SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF GRADUATE STUDIES

CLINICAL APPLICATION OF DIODE LASER IN THE TREATMENT OF DENTINE HYPERSENSITIVITY BY DIFFERENT POWER

التطبيق السريري لليزر الصمام الثنائي في علاج فرط الحساسية لعاج الاسنان بطاقة مختلفة

A Dissertation Research of Project Submitted in Fulfillment of the

Requirement for the Requirement of the Degree of **Postgraduate Diploma in Laser Applications in Medicine (Dentistry)**

By

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Marsh 2022

Appendix B: Examiners Approval Letter

"I/We hereby declare that I/we have read this dissertation and in my/our opinion this graduation research is sufficient in terms of scope and quality for the award of the degree of Postgraduate Diploma ………………………. (Specialization)

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I hereby declare that this dissertation (CLINICAL APPLICATION OF DIODE LASER IN THE TREATMENT OF DENTINE HYPERSENSITIVITY BY DIFFERENT POWER) is the result of my own research except the citations in the references. The dissertation has not been accepted for any degree nor concurrently submitted in candidature for any other degree.

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is the result of my own research except the citations in the references. The dissertation has not been accepted for any degree nor concurrently submitted in candidature for any other degree.

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Name of Supervisor: ______________________________

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DEDICATION

To my generous and always patient family .

Thanks God for allowing me to face all difficulties to complete this ***Postgraduate*** *diploma.*
And despite the unfortunate situation in the country I accomplished something

Acknowledgement

I would like to thank Dr. Modather for the assistance he gave us.

Great thanks for my supervisors Dr. Alhadi Mohieldin Awooda and Dr. Nadir S.E. Osman for their patience

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ABSTRACT

This work aims to evaluate the clinical efficacy of low and high output power of a 980 nm diode laser in the treatment of dentin hypersensitivity. Twelve teeth were selected having dentine hypersensitivity. Dentin hypersensitivity (DH) was assessed by tactile and thermal stimuli and measured by visual analogue scale

(VAS) Teeth were randomly divided into two groups namely: group A, treated with high power diode laser of 1 W and group B, treated with low power of 500 mW. A 980 nm diode laser was used for duration of 60 second. Teeth from both groups were subjected to one laser session. Dentin hypersensitivity was measured before and after laser application by 15 minutes and again evaluated after one week. The obtained results for both groups, (before versus after 15 minute of laser sessions) showed a significant reduction in VAS scores (*p*-value < 0.05). Intergroup comparison showed that reduction in VAS scores was significantly high in group A. However, the comparison between after 15 minutes versus one week, mean reduction in VAS scores decreased in the two groups may indicate slit recurrence of hypersensitivity. This study shows that a 980 nm diode laser with high output power of 1 W can be used effectively in providing immediate relief in severe cases of dentin hypersensitivity and still better after one week.

المستخلص

هذه الدراسة تهدف لتقييم الفعالية الإكلينيكية لليزر الثنائي 980 نانومتر منخفض وعالي الطاقة في علاج فرط حساسية العاج.

: تم اختيار اثني عشر سنًا ذات حساسية مفرطة لعاج الأسنان. تم تقييم الحساسية المفرطة لعاج الأسنان (DH) بواسطة المحفزات اللمسية والحرارية وتم قياسها بواسطة مقياس النظير البصري (VAS). تم تقسيم الأسنان بشكل عشوائي إلى مجموعتين المجموعة أ، المعالجة بليزر مع خرج قدرة 1 واط والمجموعة ب، تعامل بقدرة منخفضة 500ملواط. تم استخدام ليزر الثنائي 980 نانومتر لمدة 60 ثانية. خضعت أسنان المجموعتين لجلسة ليزر واحدة، حيث تم قياس حساسية العاج قبل وبعد تطبيق الليزر بمدة 15 دقيقة ثم تم تقييمها مرة أخرى بعد أسبوع.

في كلتا المجموعتين، أظهرت القيم المتوسطة قبل الليزر مقابل بعد 15 دقيقة انخفاضًا كبيرًا في درجات VAS (القيمة الاحتمالية <0.05). أظهرت المقارنة بين المجموعات أن الانخفاض في درجات VAS كان أكثر معنوياً في المجموعة المعالجة بالليزر A. ومع ذلك ، فإن المقارنة بين بعد 15 دقيقة مقابل أسبوع واحد، قد يشير انخفاض متوسط درجات VAS في المجموعتين إلى تكرار مرض فرط الحساسية. يمكن استنتاج أن ليزر الثنائي عالي القدرة فعال في توفير الإغاثة الفورية في الحالات الشديدة من فرط حساسية العاج ولا يزال أفضل بعد أسبوع واحد.

