (figure 3-26). this scale consist of 10 scores the pain start from 0 (no pain) to 10 (very severe pain) where we ask the patient to choose a number from the scale that refer to the degree of pain sensation.

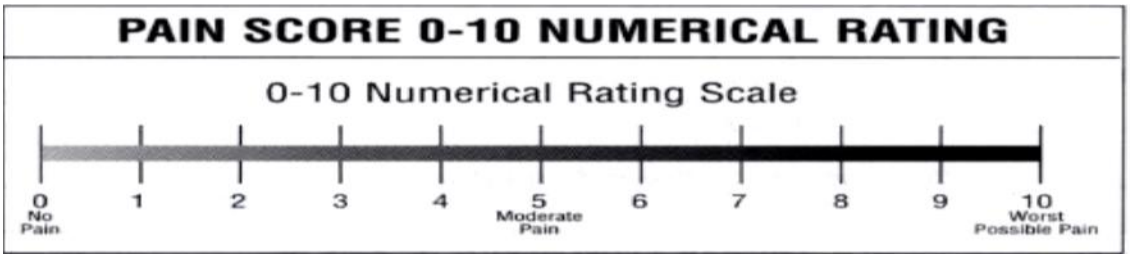
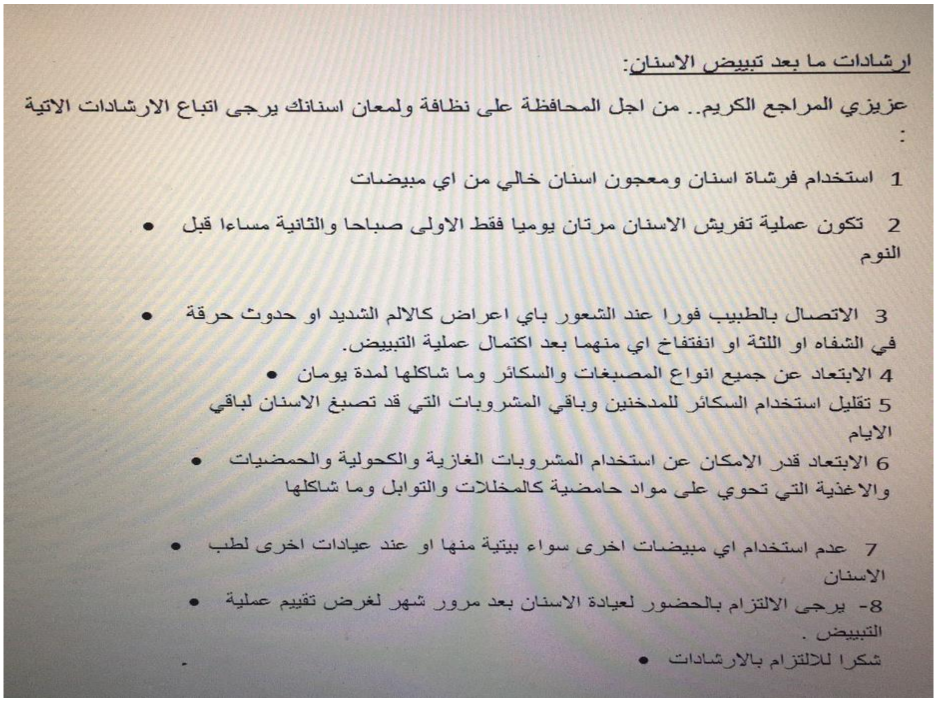


Figure (2- 26) VAS scale (Heft 1984)

2-3-8 Instructions to the patients:

Specific instructions were given to the patients orally and also as a written notes (figure 2-27) which include :

1- Keep teeth brushing with paste free of any whitening ingredients.
2- Teeth brushing at morning & before bed time.
3- Call the doctor immediately after feeling any severe or burning sensation or post operative oedema.
4- Avoid any beverges or smocking within post operative two days.
5- Lessen consumption of beverages or smocking for the rest days of the month.
6- Avoid or lessen consumption of acidic foods and alcohols.
7- Avoid teeth whitening within one month postoperative procedure.
8- Return back to the clinic for follow up after one month.



ارشادات ما بعد تبييض الاسنان:

عزيزي المراجع الكريم.. من اجل المحافظة على نظافة ولمعان اسنانك يرجى اتباع الارشادات الاتية :

1 استخدام فرشاة اسنان ومعجون اسنان خالي من اي مبيضات

2 تكون عملية تفريش الاسنان مرتان يوميا فقط الاولى صباحا والثانية مساءا قبل النوم

3 الاتصال بالطبيب فورا عند الشعور باي اعراض كالالم الشديد او حدوث حرقة في الشفاه او اللثة او انفتفاخ اي منهما بعد اكتمال عملية التبييض.

4 الابتعاد عن جميع انواع المصبغات والسكائر وما شاكلها لمدة يومان

5 تقليل استخدام السكائر للمدخنين وباقي المشروبات التي قد تصبغ الاسنان لباقي الايام

6 الابتعاد قدر الامكان عن استخدام المشروبات الغازية والكحولية والحمضيات والاغذية التي تحوي على مواد حامضية كالمخللات والتوابل وما شاكلها

7 عدم استخدام اي مبيضات اخرى سواء بيتية منها او عند عيادات اخرى لطب الاسنان

8- يرجى الالتزام بالحضور لعيادة الاسنان بعد مرور شهر لغرض تقييم عملية التبييض .

شكرا للالتزام بالارشادات

Figure (2-27) Instructions given to the patient after bleaching

2-3-8 One month follow up evaluation:

Whitening stability of teeth in both sides was evaluated after one month post-operative bleaching procedure by assessing shade of teeth as mentioned in 2-2-2 also teeth sensitivity in both sides were assessed for both sides as mentioned in 2-3-7 .

2-3-9 Statistical analysis:

All the results of the methods (in vitro and in vivo) were analyzed statistically by SPSS , V.17 OF WINDOWS 10 and Excel 2010 used for the tables of data.

These statistical data consists of:

A-Descriptive Statistics:

1- Maximum value.

2- Minimum value.

3- Mean.

4- Median.

5- Standard deviations (SD).

6- Standard errors (SE).

B-Inferential Statistics:

1- Statistics of in vitro results :

Analysis of shade change of staining groups after staining test was done by Kruskall- Wallis test and multiple Mann-Whitney test. Wilcoxon sin rank test was performed to compare each group separately at P value 0.05.

Paired t test was done for analysis temperature change for laser and LED groups.

Kruskal walis test used also for analysis shade change for each group of bleaching (laser and LED).

Multiple Mann-Whitney test used also for analysis and comparing each stain group by laser and LED.

Wilcoxon rank test used to compare shade change pre and post bleaching for each bleaching group.

Mann-Whiney test used also for analysis shade change means rank of LED group and that of laser group after bleaching.

Shapiro-wilk test used to analyze both thickness and temperature change for each bleaching group.

Pearson correlation test used to show the relation between thickness and temperature rise for each bleaching group.

2- Statistics for in vivo results:

Multiple Mann Whitney U test corrected by Dunn Bonferron to show if there is significant effect before and after bleaching of teeth by both laser and LED.

Fisher Exact test to show any significant difference between bleaching by laser and LED on teeth sensitivity during and after one month.

Mann Whitney test to evaluate the stability of shade reduction after one month bleaching for both laser and LED.

Fisher exact test for evaluation of teeth sensitivity during procedure of bleaching.

Marginal homogeneity test to show any significant difference between teeth sensitivity by laser and by LED after one month evaluation.

Levels of the significance:

$P > 0.05$ = (Non significant).

$P \leq 0.05$ =(Significant).

$P < 0.01$ =(Highly Significant).

Chapter Three Results , Discussion And Conclusion

3-1 Results of in vitro study

3-1-1 Results of staining:

The shade values for each stained teeth (coffee, tea, cola and juice) were recorded before and after staining as in table (3-1).

Table (3-1) Medians of shade values of different teeth before and after artificial staining .

Group	N	Baseline	After staining
COFFEE	10	1.50	8.50
TEA	10	2.00	12.00
COLA	10	2.00	11.50
JUICE	10	2.00	6.50

Such shade values of the stained teeth were analyzed as inferential statistical analysis using Kruskal – Wallis test which showed high significance difference (P = 0.000) (table 3-2):

Table (3-2) Descriptive and inferential statistical test of shade between groups using Kruskal- Wallis test.

Stain		Shade1						Shade2					
	N	Min.	Max.	Median	Mean rank	Chi square	P value	Min.	Max.	Median	Mean rank	Chi square	P value
Coffee	10	1.00	2.00	1.50	9.00	6.979	0.073 NS	8.00	10.00	8.50	9.50	19.888	0.000 HS
Tea	10	1.0	2.00	2.00	12.67			11.00	13.00	12.00	18.92		
cola	10	2.00	3.00	2.00	17.50			11.00	13.00	11.50	18.08		
Juice	10	1.0	3.1	2.00	10.83			6.00	7.00	6.50	3.50		

Shade 1 = shade of teeth before staining **Shade 2=** shade of teeth after staining

By multiple pair wise comparisons for the shade change between each staining group with the other staining groups which showed high significance for tea & juice groups (P=0.001) and for Cola & juice groups (P=0.002) (table 3-3).

Table (3-3) Multiple pair wise comparisons of shade(after staining) between groups using Multiple Mann- Whitney U test.

Stain		Dunn Bonferroni p value
Coffee	Tea	0.119
	Cola	0.202
	juice	0.825
Tea	Cola	1.00
	juice	0.001
cola	juice	0.002

By using Wilcoxon sign rank test, the shade values for each staining group separately before and after staining showed various significance difference for each groups as in table (3-4).

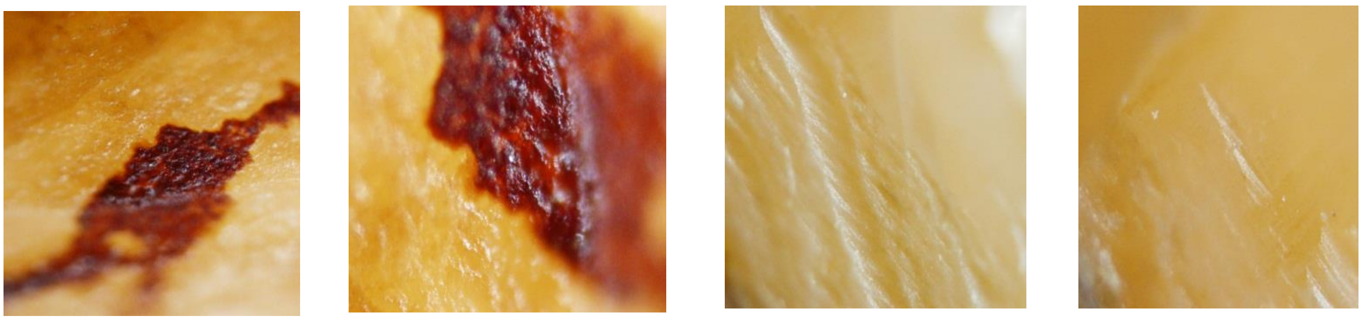
Table(3-4) Change of shade between groups using Wilcoxon sign rank test.