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Chapter one

Introduction

1.1 Research Background

Teeth are an important part of human body; they serve several functions such as mastication, esthetic and for proper speech.

Anatomically the tooth consists of a crown and a root which form by enamel, dentine, and pulp. Dentin is a mineralized, elastic, yellowish-white, a vascular tissue enclosing the central pulp chamber characterized by a traveling tubules through its entire thickness, containing the cytoplasmic extensions of odontoblasts (Nanci, 2017). Radiographic and histological studies of the dentine proved that the wall of the tubule was considerably more mineralized than the rest of the dentine and containing a fluid, which described by Spreter von Kreudenstein as clear, thin, devoid of cells and similar in composition to the aqueous humor of the eye (Brännström, 1966).

Dental diseases are a chronic disease with a high prevalent that people complain about, one of them is dentine hypersensitivity.

Dentine hypersensitivity (DH) is a comparatively common, painful dental condition affect any age. It has been defined in an international workshop as: "Dentine hypersensitivity is characterized by short, sharp pain arising from exposed dentine in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or pathology" (Addy, 2002). This definition identifies dentine hypersensitivity as clinical condition, subsequently the clinician must consider a deferential diagnosis for the causes of DH. In 2003 the Canadian Advisory Board on Dentine Hypersensitivity suggested that it would be more correct to replacement 'disease' for 'pathology' (Porto et al., 2009).

Other terms have been used to describe dentin hypersensitivity based on the part of tooth affected by hypersensitivity (sensitivity); such as dentine sensitivity, dentinal hyper sensitivity, cervical hypersensitivity (sensitivity), root hypersensitivity (sensitivity) and cemental hypersensitivity(sensitivity) (Davari et al., 2013).

Dentine hypersensitivity usually affects 1 out of 7 adult patients attending dental clinic (Dowell and Addy, 1983) **.** On the other hand, it was found that its prevalence is more in patients aged 30-40 years and mainly in female individuals (Davari et al., 2013). Furthermore the commonest teeth affected were the upper premolar and molar teeth more than others (Rees, 2000).

Many theories have been proposed to explain (DH) for instance, hydrodynamic theory which produced by Brännström (Brännström and Åström, 1964),was adopted more than odontoblast transducer and direct innervations theory (Addy, 2002) . It considers a pressure change a cross the dentine that can be generated by certain stimuli such as thermal stimulation (mainly cold), chemical, tactile, cosmetic or evaporation. These stimuli increase the outward flow of fluid in dentinal tubules which can create a pressure change within the dentine and thus activates intra-dental nerves at the pulp-dentine border or within the dentinal tubules (Bamise and Esan, 2011).The morphological studies of both hypersensitive and non-sensitive dentine demonstrating an amorphous and thick smear layer on most of the non-sensitive dentine which responsible for the major resistance to fluid movement across dentine, and reduces dentine permeability (Rimondini et al., 1995). In addition, hypersensitive teeth have a larger numbers and wider tubules when compared to non-sensitive teeth (Holland, 1994).These studies and evidences supported the hydrodynamic theory, and treatment strategies base on it.

In the odontoblast transducer theory, they propose that odontoblast process (the Tomes' fiber) act as a type of nerve fiber which transmits pain to the pulp. This theory was disproved because odontoblast is a mesenchymal cell responsible for dentine formation not for pain transmission, also there is no an extension of odontoblast process in the peripheral tubules. Regarding the direct innervations theory, this theory is unlikely accepted because it was proved by histological studies there are no neural cells in the outer dentine (Dowell and Addy, 1983, Dababneh et al., 1999, Brännström, 1966).

Basically, dentine hypersensitivity can be attributed to either exposed dentine due to removal of the enamel covering the crown, or denudation of the root surface by loss of cementum. Removal of enamel occurs due to many factors such as attrition, toothbrush abrasion, dietary erosion, or habits. While denudation of the root surface is associated with gingival recession increasing in severity with advancing age, incorrect tooth brushing technique, chronic periodontitis and periodontal surgery (Que et al., 2013).