Stain	Shade	Z	p	Sig.value
Coffee	Shade 2 - Shade1	2.226	0.026	HS
Tea	Shade 2 - Shade1	2.232	0.026	HS
cola	Shade 2 - Shade1	2.214	0.027	HS
Juice	Shade 2 - Shade1	2.232	0.026	HS

Shade 1 = shade before staining **Shade 2 =** shade after staining

3-1-2 Optical microscope investigations:

Which showed some teeth were cracked that were excluded.



20X (Cola stain) **40X (Cola stain)** **10X (tea stain)** **20X (tea stain)**

Figure (3-1) Some images of stained teeth under optical microscope

3-1-3 Result of the absorption spectrum of the bleaching gel:

The absorption values of the bleaching gel within (265-1100) nm which was the range of light waves used in this study regarding the diode laser 940nm and the LED 450-505 nm. The absorption spectrum showed higher absorption at 300 and 400 nm with slightly more absorption between 450-505 nm (LED) than 940 nm (diode laser) (figure 3-2).

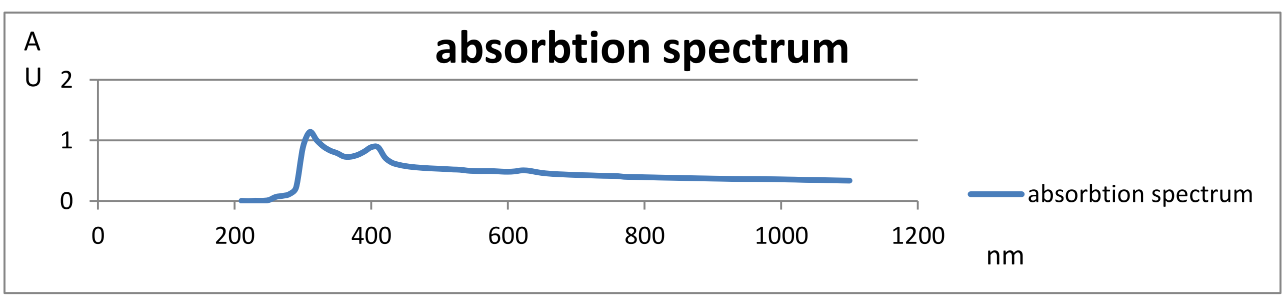


Figure (3-2) Absorption spectrum of the bleaching gel within range UV-NIR (200-1200 nm)

3-1-4 Results of analyzing optical spectrum of LED:

Where the OSA device showed that the spectrum of LED out put was within range of 450-505 nm (figure 3-3).

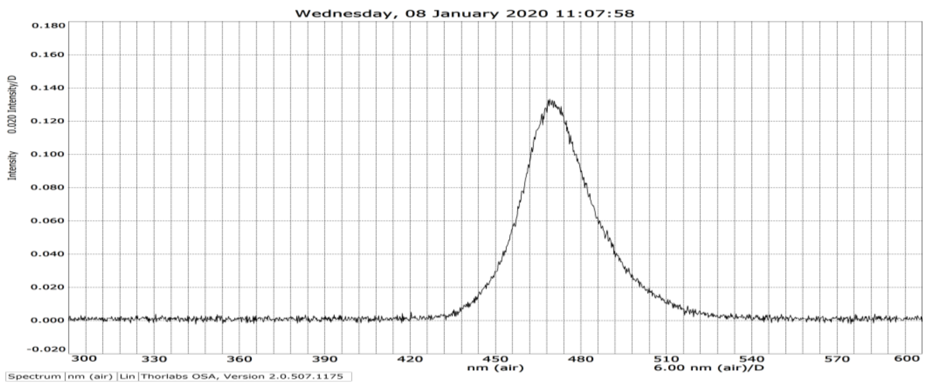


Figure (3-3) Spectral analysis of the LED

3-1-5 Results of assessment of temperature before and after irradiation by both laser and LED:

Table (3-5) showed the means of temperature of 10 samples of both bleaching groups inside the warm water bath before and after bleaching**.**

Table (3-5) Means of temperature degrees of 10 samples (before and after) for laser and LED bleaching:

N	Means of Temperature before bleaching	Means of Temperature after LED bleaching	Means of Temperature after Laser bleaching
10	**37.2**	**40.6**	**38.5**

Using paired t-test the means of temperature of the 10 samples from each group showed significance difference (P=0.000) for the laser group and significance difference (P=0.000) for the Led group (table 3-6).

Table (3-6) Paired t test show p values for the temperature change of bleached teeth by both laser and LED:

Paired Samples Statistics						Mean difference	Paired t test	P value
GROUPS		N	Mean	SD	SE			
LED	T1	10	37.2000	0000	.0000	3.43	57.433	0.000 HS
	T2	10	40.6300	1889	.0597			
LASER	T1	10	37.2000	0000	.0000	1.19	24.694	0.000 HS
	T2	10	38.3900	1524	.0482			

Table (3-7) showed the t test for the post temperature of both bleaching groups

(random 10 teeth from each) with significance difference (P=0.000) between them, figure (3-4).

Table (3-7) Means of temperature rises, SD, SE and p values for both laser and LED groups:

	GROUPS	N	Mean	SD	SE	T	P value
T2	LED	10	40.6300	.18886	.05972	29.190	0.000 HS
	LASER	10	38.3900	.15239	.04819		

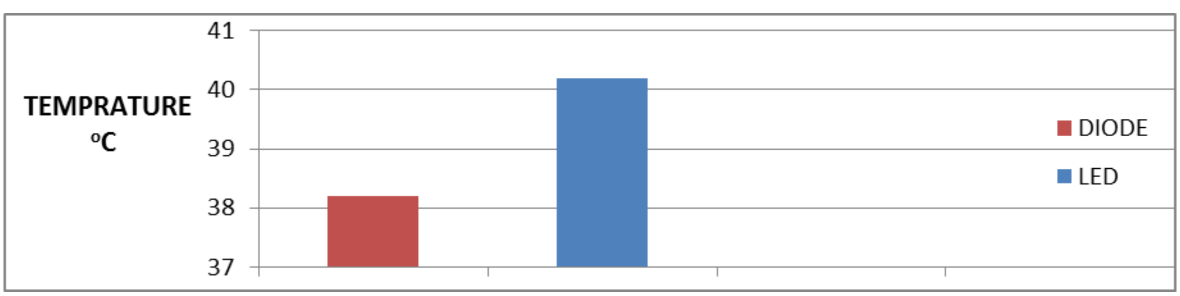


Figure (3-4) Means of pulp temperature assessed values after laser and LED assisted bleaching techniques.

3-1-6 Shade reduction of different stained groups by both laser and LED irradiation:

The maximum , minimum values of shades for each staining group after bleachinmg by both laser and LED were summerized in table (3-8).

Table (3-8) minimum, maximum and median reduction in shade change for different stained groups by both laser and LED assisted bleaching :

Stain	Before						After					
	LED			Laser			LED			Laser		
	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
Coffee	8	10	9	8	10	9	1	2	2	4	6	5
Cola	10	13	11	11	13	12	1	2	1	6	7	6
Juice	6	8	7	6	7	6	2	3	2	3	4	4
Tea	10	13	10	10	13	12	4	5	4	5	6	6
Tobacco	11	13	12	10	13	12	5	6	6	4	8	7

Data of table (3-8) were put in Willcoxin sign rank test to show the statistical analysis of the results of changing the shades before and after bleaching theses various staining groups by both laser and LED with various significance differences (different P values) (table 3-9) (3-10) (3-11).

Table(3-9) Effective size before and after bleaching in different groups.

Stain	N	Bleaching			P	ES
Coffee	5	LED	After - Before	2.236	0.025	0.707
	5	Laser	After - Before	2.032	0.042	0.643
Cola	5	LED	After - Before	2.041	0.038	0.655
	5	Laser	After - Before	2.070	0.041	0.645
Juice	5	LED	After - Before	2.070	0.034	0.671
	5	Laser	After - Before	2.121	0.038	0.655
Tea	5	LED	After - Before	2.121	0.034	0.671
	5	Laser	After - Before	2.060	0.039	0.651
Tobacco	5	LED	After - Before	2.121	0.034	0.671
	5	Laser	After - Before	2.060	0.039	0.651

Table (3-10) Kruskal –Wallis test: mean ranks, chi square and P value for shade change of different stained groups after bleaching

Bleaching		stain					Chi-square	P value
		Coffee	Cola	Juice	Tea	Tobacco		
		Mean Rank	Mean Rank	Mean Rank	Mean Rank	Mean Rank		
LED	Before	8.70	17.60	3.10	14.90	20.70	18.973	0.001
	After	7.40	4.80	11.80	18.40	22.60	21.336	0.000
Laser	Before	8.40	18.10	3.00	17.20	18.30	18.313	0.001
	After	10.60	18.40	3.90	13.60	18.50	14.621	0.006

Table(3-11): Mann-Whitney U test to compare effect of bleaching systems on different stain groups before and after bleaching by LED and laser:

Stain		Bleaching		Z	p
		LED	Laser		
		Mean Rank	Mean Rank		
Coffee	Before	5.80	5.20	0.332	0.841
	After	3.00	8.00	2.668	0.008
Cola	Before	4.70	6.30	0.876	0.421
	After	3.00	8.00	2.739	0.008
Juice	Before	6.20	4.80	0.808	0.548
	After	3.40	7.60	2.324	0.032
Tea	Before	4.40	6.60	1.205	0.310
	After	3.40	7.60	2.324	0.032
Tobacco	Before	5.60	5.40	0.111	1.000
	After	4.30	6.70	1.302	0.222

Means of shades for Laser group and Led group was analyzed to compare each other (table 3-12) (3-13) (3-14).

Table (3-12) Descriptive and statistical test of shade before and after bleaching between devices using Mann Whitney U test table:

	N	Bleaching	Z	P value	ES
LED	25	Sh2 - Sh1	4.383	0.000	0.8996
Laser	25	Sh2 - Sh1	4.398	0.000	0.8766

Table (3-13) Descriptive and statistical test of shade reduction by each technique using Wilcoxon sign rank.