Management of dentine hypersensitivity depends on an adequate diagnosis. That is why it must be distinguished from the other causes of sharp dentinal pain such as caries, fractured restorations, cracked tooth, and marginal leakage around restorations. These are treated differently compared to dentine hypersensitivity.

For definitive diagnosis, a good clinical history and investigations can assist to exclude any other causes of pain.

Commonly, clinician stimulates the exposed dentine by dental probe walking mesio-distally; as tactile stimulus, via jet of air through a triple syringe or from dental air unite syringe for evaporative stimulus and thermal stimulation by cold water. These methods of stimulation are recommended as these are more controllable than using hypertonic solution or chemicals (Holland et al., 1997).

Tooth hypersensitivity assessed by verbal and numerical scales as such as McGill Pain Questionnaire (MPQ). McGill Pain Questionnaire (MPQ) is one of the first verbal tests was utilized to measure the nature of the pain .However the complexity of used terminology and its time consuming led to replace by another methods (Gilam and Newman, 1993). Ordinarily Schiff cold air sensitivity scale (SCASS), the Visual Analogue scale (VAS), the Verbal Rating Score (VRS), and the Numerical Rating Scale (NRS) are the most used scales for (DH) assessment. The (SCASS) is a four-point scale used to assess subjects' responses to air blast.

Visual Analogue scale (VAS) possesses a 10 cm horizontal lines start from no pain and graduate to sever pain with verbal descriptors of pain intensity. The patient signs at the point indicating the pain-intensity level. Other tool, the Numerical Rating Scale (NRS), graduate from 0 – 10, and the patient select the number stand for its pain level. The Verbal Rating Score (VRS), sometimes also named Verbal descriptor scale (VDS) can be also used for pain assessment. It uses word to describe the variations in pain (Idon et al., 2019). Recently, Labeled Magnitude Scales (LM scales) are used to measure the intensity, duration, tolerability, and to assess even low-level pain conditions (Heaton et al., 2013).

Successful management start by the treatment of risk factors; correct the method of tooth brushing, avoid abrasive tooth paste, avoid brushing at least for one hour after acid drinks or foods, treatment of periodontitis to prevent gingival recession and occlusal adjustment for premature contact (Davari et al., 2013).

There are two treatment approaches for DH. Who occlude dentinal tubules; subsequently it blocks the flow of tubular liquid. Who prevent the neural response to pain stimulus.

Theses treatment approaches classified based on the mode of application, either at the home by the patient, or in office by the clinician (Porto et al., 2009, Bamise and Esan, 2011, Davari et al., 2013).

Generally, topical desensitizing agents were classified on the basis of their chemical properties such as calcium hydroxide, potassium nitrate and fluorides, as well as physical properties such as soft tissue grafts and glass-ionomer cements (Dababneh et al., 1999).

Because of (DH) is considered as unpleasant disease, patient constantly searches for more effective and long lasting therapies. Development of light amplification by stimulated emission of radiation (laser) applications in dentistry has opened a new gate of treatment.

In 1989, first laser model designed specifically for the dental profession has become available for treating oral soft tissue. Since then, many different wavelengths have been produced. These can be simply applied by practitioner on both hard and soft tissues for both surgery and healing (Coluzzi and Parker, 2017).

Laser is an acronym for light amplification by stimulated emission of radiation. This term can be used to describe an apparatus that generates monochromatic coherent light in the visible, infrared, or ultraviolet regions. Thus it has wide range of different applications such as in medical field, research and communications (Hecht, 2010).

In medical fields particularly in dentistry laser is used as an alternative to mechanical drills as illustrated by Niemz et al. (1993b) and Pioch et al. (1994),

According to a published systematic review regarding the effectiveness of laser therapy in the treatment of DH, laser therapy can reduce DH-related pain, based on the applied power, wavelength and exposure time (Sgolastra et al., 2011).

1.2 Literature Review

Rakesh Mittal et al evaluated the clinical efficacy and longevity of 810 nm (GaAlAs) diode laser with moderate output power in the treatment of severe dentin hypersensitivity. The utilized laser power was 0.5 W for duration of 2 minutes. Patients were divided into two groups. Both groups were subjected to three sessions of treatment for intervals of 0 hours (first application), 24 hours, and 48 hours. Dentin hypersensitivity was measured before and after each session and again evaluated after 12 weeks. The results showed that the moderate output power (0.5 W) of the diode laser was effective in providing immediate relief in severe cases of dentin hypersensitivity. Although 12 weeks evaluations show recurrence of dentin hypersensitivity(Mittal et al., 2014).

A randomized, longitudinal clinical study was conducted by Anely Oliveira Lopes et al to evaluate different protocols for dentin hypersensitivity treatment with low-power laser at different dosages, desensitizing agent and associations, for a period of 6 months. Twenty-two patients were divided into five groups (designated as G*x*, where *x* = 1,2,3,4 and 5). G1: Gluma Desensitizer (Heraeus); G2: low output -power laser at low dose (three vestibular points and one apical point of irradiation: 30 mW, 10 J/cm^2, 9 seconds per point with wavelength of 810 nm), three sessions were performed with an interval of 72 h between them; G3: low power laser at high dose (application at one cervical and one apical point: 100 mW, 90 J/cm^2, 11 seconds per point with wavelength of 810 nm), three sessions were performed with an interval of 72 h between irradiations; G4: low-power laser at low dose with Gluma Desensitizer; and G5: low-power laser at high dose with Gluma Desensitizer. They evaluated the pain 5 min, 1 week, month, 3 months and 6 months after treatment. They observed that for both stimuli, the protocol with the Gluma desensitizing agent presented immediate effects of pain reduction. For low-power lasers, it was observed that there were distinct effects for the different doses; however, both were efficient in reducing pain up to the 6 months of clinical follow-up (Lopes et al., 2015)

Felice Femiano et al performed a study to evaluate the desensitizing effect of the combination of two different output powers and compared it with single power diode laser. Sixty-nine non carious cervical lesions (NCCLs), responsible of pain by DH, were considered in the research. The teeth were divided into three groups. First group treated with 0.2 W in continuous emission for 60 seconds and the treatment repeated after 24 hours. In the second group laser applied in pulse mode with 2.0 W for 60 seconds and the treatment repeated after 24 hours (High-power laser therapy: HPLT). Third group: NCCLs were firstly treated with the same parameters used for the first group, then after 24 hours the same lesion underwent a second session with the same parameters as the second group (low power +high power).

The pain by DH was evaluated at baseline, treatment completion, 15 days, and 3 months after each laser treatment. The best improvement of DH pain was assessed when a combined protocol of two different output powers of diode laser was used(Femiano et al., 2020).

A study carried out by J. A. Gerschman et al in the management of dentinal tooth hypersensitivity. Low level laser therapy (30 mW) with a wavelength of 830 nm was applied for one minute to both the apex and cervical area of the tooth and then reapplied at one week, two weeks, and eight week intervals. The results showed that both the tactile and thermal sensitivity groups difference between the active and placebo groups (unpowered laser) were significant from the first week and increased further in the second and eighth weeks (Gerschman et al., 1994).

1.3 Problem Statement

DH is a prevalent disorder and one of the weary dental diseases. It has a negative impact on patient' life, and forces him to eat certain types of food and drink, also affect his oral hygiene practices. Recently, it was found that laser is one of the modern treatment methods that have had effective result in treating dentine hyper sensitivity.

- Researches have shown that laser is one of the easiest and most effective ways in desensitization, it has been shown that laser increase the formation of secondary dentin by the odontoblasts.

- The literature shows plenty of studies on using laser for the treatment of dentin H, using different lasers, different parameters wavelengths, time for exposure, power and mode of application. Diode lasers have been uses tremendously, with still no conclusive results on how it occludes dentinal tubules, what suitable time of exposure duration, power, or wavelengths. So there is a need for more studies to confirm the beneficial effect of treatment when comparing different parameters of laser.

1.4 Objectives

1.4.1 General Objective

To evaluate the effect of diode laser, with different power, in the treatment of dentin hypersensitivity.

1.4.2 Specific Objectives

- To evaluate the efficacy of low power diode laser (500 mWatt), as immediate response after laser application and after one week.
- To evaluate the efficacy of high power diode laser (1 Watt), as immediate response after laser application and after one week.
- To compare the patients’ response between the two different power.