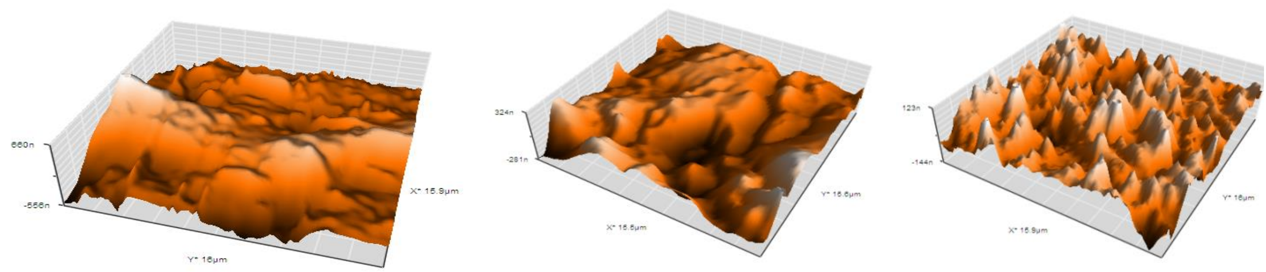
Shade difference	Bleaching	N	Mean Rank	Z	P value
	LED	25	33.04	3.710	0.000 HS
	Laser	25	17.96		

Table (3-14) Descriptive and statistical analysis of shade difference between bleaching techniques.

		Bleaching								Mann Whitney U test	
		LED				Laser					
	N	Min.	Max.	Median	Mean rank	Min.	Max.	Median	Mean rank	Z	P value
Sh1	25	6	13	10.00	24.64	6	13	11.00	26.36	0.422	0.673
Sh2	25	1	6	2.00	17.06	3	8	6.00	33.94	4.151	0.000

3-1-7 Assessment of roughness and topography of stained teeth and control group :

Figure (3-5) show samples of the results of AFM images of the control,laser and LED groups with the various AFM data results of 5 samples from each group illustrated in table(3-15), SEM also used 5 samples from each group using 100 square micrometer area with 200X magnification, samples of their images results shown in figure (3-6).

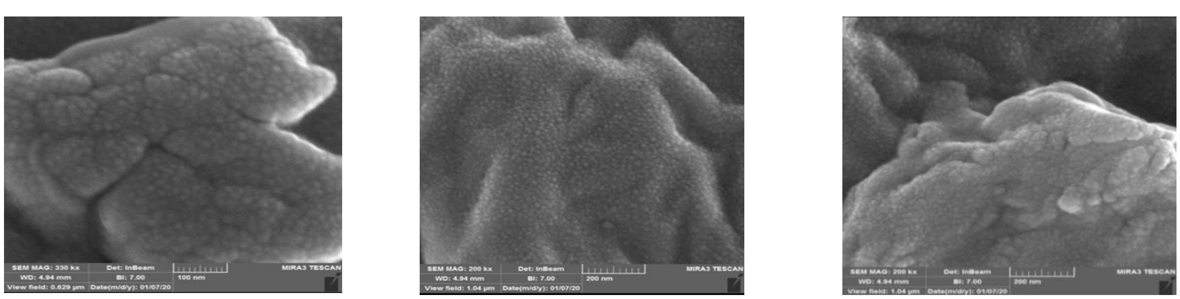


Control group **Laser group** **LED group**

Figure (3-5) AFM images of control, laser and LED groups

Table (3-15) Means of Sa for control, laser and LED groups recorded by AFM

		N	Mean	SD	ANOVA statistics	groups	groups	P value
Sa	control	5	136.03	5.018	F=301.751 P=.000	control	Laser	.000
	Laser	5	71.951	2.330			LED	.000
	LED	5	78.01	2.115		Laser	LED	.014



Control **Laser** **LED**

Figure(3-6): SEM images for control, laser and LED groups

3-1-8 Thickness of crowns of bleached teeth assessment and its relation with temperature rise:

The minimum, maximum and means of each thickness of 10 samples from each group (2 samples from each stain group) with the means of temperature rise for each group were summarized in table (3-17).

Table (3-16) Normality test for thickness and temperature rise in laser and LED groups after bleaching

Variables	GROUPS	Shapiro-Wilk		
		Statistic	Sig.	
THICKNESS	LED	0.852	0.061	NS
	LASER	0.878	0.125	
T2	LED	0.860	0.076	
	LASER	0.848	0.055	

Table (3-17) Means, SD and p values for thicknesses of 10 samples from both laser and LED groups :

	GROUPS	N	Mean	SD	SE	T test	P value
THICKNESS	LED	10	2.8600	.3893	.1231	0.051	0.960 NS
	LASER	10	2.8700	.4855	.1535		

Table 3-18 showed High significance relation between LED and thickness of teeth bleached by it while the laser groups showed less relation between laser bleaching and thickness of bleached teeth by Pearson correlation test, same results of relation shown in figure (3-7).

Table (3-18) Relations between thickness and temperature rise of both laser and LED groups:

Correlations			
GROUPS		THICKNESS	
		r	p
LED	T2	-0.904	.000 HS
LASER	T2	-0.650	.042 Sig.

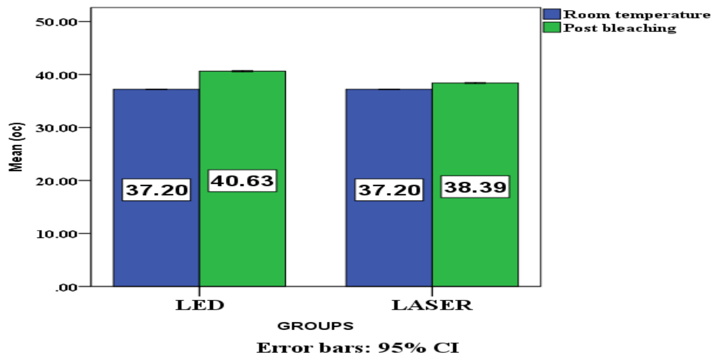


Figure (3-7) Pre and post maximum temperature for laser and LED groups

3-2 Results of vivo study :

3-2 -1 Results of shade reduction and whitening stability :

Minimum, maximum scores of the shades of bleached teeth were summarized as means before bleaching, after bleaching as shown in table (3-19).

Table (3-19) Descriptive statistics of shade by time and group:

groups		Sh1	Sh2	Sh3
Laser	Minimum	10.00	5.00	5.00
	Maximum	14.00	8.00	9.00
	Median	11.50	6.50	8.00
LED	Minimum	9.00	3.00	5.00
	Maximum	13.00	8.00	9.00
	Median	10.50	4.00	6.50

Sh 1= shade before bleaching

Sh2 = shade after bleaching procedure

Sh3 = shade after one month post bleaching

The statistical results of the data of table (3-19) were shown in table (3-20)(3-21) which showed high significant results for changing shades of bleached teeth before and after laser and LED bleaching also showed more significant shade stability for laser bleached teeth than LED bleached teeth in one month post bleaching period (figure 3-8).

Table (3-20) Descriptive and statistical test of shade means during time in each group using Friedman test and Multiple Mann Whitney U test corrected by Dunn Bonferroni method.

groups		Mean Rank	Chi square	df	P value	ES	P value	
Laser	Sh1	3.00	16.632	2	0.000 HS	0.832	1 x2	0.000 HS
	Sh2	1.30					1 x 3	0.011 Sig.
	Sh3	1.70					2 x3	1.00 NS
LED	Sh1	3.00	20	2	0.000 HS	1	1 x2	0.000 HS
	Sh2	1.00					1 x 3	0.076 NS
	Sh3	2.00					2 x3	0.076 NS

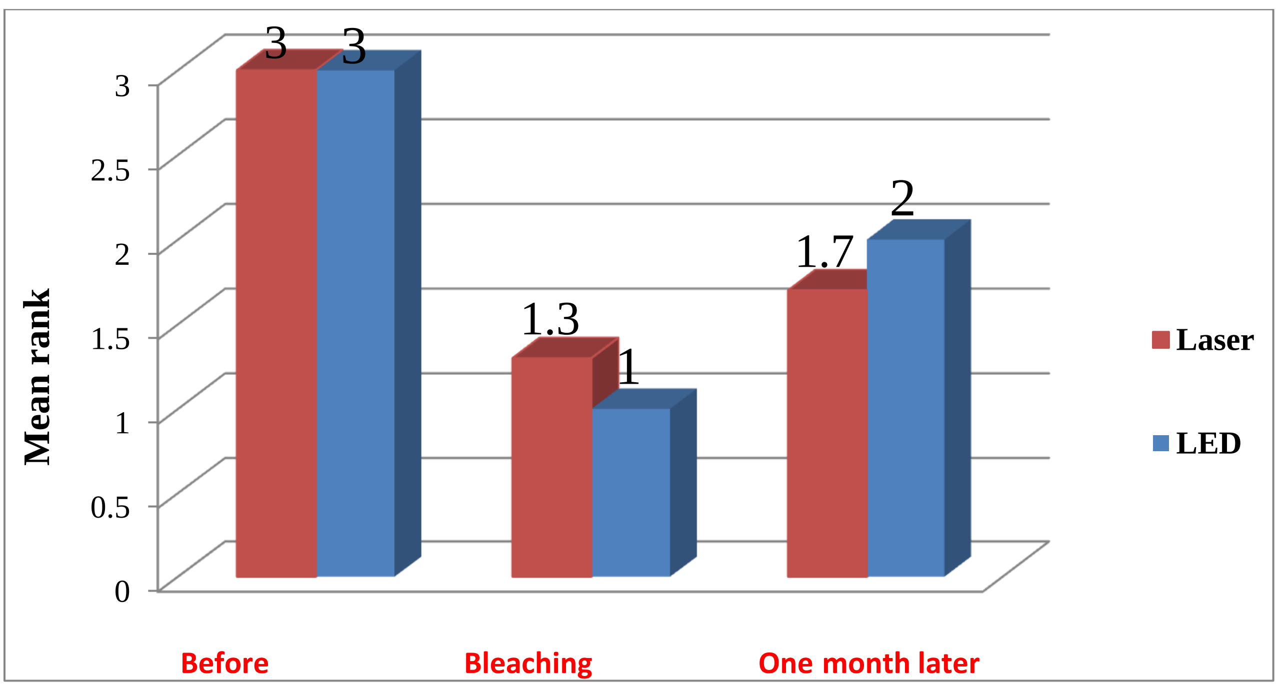


Figure (3-8) Bar chart of means of ranks shade scores before, after and one month post bleaching by laser and LED

Table(3-21) Descriptive and statistical test of shade between groups in each time using Mann Whitney U test table:

Score of VAS During bleaching	groups								Total		
	Laser			LED			Fisher exact test	P value			
	N.	%	% T	N.	%	% T			N.	%	% T
0	7	46.67	23.33	0	.00	.00	20.571	0.000 HS	7	23.33	23.33
1	1	6.67	3.33	0	.00	.00			1	3.33	3.33
2	2	13.33	6.67	0	.00	.00			2	6.67	6.67
3	2	13.33	6.67	1	6.67	3.33			3	10.00	10.00
4	3	20.00	10.00	4	26.67	13.33			7	23.33	23.33
5	0	.00	.00	7	46.67	23.33			7	23.33	23.33
6	0	.00	.00	1	6.67	3.33			1	3.33	3.33
7	0	.00	.00	1	6.67	3.33			1	3.33	3.33
8	0	.00	.00	1	6.67	3.33			1	3.33	3.33

3-2-2 Results of teeth sensitivity:

According to VAS (visual analogue scale), the results were statistically analyzed as in (table 3- 22) (table 3-23) (figure 3-10).