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Chapter two

Basic Concepts of Laser

Electromagnetic spectrum consists of wide range of radiation extends from x-rays with wavelengths less than a billionth of a meter up to radio waves with wavelengths of a meter or more. It also involve infrared, visible light and ultraviolet waves (Ryer et al., 1997). Light is a part of electromagnetic radiation having unique properties make it suitable to be used in reflection, refraction, diffraction, and polarization applications. Many theories were developed to explain nature of light, at first Huygens believed that light was made up of waves move up and down perpendicular to the direction of the wave propagation. Therefore, he adopted wave theory of light. Then electromagnetic theory was developed by Maxwell who noticed that electrical field and magnetic field can interact and couple together perpendicularly to each other to form electromagnetic waves. Until the beginning of twenties century particle theory of light was promoted; when Newton advocate of the particle nature of light, they noticed that light is able to release an electron from atom. The energy of this electron is greater than the atom energy; this localized energy is defined by Einsten as photon. Followed by Planck who observed that light energy emerges in multiple of certain energy unites known quantum which depend on wavelength of the radiation as

$$E = hc/\lambda \qquad (2.1)$$

where h is represent Planck constant (6.6×10^{-27}) , c is the speed of light and λ is wavelength (Ditchburn, 2013).

2.1 Laser Fundamentals

Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. It can be also referring to a device that produces monochromatic, focused, collimated and coherent beam of light. This scientific discovery was developed based on theoretical work by Townes and Arthur Schawlow. It associated with building of an optical oscillator to generate coherent light by amplifying stimulated emission of radiation, Schawlow and Townes produced the idea of using an optical pumping of a vaporized alkali metal such as potassium (Hecht, 2010) . In 1960, the scientist Maiman was developed the first laser prototype by stimulating a crystal of ruby as an active medium (see figure 2.1). A flash lamp was used to excite the electrons in the chromium, subsequently the excited electrons dropped spontaneously into a metastable state emitting the energy as red light (Hecht, 2005).

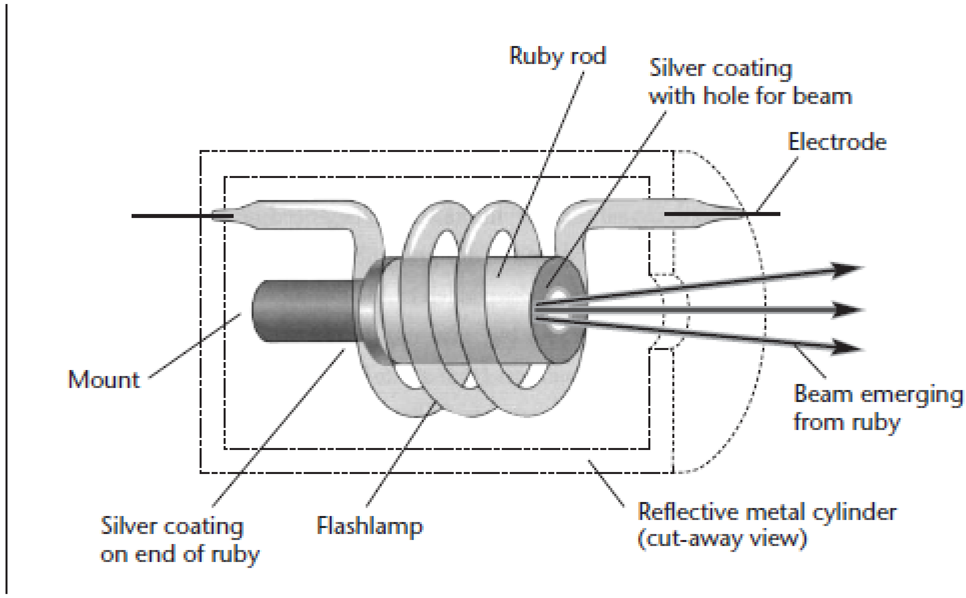

Figure 2.1. First laser prototype (Hecht, 2005).

In 1961, ruby laser was initially used by Goldman for clinical practices (Mavrogiannis et al., 2004) . Thereafter, many other lasers were created rapidly, for instance, in 1961 Javan et al illustrated the first continuously operating gas laser (Mishra and Mishra, 2011).
Properties of laser can be discussed based on absorption and emission as a result of the interaction between atom and radiation. Atoms can be excited by absorption energy which causes electrons transition to the upper energy level and then dropped to the lower level accompany by emitting energy as shown in figure 2.2. When excited electron transferred to upper level the population become doubling from that at lower state, by spontaneous emission the electron go down to the lower level, with no relation between them (Koechner, 2013). In return, if an excited atom in the upper state stimulated by external stimulus the atom's energy level drop from e_2 to e_1, this change will generate a second photon in relation with-and propagate in the same direction as-the excitation photon. This phenomenon, which is called stimulated emission, is the basis of laser light generation. If more atoms become excited, additional in-phase photons will be generated, and the process could continue indefinitely (Welch et al., 1989).