Table (3-22) Descriptive and inferential statistical analysis of VAS scores during bleaching by laser and LED:

Time	groups	Mean Rank	Z	P value	ES
Sh1	Laser	12.30	1.406	0.190 NS	0.314 medium
	LED	8.70			
Sh2	Laser	14.30	2.917	0.003 HS	0.652 large
	LED	6.70			
Sh3	Laser	12.6	1.625	0.123 NS	0.363 medium
	LED	8.40			

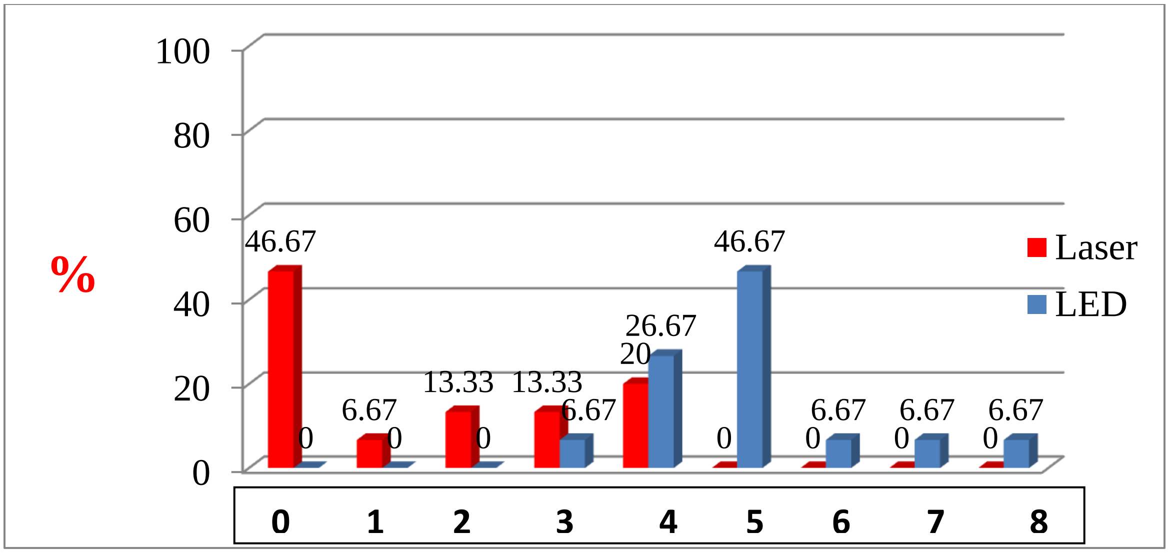


Figure (3-9) Bar chart of the variation in teeth sensitivity during bleaching by both laser and LED.

Table (3-23) statistical analysis for VAS scores of bleached teeth after one month

Score of VAS Post month	groups						Fisher exact test	P value	Total		
	Laser			LED							
	N	%	% T	N	%	% T			N	%	% T
0	9	60.00	30.00	0	.00	.00	24.769	0.000 HS	9	30.00	30.00
1	3	20.00	10.00	0	.00	.00			3	10.00	10.00
2	3	20.00	10.00	3	20.00	10.00			6	20.00	20.00
3	0	.00	.00	8	53.33	26.67			8	26.67	26.67
4	0	.00	.00	4	26.67	13.33			4	13.33	13.33

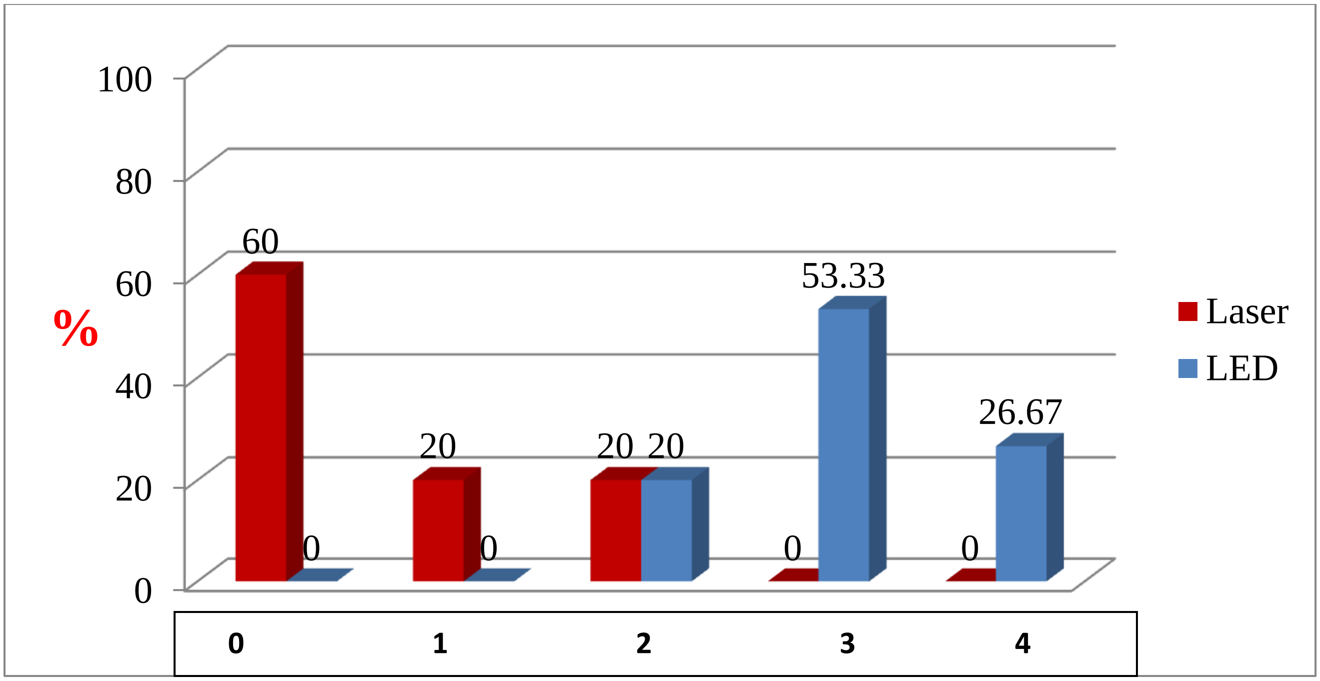


Figure (3-10) Bar chart of variation in VAS scores for bleached teeth after one month bleaching by laser and LED.

In table (3-24) although VAS reduce after bleaching (post month) in both Laser and LED but the reduction is more in Laser than in LED with highly significant change in both procedures (whitening) (figure 3-10).

Table (3-24) show Change of VAS in both Laser and LED using Marginal homogeneity test comparing them during and after one month after bleaching:

groups		Bleaching	Post month	Z	P value
Laser	Min.	.00	.00	2.021	0.043 Sig.
	Max.	4.00	2.00		
	Median	1.00	.00		
LED	Min.	3.00	2.00	3.183	0.001 HS
	Max.	8.00	4.00		
	Median	5.00	3.00		

3-3 Discussion

The idea of the bleaching is the chemical lysis of the composition molecules of the stain that present within or on the outer surface of the enamel structure. This lysis is achieved by the action of strong free oxygen radicles that liberated from the highly oxidative agent of the bleaching gel which is HP (Shivaprasad et al 2019).

The bleaching agents regardless of their main oxidative bleaching agent, but at last it is decomposed to form the HP which play the important role in the process of whitening with variation in it concentration, and this decomposition of this agent either occurs as self chemical reaction without need for any accelerating agents or heat as the main accelerator that lead to the decomposition of the HP to liberate the free radicles or some times assisted by light which end with heat generation that achieve the same role. This type of bleaching called “ power bleaching“ (Saha et al 2017; Sulieman 2005).

The most common types of lights used for the light assisted bleaching is the LED (400-500 nm) even though the laser also used in recent years as an accelerator with variation in its parameters as: wavelength, power density , intensity, exposure time, exposure area, ..etc (Hien et al 2003). There was clear controversial argument about the benefits and adverse effects of each, most of researches conducted by invitro or invivo studies and there was limitation in achieving both studies in one experiment. Accordingly, power bleaching was performed on extrinsic stained teeth made artificially in the lab (in vitro) or found in patients (in vivo), as there were many types of teeth staining whether extrinsic or intrinsic types, therefore, it was of important thing to conduct such power bleaching on the same types of staining, hence, an artificial staining was done as an extrinsic staining to use both types of light by the same bleaching agent “ WHITE LIGHTSMILE 32% HP”. Then assessment of the shade reduction efficiency, temperature changes of the bleached teeth, surface topography was done. In vivo study included the use of split mouth technique to ensure the unbiased conditions for both techniques regarding same stain, same PH, same humidity and same temperature. It was proposed to include 30 patients(in vivo study), but the pandemic of COVID19 forced to include only 15 patients assessed for both whitening efficiency and teeth pain sensation during and after the bleaching process. Also after one month postoperative bleaching, the whitening stability and the teeth pain sensation were assessed .

3-3-1 Artificial staining :

In the invitro study the most common types of extrinsic stain in the like: tobacco, coffee, tea, cola and juice were used. The tobacco stained teeth chosen from the extracted anterior teeth for periodonontal problems that already stained by tobacco stain, while other stains solutions were prepared by using these beverages that are common consumed in the Iraqi society. Methods used were also used in many studies published regarding teeth artificial staining (Patrica and Zyeneb 2006 ; Yan et al 2012). This study showed that tea used within such experiment has the highest staining effect on teeth and juice had the least which could be attributed to the chemical composition of tea solution and its chemical effect on the teeth surfaces.

3-3-2 Thermal effect

Thermal effects of bleaching systems may occur with varying degrees due to many factors such as concentration of gel, parameters of bleaching technique, duration of exposure and the morphology of tooth structure. Using of light activation during bleaching cause some thermal effect, this lead to rise in temperature in the pulp tissues. This could be governed by the nature of light applied, the laser (High intensity light) rise temperature more than other conventional lights but the short irradiation time lead to rising the surface temperature more than the pulp temperature (White 2000).

The temperature reports of this study showed more rise (3.4 ^{o} C) in teeth bleached by LED that was nearer to critical hazardous temperature degree of the pulp (5.5^{o}C) compared to (1.3 ^{o} C rise) for the laser group (table 3-11). This might be attributed to prolonged exposure time of LED on the teeth surfaces that led to more exothermic absorption by the gel which convey such high temperature to the pulp tissue, such absorption was clear by the spectral analysis of the bleaching gel figure (3-2). Similar results conducted by Ligia et al. in 2014 who showed that more pulp temperature increased in LED group than diode laser although using of 35% HP.

The result of thermal effect in this study may disagree with Zhang et al (2007) who used 35% HP with 980nm diode laser and LED 470 nm and concluded that bleaching with diode laser may rise pulp temperature more than LED, such difference could be due to use of different bleaching gel, wavelengths and HP concentration. The significant difference of temperature rise indicates that diode laser 940nm in this research could be more safe to be used in bleaching because of the less amount of heat generated during bleaching procedure which reduced the damage effect to the pulp vitality.

The rise in temperature during whitening process may traumatize the vitality of pulp tissues especially when the procedure takes longer time. Therefore, proper selection of whitening technique and instrument is an ethical responsibility, solving patient's complain without damage or poor prognosis is ultimate goal. For such demand we chose this type of bleaching gel (Light White Smile) with reasonable concentration of hydrogen peroxide (32%) (Ozyilmaz et al 2015).

3-3-3 Whitening efficacy:

In this study light application on a chemical substance (bleaching gel) which cause liberation of free radicles that reacts with the stain molecules to cause degradation of the stain molecules. Such degradation occurs due to accelerating effect of light photons on the chemical absorbers, such reaction lead to thermal generation which then degrade the HP and liberating strong free radicles, i.e. increase in the temperature may increase collisions among the molecules of the bleaching gel that frequently increase the possibility of bonding cleavages of organic molecules of stain where the 10 ^{o}C increase in temperature double the bleaching time (Carlos et al 2013 ; Joiner 2006). Although there is a harmony between light sources (LED and diode laser), the absorption rate of the light photons by the bleaching ingredients will play a great role as an effective parameter in light bleaching process, therefore, the more the liberation rate of free radicles, the more whitening efficacy.

In the results of invitro study, there was more significant whitening efficiency in the LED group compared to laser which could be due to more heat generation beside more time of such heat application that gave more chances for liberation of free radicles which enhanced more whitening effects although led to adverse effect on the pulp of the bleached teeth. Akin et alin (2002) found that diode laser 940nm has more whitening efficiency than LED bleaching and it may cause weakening in bond strength of the enamel structure by investigating the laser bleached teeth surfaces by AFM, such results may not be agreed with our study although they used 40 % hydrogen peroxide with longer exposure time. Nicklaus et al (2004)showed that LED (470nm) achieved better results than the diode laser (808nm) regarding the luminosity when associated with the Opalescence Xtra bleaching agent. In this study the results come in agreement with Lagori et al (2014) who showed that diode laser has superiority in bleaching coffee staining. while this study is disagreed with a study conducted by Fekrazad et al (2017) who showed that diode laser produced more whitening efficiency compared to LED which may be attributed to some factors which may include using of 38% bleaching gel and different exposure time. The invivo study showed close results of whitening efficiency between LED and diode laser which could be attributed to the internal conditions of the living tissue inside the mouth like the PH, humidity, blood circulation and others that affect the temperature of the pulp and tooth surface which eventually affect the bleaching action, such results come in agreement with Gurgan et al (2009), and disagree with Domingeus et al (2011) who showed LED bleached teeth gave best thermal results than diode laser which could be due to use of different bleaching agent.

3-3-4 Surface Roughness and topography:

In this study AFM results of bleached teeth showed significant difference between control group and LED and laser groups regarding the Sa(Figure 3-5) (table 3-15), it was also purposed to compare the ultra-structural changes in enamel surface caused by bleaching technique with 32% concentration. The AFM test showed less surface roughness for the diode laser bleached teeth than LED bleached teeth which could be attributed to the melting effect of the intense laser light on the enamel surface which cause re solidification of the enamel outer surface. High concentration of HP may also affect the surface roughness of the bleached teeth causing more roughness or altering the enamel microhardness (Alhano 2013; Al Shammeri et al 2010). Which may need further investigation using higher number of samples to confirm such roughness investigation. SEM investigations showed Both bleaching systems have no significant effect on the teeth surface topography(figure 3-5) which come in agreement with other studies like of Azarbiani et al (2018) who investigated the surface topography after

810 nm diode laser light bleaching. Ilkat et al (2006) investigated the enamel surface topography for diode laser bleached teeth and found the same results.

3-3-5 Teeth sensitivity:

Teeth sensitivity during and after the bleaching could be attributed to the penetration of the HP inside the dentinal tubules which then irritate the nerve endings by both positive pressure and osmosis pressure. This event has variable degree according to the amount of the bleaching agent penetrating the dentinal tubules, thickness of teeth, amount of temperature rising, pain threshold of the patient, enzymatic defense mechanism and others. LED bleached teeth showed more teeth sensitivity than laser bleached teeth, Such sensitivity may be attributed to some affecting factors:

1- Long time exposure to LED compared to diode laser.

2- More chances for LED to enhance gel adsorption which may cause more chances for dentinal tubular entrance of gel free radicles toward the pulp that lead to more irritation of nerve endings and more osmotic pressure beside positive pressure of the HP which press the nerve endings inside the dentinal tubules enhancing prolonged teeth sensitivity pain.

3- More temperature rising in LED bleached teeth than laser bleached teeth.

These results come in agreement with results of study done by (Sevil et al 2010) who used 38% HP and concluded that diode laser 810 nm cause less teeth sensitivity than LED after bleaching teeth. However the result regarding temperature rise and teeth sensitivity disagreed with Roche et al 2012 and Giudice et al 2016 who found that LED bleaching can cause insignificant teeth sensitivity or diode laser bleaching cause teeth sensitivity more than LED which may be due to the use of different parameters like using of UV, IR and white light combination within the LED source beside using

35% carbamide peroxide. Almaliky (2019) found that use of diode laser 940 nm during bleaching lead to reduce sensitivity that occur due to effect of HP.

Many researches indicated that high concentration of hydrogen peroxide causes teeth sensitivity and trauma to the soft tissues during and after treatment (Kossatz et al 2011). High concentration of HP lead to more release of free radicles that may hurt the pulp due to penetration of excess of them inside the dentinal tubules leading to the irritation of the pulp (Davidi et al 2008 ; Abdul Sattar et al 2010). Therefore, the 32% bleaching gel chosen in this study for more safety and vitality of teeth structure. It is important to take into consideration the protective mechanism In the vital pulp where the pressure of the pulpal fluid is capable to reduce the inward diffusion of chemicals toward the pulp beside the lysing enzymes found in the pulpal fluid that degrade the chemicals passing through the dentinal tubules (Carlos et al 2013). VAS scale was useful in evaluation the teeth sensitivity during bleaching by both laser and LED were there were significantly less teeth sensitivity for laser bleached teeth compared to LED bleached teeth during the whitening procedure. This study come in agreement with Fekrazad et al (2017) who showed less teeth sensitivity for laser bleached teeth than LED but disagree with Roche et al (2004) which could be due to higher HP concentration.

For such reasons, the one month postoperative evaluation showed less teeth sensitivity in laser bleached teeth compared to LED bleached teeth beside that researches indicated that the diode laser also caused narrowing of the openings of dentinal tubules due the melting action of it at the enamel structure, therefore, less sensitive teeth in diode laser bleached groups.

3-3-6 Whitening stability:

One month post bleaching results showed more stability of whitening of the laser bleached teeth than LED bleached teeth which could be due to the less rough surface of the laser bleached teeth as appeared in AFM test. This result come in agreement with Al Quran et al (2011) after 3 months assessment. The LED irradiated teeth showed more surface roughness due to the effect of surface temperature raise which created favorable surfaces for staining on such teeth. Many studies showed the diode laser could cause surface enamel re solidification which may enhance more smooth harder surface that resist etching or roughness compared to LED treated teeth and such effect may decrease the possibility of relapse of teeth staining (Ilkat et al 2006).

3-4 Conclusion

1- The laser bleaching had better safety effect on the teeth pulp temperatures compared to LED (within the parameters and conditions of our study).

2- SEM investigations showed no difference in tooth topography while AFM showed slightly less surface roughness for laser compared to LED due to re solidification of the outer enamel surface.

3- One month post bleaching showed more whitening stability for laser than LED bleaching.

4- One month post bleaching showed less teeth sensitivity for laser bleached teeth than LED bleached teeth.

3-5 Suggestions :

1- Light assisted teeth whitening using other type of bleaching gel.

2- Light assisted teeth whitening using shorter exposure time for the LED.

3- Light assisted teeth whitening using Double session time of laser.

4- Evaluation of surface roughness of bleached teeth using profilometry technique.

5- Postoperative teeth bleaching evaluation follow up of more than one month.

References

Abdelfattah, M.(2014) . Different types of laser use in teeth bleaching. J Med Med Sci, 5:230-7.

Abdulrahman A.,N. Alsolaihim ,A., Aljood A. Alsolaihim,D. Layla O. Alowais A. (2020) . In Vivo and In Vitro Diagnosis of Cracked Teeth: A Review.Journal of International Oral Health , pp.329-333.

Abdul Sattar S., Abdulla K., Zainab M. (2010). Study the hardness and temperature changes during tooth bleaching using different Laser Sources, J Bagh Colle Dentistry Vol. 22(4).

Akin C. , Sevimay M., Ozyilmaz O., Cokuk N. (2020). Evaluation of the shear bond strength of resin cement to enamel after bleaching with Er: YAG and diode laser, Advanced Composites Letters ,Volume 29: pp.1–7.

Alhano F. (2013). Changes in Color and Roughness with Laser Bleaching using different Peroxide Concentrations, , Al Hano JOR .1, (1): p:6-11.

Almaliky A.(2019) . Clinical Investigation of 940 nm Diode Laser Power Bleaching: An In Vivo Study, J Lasers Med Sci. 10(1): pp.33–36. doi: 10.1517.

Al-shimmer A., Al-Maliky M. and Al-casey M. (2010). Effect of in-dental clinic bleaching agents on the releases of mineral ions from the enamel surfaces in relation to their times intervals, J Bagh College Dentistry Vol. 22(1), pp:76-78.

Alqahtani M. (2014).Tooth-bleaching procedures and their controversial effects: A literature review. The Saudi dental journal , 26(2) : pp. 33-46.