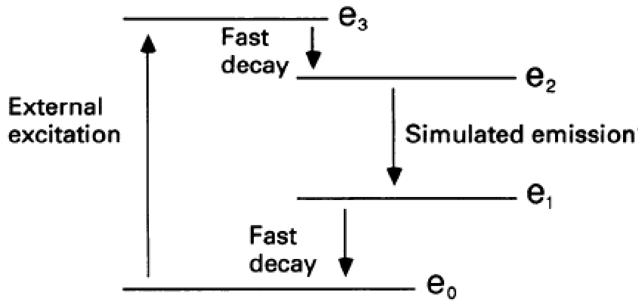

Figure 2.2. Four-level energy diagram. (Welch et al., 1989)
Population inversion is achieved between levels 1 and 2. (Welch et al., 1989)

2.2 Elements of Laser

To fabricate a coherent light source, feedback is necessary to regulate the excited atoms by stimulated emission. Thus the crucial components of a laser device are active medium, pumping source and optical feedback. These are shown in figure 2.3.

(i) Active medium (gain medium**)**

It consists of the material that can be used to produce the laser beam. It also allows the amplification of light by stimulated emission process.

(ii) Pumping source

This process aims to excite the martial of laser active medium to higher energy level. Several types of pumping process can be used. Particularly, optical pumping can be achieved by using xenon flash lamp, or another laser; also it may be implemented by an electric current.

(iii) Optical feedback elements

These consists of two mirrors that allow the beam of radiation to either pass through the laser medium or rebound back and forth frequently through the laser medium (Siegman, 1986). Previously this structure was known in the optics community as a Fabry–Pérot interferometer (Al-Amri et al., 2016).

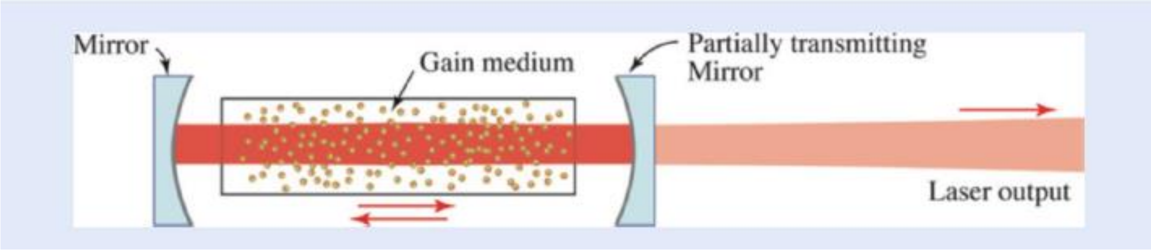

Figure 2.3. Basic elements of laser (Al-Amri et al., 2016).

2.3 Properties of Laser

Laser beam is unique because of it distinct characteristics compared to ordinary light rays. For example, laser beam possesses a narrow divergence angle which is measured in milli-radians. This allows laser beam to travel for a long distance. Laser beam is emitted as a single wave length. This feature called monochromaticity. The most important characteristic of the laser is coherence; it is a term describes particular relationships between two wave forms, these waves with the same frequency, phase, and direction. Laser intensity is higher compared to other light sources. (Van Pelt, 1970).

2.4 Types of Laser

Lasers can be classified according to different factors for instance, based on state of gain medium laser types are solid state, gas, excimer, dye, or semiconductor. According to spectrum of light laser classified into infrared, visible, or ultraviolet. Furthermore, the classification according to tissue applicability can be hard or soft tissue lasers. Other classifications of laser types are based on output energy and laser hazards (Luke et al., 2019).

Laser often described by the kind of lasing medium, in 1907 Henry J. Round first observed light emission from semiconductor junctions ,followed by Rubin Braunstein in 1955 who observed light emission from junctions in gallium arsenide, indium phosphide, and indium antimonide (Hecht, 2010)

2.4.1 Gas Laser:

Gas laser had a favorable historical period, since 1960. It has a characteristic that make it one of the most interesting fields of development, according to its nature gas can adopt the laser device it also flowing fast so the producing heat can be removed easily, recycling of gas increase its life time. The huge advantage of gas that can be mixed in different ratio and pressure, gas laser cover from infrared radiation to x-ray (Endo and Walter, 2018). Gas lasers are generally obtainable in almost all power and can be operated in pulsed and continuous modes. Based on the nature of active media, there are three types of gas lasers atomic, ionic, and molecular. Most of the gas lasers are pumped by electrical discharge.