Al-Quran F., Yasar M., Saba A., Ahed A.,Lawrence M.(2011). Efficacy and Persistence of Tooth Bleaching Using a Diode Laser with Three Different Treatment Regimens. Eur J Esthet Dent ,6:pp.436–445.

American Academy of Pediatric.(2000) . The role of prophylaxis in pediatric dentistry Dentistry , 22(7) : p. 37.

Ames J. (1937). Removing stains from mottled enamel. J Am Dent Assoc, 94: pp.1674-1677. doi: 10.14219/jada. Archive , 304

Araujo L., Baratieri N. and Ara´ujo E.(2010).In situ study of in-office bleaching procedures using light sources on human enamel microhardness. Operative Dentistry, vol. 35, no. 2, pp.139–146.

Aryan, H.(2013). Tooth whitening industry opens wide with myriad procedures and products. . J. Acad. Indus. Res. Vol. 1(8). pp.435-442.

Azarbiani Z., Tahereh S., Jafarzadeh K., Yasaman E.,Nasim C. and Vahid R.(2018) . Efficacy of diode laser irradiation during dental bleaching in preventing enamel damage caused by bleaching, Dent Res J (Isfahan), 15(5):pp. 320–326.

Azer S., Machado C, Sanchez E. and Robert R. (2009) . Effect of home bleaching systems on enamel nanohardness and elastic modulus. J Dent , 37(3):pp. 185–190.

Batista G., Daphne C., alessandra B. and Carlos R.(2001) . Analysis of the pulp chamber temperature of teeth submitted to light activation with and without bleaching gel. World J of Dent , 2:23-7.

Berger, Cavalli V., Martin A., Sandrin B. , Vanisa C. , Airton M., luis S., Marco A., Maecel B. and Maecelo G. (2010).Effects of combined use of light irradiation and 35% hydrogen peroxide for dental bleaching on human enamel mineral content. Photomedicine and Laser Surgery, 28, (4): pp. 533–538 .

Bernardon J., Sartori N., Ballarin A., Perdigao J., Lopes G., Baratieri N. (2010).Clinical performance of vital bleaching techniques. Oper Dent, 35: pp.3–10.

Boksman L.(2007). Shade selection; accuracy and reproducibility. Ont Dent, pp. 24-27.

Bridges W.(1964). Laser oscillation in singly ionized argon in the visible spectrum, Appl. Phys. Lett. , 4(7): pp.128-130.

Bromberg J. (1992).Amazing light. Invention & Technology Magazine., 7(4): pp.1-8

Browning W. (203).Use of shade guides for color measurement in tooth-bleaching studies. J Esthet Restor Dent , 15(Suppl 1): pp.13–20.

Buchalla and T. Attin, (2007). External bleaching therapy with activation by heat, light or laser a systematic review. Dental Materials, 23, (5): pp. 586–596.

Cadenaro M, Breschi L, Nucci C , Lorenzo B. , Franceska A. Erika V. , Carlo P. Bruce A. and Roberto L. (2008). Effect of two in-office whitening agents on the enamel surface in vivo: a morphological and non-contact profilometric study. OperDent , 33(2): pp.127–134.

Calmon, A. Brugnera J. and Munin E. (2004). Estudo do aumento de temperatura intra-pulpar gerado pelo clareamento dental . Revista Ga´ucha de Odontologia, 52, (1): pp. 19–24.

Camarga S. and Valera M (2007). Penetration of 38% Hydrogen peroxide into the pulp chamber in bovine and human teeth. J Endod , 33(9): pp.1073-1077.

Can D.And Karabulut B.(2011). Influence of activated bleaching on various adhesive restorative systems. Journal of Esthetic and Restorative Dentistry , 23(6): pp.399-408.

Carlos G., Torres, C., Cristiane S., Alessandra B., Maria R. , Huhtala L., and Taciana M. (2013). Influence of Concentration and Activation on Hydrogen Peroxide Diffusion through Dental Tissues In Vitro, The Scientific World Journal,(12) Article ID 193241, pp.1-5 pages.

Carrasco, L., Carrasco G. and Frone C. (2008).In vitro study of the pulp chamber temperature rise during lightactivated bleaching .Journal of Applied Oral Science, vol. 16, no. 5, pp. 355–359.

Cesar,L. Soares S., Alves P., Martin, A. , Munin E., and Liporoni S. (2009). Fourier transform-raman andreflectance studies on dental enamel bleached with hydrogen peroxide activated using a light-emitting diode-laser system .Photomedicine and Laser Surgery, 27, (6): pp. 913–919.

Clifton M.(2014).Tooth Whitening: What We Now Know, J Evid Based Dent Pract. 14 Suppl: 70–76. doi:10.1016/j.jebdp.02.006, p9 .

Collins L, Brenda M., Joanne L., Maria B., Stephane L., Philip W., David L. and Mojgan N. (2004).Clinical evaluation of a novel whitening gel, containing 6% hydrogen peroxide and a standard fluoride toothpaste. Journal of Dentistry ,1,(32) : pp.13–17.

Convissar R. (2015).Principles and practice of laser dentistry. Elsevier Health Scinces; 2nd. Ed. (6) p: 12- 38.

Coutinho L., Silveira J., NicolauA., Zanin F., and Brugnera J.(2009). Comparison of temperature increase in in vitro human tooth pulp by different light sources in the dental whitening process," Lasers in Medical Science, 24, (2): pp. 179–185.

Das UK, Maiti N. (2014).Vital tooth Bleaching. Am J Advan Med Sci,(2) :pp.1-6. www.arnaca. fopras. org/ images vol 2 no.1 201-104-1-6.

David J. ,Cherylen G. , Jacinthe M. and Paqete,D.(2003).Definitive Diagnosis of Early Enamel and Dentin Cracks Based on Microscopic Evaluation,j. Esther Restor Dent 15:391401.

Davidi M., Hadad A., Weiss E., Domb A., Mizrahi B., and Sterer N. (2008).The effect of a mild increase in temperature on tooth bleaching. Quintessence Int , 39 (9): pp.771–775.

Demarco F., Meireles S.and Masotti S.(2009). Over-the-counter whitening agents: a concise review. Brazilian oral research , 23: pp. 64-70

Dharti N. (2015).Tooth Discoloration, MedScape , Updated: Dec. 07.

Dixit H, Bachkaniwala M, Khan S, Yadav H, Pandit V, Mandlik J. (2016). In- Office teeth Whitening: Case Report. Int J of Oral Health Med Res, 3(3): pp.70-72.

Dominguez. A. , Juan A., Angel C. and Clara G. (2011). Influence of the Light Source and Bleaching Gel on the Efficacy of the Tooth Whitening Process. Photomed Laser Surg , 29: pp.53-59.

Dostalova T. Helena J., Devana H., Jan s., Michal N.,Mitsunobu M., Aldo B., JUNIOR A. and Fatima Z.(2004) . Diode laser-activated bleaching. Brazilian Dental Journal ,15: pp.I-3.

Emily S.(2012). The Basic Principles Of Laser Technology. Uses And Safety Measures In Anesthesia, p: 1-9.

Eada E. , Tominaga T.,Yasukawa H.and Oshida Y.(2019). Temperature Increase during Tooth Whitening , Dentistry and Practices , 2(1): p.3-4.

Fekrazad R. , Shervin A., Katayoun A. , Hadi A. , Seyed Mirmohammadi M.(2017). Comparison of laser and power bleaching techniques in tooth color change, J Clin Exp Dent. 9(4):e511-5.

Fumio W. (2005). In situ quantitative analysis of etching process of human teeth by atomic force microscopy. Journal of Electron Microscopy , 54(3): pp.299–308 .

Lagori G., Vescovi P.,Merigo E., Meleti M.and Fornaini C.(2014).The bleaching efficiency of KTP and diode 810 nm lasers on teeth stained with different substances an in vitro study. Laser Therapy, 23:pp. 1,21:30 pp. ,21-3 .

Gaurav P., Yoshaskam A., Saketh R., Namratha L., Sambarta D.(2013). An in Vitro Spectrophotometric Analysis of the Penetration of Bleaching Agent into the Pulp Chamber of Intact and Restored Teeth . J Clin Diagn Res, 7(12):pp. 3057–3059. DOI: 10.7860/JCDR/2013/7589.3852.

George P .(2016).Tooth Whitening,e book, Springer, 3rd ed.

Gerlach RW and X Zhou . (2001).Vital bleaching with whitening strips: summary of clinical research on effectiveness and tolerability. The Journal of Contemporary Dental Practice , 2(3):pp. 1-16.

Geusic J., Marcos A., and Uitert G. (1964). Laser oscillations in Nd-doped yttrium aluminum, yttrium gallium, and gadolinium garnets. Appl. Phys. Lett , 4(10):pp.182-184.

Giudice R., Pantaleo G., Lizio A., Romeo U., Castiello G., Spagnuolo G.(2016). Clinical and Spectrophotometric Evaluation of LED and Laser Activated Teeth Bleaching. Open Dent J, 10: pp.242–250, DOI: 10.2174/1874210601610010242.

Gohar k., Schoop U., Wernisch J., Hartl S., De Moor R., and Moritz A. (2009). Frequency doubled neodymium:yttriumaluminum- garnet and diode laser-activated power bleaching ,pH, environmental scanning electron microscopy, and colorimetric in vitro evaluations. Lasers in Medical Science, 24,(3):pp. 339–346.

Gokay O, Mujdeci A, Algin E. (2005).In vitro peroxide penetration into the pulp chamber from newer bleaching products. Int Endod J ,38 (8):pp. 516–520.

Goldberg, M. and Lynch E. (2010).Undesirable and adverse effects of tooth-whitening products: a review. Clinical Oral Investigations, 14, (1) : pp. 1–10.

Gotz H, Duschner H, White DJ. And Malgorzata A. (2007). Effects of elevated hydrogen peroxide ‘strip’bleaching on surface and subsurface enamel including subsurface histomorphology. micro-chemical composition and fluorescence changes. J Dent , 35(6):pp. 457–466.

Guptaa, S. and S. Kumarb. (2011).Lasers in Dentistry-An Overview, 25(3): pp.119-1230.

Gurgan S, Cakir FY, Yazici E. (2010). Different light-activated in-office bleaching systems: a clinical evaluation. Lasers Med Sci, 25(6): pp.817-812.

Hahn P, Schondelmaier N, Wolkewitz M, Altenburger MJ, Polydorou O.(2013). Efficacy of tooth bleaching with and without light activation and its effect on the pulp temperature: an in vitro study. Odontol , 101:pp.67–74.

Heft MW, Parker SR. (1984). An experimental basis for revising the graphic rating scale for pain. Pain j., 19(2):pp.153–61.

He L.B. , MY Shao, K Tan, X Xu, and JY Li. (2012).The effects of light on bleaching and tooth sensitivity during in-office vital bleaching: a systematic review and meta-analysis. Journal of dentistry , 40(8):pp. 644-653.

Hegde Mithra N. and S. Krishna.(2012). Overview of in-office bleaching of vital teeth. Int Res J Pharmacy , 3(11):pp. 12-16.

Hein K., Brad J., Jason K., Rachelle S., Timothy M.and Lee D. (2003). vital tooth bleaching what do lights ,Compend Contin Educ Dent. 24(4):pp.340-352.

Iklat K., Eduard K.,Kohara M.,Jorje E., Niklaus E.(2006).Effect of 960 nm Diode Laser Irradiation on Calcium Solubility of Dental Enamel :L in Vitro study,Photomedicine and Laser Surgery, 2, (24): pp.810-822.

International Organization for Standardization.(2011). Dentistry-Products for External Tooth Bleaching. Geneva ISO , 28: p.399.

Jagdish P.(2015). Dopant induced changes in structural, optical and electrical properties of CdSe thin films, Journal of Alloys and Compounds ,pp. 953–959.

Janković B. (2009).Tooth Whitening in Esthetic Dentistry: principles and techniques. Acta stomatologica Croatica , 43(2): pp.75-162.

Jiang T, Jiang T, Ma X, Wang Z, Tong H, Hu J, Yining Wang Y.(2008). Beneficial effects of hydroxyapatite on enamel subjectedto 30% hydrogen peroxide. J Dent , 36(11): pp.907–914.

John S. and Mamoun, D. (2015).Cracked tooth diagnosis and treatment : An alternative paradigm, Eur J Dent, 9:pp.293-303:pp. 04.09.

Joiner A .(2006). The bleaching of teeth: a review of the literature. J Dent ,34: pp.412-9.

José Roc R. ,(2018). Effect of bleaching agents on black tooth stains caused by chromogenic bacteria: 10 years follow-up case report, RGO, Rev. Gaúch. Odontol. vol.66 no.2 Campinas.

Joiner A. (2008). A review of tooth color and whiteness. Journal of dentistry , 36: pp.2-7.

Kabbacha, , D. M. Zezellb, M. C. Bandécaa, T. M. Pereirab, and M. F. Andradea.(2010). An in vitro thermal analysis during different light activated hydrogen peroxide bleaching. Laser physics, 20(9): pp.1833-1837.

Kaschke M, Donnerhacke KH. And Rill MS.(2014). Optical devices in ophthalmology and optometry. Saksa: Wiley-VCH. Pp.52-56.

Kaung W. (2009).Lasers Principles and Applications : Past, present, and future, P 7.

Kikly A., Sabra J. and Saida S. (2019) . Vital laser-activated teeth bleaching and postoperative sensitivity: A systematic review. J. Esthet. Restor. Dent, pp.1-10.

Klunboot U, Arayathanitkul K, Chitaree R, Emarat N.(2011). Effective of diode laser on teeth enamel in the teeth whitening treatment. Proc of SPIE,PP.1-8. Doi: 10.1117/12.904472.

Kossatz S, Dalanhol AP, Cunha T, Loguercio A, Reis A. (2011).Effect of light activation on tooth sensitivity after in-office bleaching. Oper Dent , 36(3):pp.251-257.

Lagori,P., Vescovi E., Merigo,M.,Meleti and Fornaini C.(2014).The bleaching efficiency of KTP and diode 810 nm lasers on teeth stained with different substances an in vitro study,Laser Therapy, 23:pp.1,21:pp.30 ,21-30.

Lewinstein I., Fuhrer N. and Churaru N.(2004). Effect of different peroxide bleaching regimens and subsequent fluoridation on the hardness of human enamel and dentin. J Prosthet Dent , 92(4):pp. 337–342.

Li-Bang A., Mei-Ying S., Ke T., Xin K., Ji-Yao L.(2012). The effects of light on bleaching and tooth sensitivity during in-office vital bleaching: A systematic reviewand meta-analysis, journal of dentistry, 4 0 : pp.6 4 4 – 6 5 3.

Lígia A., Ana F., Juliana B., Adilson Y., Rafael M.(2015). Whitening gel and light source influence on pulp chamber temperature, RSBO.12(2):pp.185-90

Luciano B. and Denise Z.(2007). Laser physics and laser-tissue interaction ,p: 25.

Luca F., Luigi L., Rosa D., Cesare D., Salvatore B., Giulia A., Gabriele C.(2019). Dental Whitening Gels:Strengths and Weaknesses of an Increasingly Used Method, Gels, 5(3): p.35. doi: 10.3390/gels5030035.

Maia E., Baratieri LN, Caldeira D., Andrada M. (2008). The influence of two home-appliedbleaching agents on enamel microhardness: an in situ study, J Dent , 36(1):pp. 2–7.

Markolf H. (2007) . Biological and Medical Physics, Biomedical Engineering , Laser-Tissue Interaction ,Fundamentals and Applications. 3rd edition Springer,p.77.

Marson F., Sensi LG, Vieira LC, Araujo E. (2008). Clinical evaluation of in office dental bleaching treatments with and without the use of light activation sources. Oper Dent. 33(1):pp.15-22.

Marson F, Goncalves RS, Silva CO.(2015) . Penetration of hydrogen peroxide and degradation rate of different bleaching products. Oper Dent.,40 (1): pp.72-79.

Mathews A., Mariam R, Sudeep S. (2013). Clinical evaluation of laser bleaching vs. Conventional inoffice bleaching. J Dent Laser, 7(2) : pp.54‑58.

Magalhaes M.(2016). Inflammatory response of human dental pulp to at-home and in-office tooth bleaching, J Appl Oral Sci., 24(5):pp. 509–551

Mester A. (2013). Laser biostimulation, Photomed Laser Surg, 31 (6): PP.237-239 .

Monica U .,Daniel H.,Philippe C. (2012). Dentinal Tubules Sealing by Means of Diode Lasers (810 and 980 nm): A Preliminary In Vitro Study, Photomedicine and laser surgery 31(7): pp.307-314, DOI: 10.1089-3443.

Al-Maliky A., Tamara S., Asmaa A. and Ali S. (2016). effect of bleaching gel and (940 nm and 980 nm) diode lasers photoactivation on intrapulpal temperature and teeth whitening efficiency , Australian Endodontic Journal, 24 (3): PP.124-132.

Myers T. , (2000). The future of lasers in dentistry, Dent. Clin. North Am. 44(4):pp.971-980.

Navarra C, Reda B, Diolosa M. (2014). The effects of two 10% carbamideperoxide night guard bleaching agents, with and withoutdesensitizer, on enamel and sensitivity: an in vivo study. Int J Dent Hyg.12(2): pp.115-120.

Niemz M. (2013). Laser-tissue interactions: fundamentals and applications. Springer Science & Business Media,3rd Ed. pp.51-112

Ontiveros JC, Paravina RD. (2009).Color change of vital teeth exposed to bleaching performed with and without supplementary light. J Dent, 37(11):pp.840-847.

Orazio S. (2010). Principles of Lasers, 5th edition. Springer Science &Business Media LLC, 2nd ed, DOI: 10.1007/978-1-4419-1302-9

Ozgun Y.,Tevfik Y.,Tugrul S.,Filiz A. &Atiye O. (2015). Temperature rises during tooth bleaching with different light-curing units. Journal of Adhesion Science and Technology ,29(15): pp.172-180.

Parreiras P., Vianna S., Kossatz A., and Loguercio A. (2014). Effects of Light Activated In-office Bleaching on Permeability, Microhardness, and Mineral Content of Enamel, Operative Dentistry, 39(5): pp.39-35.

Patrica V.Zeynep O. (2006) .Effects of staining and bleaching on color change of dental composit resins,The J. of Prosthetic Dentistry, 95(2): :pp.137-142.

Patricia W. Kihn, Douglas M. , Elaine R. , Ken P. (2000). A Clinical Evaluation Of 10 Percent VS. 15 Percent Carbamide Peroxide Tooth Whitening Agents ,Jada 131, (10): pp.1478-1482.

Polydorou O, Wirsching M, Wokewitz M, Hahn P. (2013).Three-month evaluation of vital tooth bleaching using light units-a randomized clinical study. Oper Dent. 38(1):pp.21-32.

Pretty IA, Ellwood RP, Brunton PA, Aminian A. (2006) .Vital tooth bleaching in dental practice: Professional bleaching. Dent Update 33(5): pp.288-304.

Rafael F., Juliana F.,David G., AZevedo M., Ana C., Cristiane M., Sérgio K. (2012). Comparative clinical study of the effectiveness of different dental bleaching methods - two year follow-up, J Oral S. 20(4):pp.435-43.

Robert A. Convissar. (2011).Principles and Practice of Laser Dentistry, 2nd ed. Mosby, Ch. 2,p 122-130.

Roche H., Yusuf O.and Sias R. (2012) .A Clinical Study of the Effectiveness of a Light Emitting Diode System on Tooth Bleaching, The Open Dentistry Journal, 6 (1): , pp.143-147.

Roderjan DA, Stanislawczuk R, Hebling J.(2015). Response of human pulps to different in-office bleaching techniques: preliminary findings. Braz Dent J , 26(3) : pp.242-248.

Rodrigo M., Carlos R. and Maria Amélia M. (2010). In Vitro Evaluation of Dental Bleaching Effectiveness Using Hybrid Lights Activation. Revista Odonto Ciência 25 (2) :pp.159-64.

Rodrigues JA, March GM, Ambrosano GM .(2005). Microhardness evaluation of in situ vital bleaching on human dental enamel using a novel study design. Dent Mater , 21(11): pp.1059–1067.

Roeland J, Jeroen Verheyen, Peter Verheyen, Andrii D,Maarten A, Peter D ,Mieke De Bruyne, and Filip K. (2015). Laser Teeth Bleaching: Evaluation of Eventual Side Effects on Enamel and the Pulp and the Efficiency In Vitro and In Vivo, Hindawi Publishing Corporation ,e Scientific W.Article ID 835405 | https://doi.org/10.1155/2015/835405.

Rotstein I. and Y. Li.(2002).Tooth discoloration and bleaching. Ingle's Endodontics ,6 (3) : pp.1383-1399.

Saha P, Sawhny A, Paul S, Raina A.(2017).Report of Two Cases using Vital Tooth Bleaching on Fluorosed Teeth, Rama Univ J Dent Sci, 4(1):pp.47-50.

Sevil G., Filiz Y., Esra Y.(2010). Different light-activated in-office bleaching systems: a clinical evaluation, Lasers in Medical Science 25(6): pp.817–822.

Shendi A.(2016) . Effect of Bleaching Gel and (940 nm and 980 nm) Diode Lasers Photoactivation on Intrapulpal Temperature and Teeth Whitening Efficiency, Msc thesis, laser institute , University of Baghdad, p.18.

Shivaprasad B. , Veenadharini G., Anju C. , Rekha B. (2019). Teeth Bleaching Using Diode Laser as an Adjunct to a Bleaching Agent, journal of dental lasers ,12(2): pp.70-73.

Sikri V.K.(2010). Color: Implications in dentistry. Journal of conservative dentistry, 13(4): p.249.

So Ran, Stevenr K.. Kurti J., Udochu Kwu Oyoyo, M. , Yiming L. (2015). Effect of Light-Activated Tooth Whitening on Color Change Relative to Color of Ar tificially Stained Teeth, Journal of Esthetic and Restorative Dentistry, doi: 10.1111/jerd.12142.

Spalding M, Taveira LA, Assis GF. (2003).Scanning electron microscopy study of dental enamel surface exposed to 35% hydrogen peroxide: alone, with saliva, and with 10% carbamide peroxide, J. Esthet. Restor. Dent. , 15(3): pp.154–165.

Sruthy P, Rajesh H., Vinitha. A. Boloor M. and Anupama. S. (2013). Extrinsic stains and management: A new insight, J. Acad. Indus. Res.1(8): 435-440 .

Subhash C., Haibo Z., Chunlei G., and Weiping C.(2012) . Lasers: Fundamentals, Types, and Operations Wiley-VCH Verlag GmbH & Co. KGaA.P.1-34.

Sulieman M. (2005). An overview of bleaching techniques: 3. Insurgery or power bleaching. Dent Update, 32 (3) :pp.101- 104.

Terry D. , Willi G., Olivier T., Mark J A., Monte T., Alvin K . (2002). Anatomical form defines color; Function, form and aesthetics. Pract Proced Aesthet Dent, 14 (1) :59-67.

Tirth, A., Srivastava, B.K., Nagarajappa, R., Tangade, P. and Ravishankar, T.L. (2009). An investigation into blacktooth stain among school children in Chakkar Ka Milak of Moradabad City. Ind. J. Oral Health Comm. Dent. 3(2): pp.34-37.

Tredwin C., Naik, N J Lewis, C. (2006).Hydrogen peroxide tooth-whitening (bleaching) products: review of adverse effects and safety issues. British dental journal , 200(7):pp. 371-376.

Turssi, R. J. Schiavoni, M. C. Serra, and I. C. Froner. A. (2006). Permeability of enamel following light-activated power bleaching, General Dentistry, 54, (5): pp. 323–326.

Watts A. and M. Addy.(2001).Tooth discoloration and staining: a review of the literature. British dental journal ,190(6): pp.309-316.

Wetter NU, Walverde D, Kato IT, Eduardo C. (2004) .Bleaching efficacy of whitening agents activated by xenon lamp and 960-nm diode radiation. Photomed Laser Surg , 22 (6): pp.489–493.

White J.M.(2000). Surface and pulpal temperature comparison of tooth whitening using lasers and curing lights. The International Symposium on Biomedical Optics. International Society for Optics and Photonics ,3910(6) : pp.21-33.

William T. Silfvast A. (2003). "Lasers" Fundamentals of Photonics. 2003; Campridge University Press,Module ,4th ed., p 4.

Wolfgang B. ,Thomas A. (2007). External bleaching therapy with activation by heat, light or laser A systematic review, dental materials , pp. 586–596.

Yan F. , Lin F. , Diana S. , Hans S. (2012). Effects of common beverage colorants on color stability of dental composite resins: The utility of a thermocycling stain challenge model in vitro., journal of dentistry, pp.40; 4 8& 56.

Yarborough DK. (1991). The safety and efficacy of tooth bleaching: a review of the literature , 12(3):pp.191-6.

Zhang X. .Wang J. ,Kinoshita D. , Xiaogu W., Jun I., Baohong Z., Teruo T., Yuichi K., and Koukichi M.(2007).Effects of KTP laser irradiation, diode laser, and LED on tooth bleaching: a comparative study, Photomedicine and Laser Surgery, 25 (2): pp. 91–95.

Ziemba S.L. , Felix H., MacDonald J. , Ward M. (2005). Clinical evaluation of a novel dental whitening lamp and light-catalyzed peroxide gel. The Journal of Clinical Dentistry, 16 (4): pp. 123–127.

وزارة التعليم العالي والبحث العلمي

جامعة بغداد

معهد الليزر للدراسات العليا

تأثير ليزر الدايود (٩٤٠ نانومتر) والليد الضوئي (٤٥٠-٥٠٥ نانومتر) على كفاءة التبييض في الاسنان المتصبغة

(دراسة مختبرية و سريرية)

رسالة مُقدمة الى مَعهَد الليزَر للدِراسات العُليا/جامِعَة بَغداد كَجزء مِن مُتَطلبات نَيل دَرجة الماجِستير في عُلوم الليزَر/ طِب الأسنان

مقدمة من قبل الطالب

علي عبد الامير حسب محمد

بكالوريوس طب وجراحة الفم والأسنان

1442 هجرية　　　　2020 ميلادية

المشرف: أ. م. دباسمة محمد علي

الخلاصة

مقدمة :

يعتبر تصبغ الاسنان واحدة من مشاكل التجميل التي واجهت كل من اطباء الاسنان والمصابين به ولذا برزت العديد من المحاولات لحل هذه المشكلة والتي تضمنت : حشوات تجميلية وتيجان متنوعة وتبييض و ... الخ . وقد استخدمت عدة وسائل محفزة خلال عمليات التبييض منها كيميائية و حرارية وضوئية ومن اهم الوسائل الضوئية المستخدمة حديثا هو الليزر والليد الضوئي حيث استخدمت عدة انواع من الليزرات في هذا المجال

الغاية :

ملاحظة تاثر فعالية التبييض بواسطة الليزر والليد الضوئي وكذلك التاثر الحراري في لب الاسنان وتاثيرها على خشونة وسطح الاسنان ودرجة حساسية الاسنان بعد التبييض وتقييمها ايضا بعد شهر من عملية التبييض.

الطرق والمواد :

في الدراسة المختبرية تم استخدام ٦٠ سن وحيد الجذر امامي حيث تم تقسيمها الى ست مجاميع شملت مجموعة المقارنة ومجموعة الاسنان المتصبغة اصلا بتبغ التدخين (والتي تم غمسهما في ماء مقطر) وبقية المجاميع الاربعة تم غمسها في محاليل شاي ، قهوة ، كولا و عصير رمان لمدة ١٤ يوم عند ٣٧ درجة سيليزية بعدها تم فحص جميع الاسنان المتصبغة تحت المجهر الضوئي ثم تم تقسيم هذه المجاميع الى مجموعة الليزر ومجموعة الليد الضوئي بعدها تم قطع ذروات الجذور للحصول على اطوال اسنان مقاربة للطول ١٧ ملم وتم ازالة كافة محتويات الجذور وتنظيفها جيدا قبل ادخال اسلاك المتحسسات الحرارية وصولا الى قلب كل سن حينها تم غمس هذه الجذور داخل حوض ماء دافي بدرجة حرارة ٣٧ درجة مؤية لتحاكي حرارة الانسان ومن ثم تم طلاء اسطح الاسنان بمادة جل التبييض (٣٢%) ض وبعدها تم اجراء عملية التبييض حيث كانت عوامل الليزر تتضمن ٩٤٠ نانومتر وبقدرة ٧ واط وبوقت اشعاع دقيقتان متجزئة اما عوامل الليد الضوئي تضمنت قدرة ٣٠ واط وطول موجي ٤٥٠-٥٠٥ نانومتر وبوقت اشعاع عشرون دقيقة متواصلة واثناء عملية التبييض تم قياس الحرارة للاسنان وقياس مستوى التغيير باللون ومقارنته باللون قبل عملية التبييض بعدها تم فحص الاسنان تحت المجهر الضوئي لدراسة اي تشققات حدثت بسبب عملية التبييض وكذلك تم فحص الاسنان بفحص المقاطع الالكترونية المجهرية وفحص نوى الذرات المجهرية من اجل معاينة اي تغير طوبوغرافي وخشونة طارئة على اسطح الاسنان التي تم تبييضها لمقارنتها مع نفس الفحصوات لاسنان مجموعة المقارنة.

فيما يخص الجانب السريري تم اختيار ١٥ مريض تتراوح اعمارهم ٢٥-٤٠ سنة لديهم تصبغ خارجي بالاسنان الامامية حيث تم اجراء فحص اولي وتوثيق كافة بيانات الفحص في استمارة خاصة وبعدها تم تنظيف الاسنان للمرضى بعدها تم تقسيم فم المريض الى نصفين من اجل اجراء عملية التبييض بواسطة الليزر على النصف الايمن واجراء عملية التبييض بواسطة الليد الضوئي على الجانب الايسر بعدها تم اجراء مقارنة لدرجة البياض المكتسبة ومقارنتها مع لون الاسنان قبل التبييض وكذلك تم توثيق اي حالة شعور بالالم خلال عملية التبييض بواسطة مقياس تقييمي بارقام يتم اختيارها من قبل المريض . بعدها تم اعطاء المرضى مجموعة ارشادات خاصة وتمت اعادة معاينة المرضى بعد مرور اربعة اسابيع بعد التبييض لتقييم ثباتية التبييض وتقييم الشعور بالالم خلال تلك الفترة. تم اجراء عمليات تحليل احصائي لكافة التجارب والقياسات بواسطة برنامج اس بي اس اس.

النتائج:

كل المعلومات الناتجة من الدراسة المختبرية اشارات الى وجود تفاوت في ارتفاع درجات الحرارة للاسنان التي تم تبييضها مع نتيجة ايجابية لمجموعة الليزر. كل من الليد الضوئي و الليزر اثبت فاعلية في تبييض الاسنان. فيما يخص الدراسة السريرية اثبتت النتائج ان كل من الليد الضوئي والليزر لهما فاعلية كبيرة في تبييض الاسنان . الاسنان التي تم تبييضها بالليزر كانت اقل حساسية للالم اثناء التبييض وكذلك بعد مرور شهر من التبييض . الاسنان التي تم تبييضها بالليزر اثبتت اكثر ثباتية اللون بعد مرور شهر من التبييض مقارنة بالاسنان التي تم تبييضها بالليد الضوئي.

الاستنتاج:

يعتبر الليزر ذو تاثير امن على حرارة لب الاسنان واكثر ثباتية لبياض الاسنان مقارنة بالليد الضوئى مع تاثير اقل على حساسية الاسنان مقارنة بالليد الضوئي