Helium –Neon (He–Ne) laser is the simplest atomic gas lasers. The active medium is a 10: 1 mixture of He and Ne gases filled in a narrow tube of few millimeter diameters. Argon ion laser is one of the widely used ion gas lasers, which usually produce several watts power of a green or blue output beam with high beam quality. The central component of an argon ion laser is an argon-filled tube made of ceramics. The argon ion laser is a four level laser, which facilitates to achieve population inversion and low threshold for lasing. Unlike atoms and ions in atomic and ionic lasers, molecules have wide energy bands instead of separate energy levels. They have electronic, vibrational, and rotational energy levels. Each electronic energy level has a large number of vibrational levels, and each vibrational level has a number of rotational levels. Energy separation between electronic energy levels lies in the ultraviolet and visible spectral ranges, while those of vibrational–rotational levels, in the near infra-red (NIR) and far-infrared (far-IR) regions. Therefore, most of the molecular lasers operate in the NIR or far-IR regions (Singh et al., 2012).

The most efficient molecular gas laser is Carbon dioxide laser that exhibits for a high power and has wave length 10,600 nm within infrared region, which is highly absorbed by water. The CO2 gas is in a cavity with nitrogen and helium ,pumped with an electrical current and operates in continuous modes mainly (Pohlhaus, 2012). CO_2 has various uses in different fields, like industrial applications including cutting, drilling, welding, and so on. It is widely used in the laser pyrolysis method of nanomaterials processing. Furthermore carbon dioxide laser has medical applications ,it has rapid soft tissue removal and haemostasis (Luke et al., 2019).Another type of gas laser is Nitrogen laser, its lasing transition takes place between two electronic energy levels, therefore this laser operates in the ultraviolet region at 337nm wavelength .In order that , upper electronic level has a shorter lifetime compared to the lower one, subsequently pulsed operation with narrow pulse width is possible. Such a laser system is known as self-terminating (Singh et al., 2012).

In addition to these types of gas laser, there is an excimer laser which obtained in 1970 by N.G.Basov et al. they used a high current electron beam to excite liquid Xe which emitted around 172 nm (Basting and Marowsky, 2005) .Excimers are molecules such as ArF, KrF, XeCl, that have repulsive or dissociating ground states and are stable in their first excited state. Various excimer lasers are developed in the wavelength range of 120–500 nm with 200 W average powers and up to 1 J peak. These lasers are widely used in materials processing and characterizations as well as for the pumping of dye lasers (Singh et al., 2012) . Now a day the largest overall market application for excimer lasers is that for corneal sculpting types of surgery, The next largest single market is the use of excimer lasers in photolithography (Ewing, 2000).

2.4.2. Solid Laser:

Further classification of laser is solid laser. Neodymium-doped yttrium aluminum garnet (Nd: YAG) laser the commonly used solid laser, has four level system, and the neodymium is act as active element and YAG is the principle host material. It is the most important solid state laser in medical , industrial and military applications ,because of its high gain and good thermal and mechanical properties , (Koechner, 2013) . (Nd: YAG) laser with wave length 10, 64 nm, highly absorbed by pigment in the tissue, primarily hemoglobin and melanin. It can be applied in contact and non-contact mode, with predominate photothermal interaction and the laser energy can penetrate deeply into tissues. Nd:YAG also have an excellent biostimulative properties and unique capacity to stimulate fibrin formation (Pohlhaus, 2012) Another type for solid laser is Erbium (Er) laser . It constructed with two different crystals, either Er:YAG (erbium: yttrium aluminum garnet crystal) with wave length 2940 nm and Er,Cr:YSGG (erbium: chromium sensitized yttrium scandium gallium garnet crystal). has 2780 nm(Pohlhaus, 2012) The Er:YAG laser produces invisible light with high affinity to water, and the almost totally converted to water vaporization, which results in minimal heating of the tissue and its surroundings (Tal et al., 2003).The Er:YAG at 2.94 µm is a promising wavelength in the dental field. A number of researchers have confirmed the Er:YAG laser's ability to cut, or ablate, dental hard tissue effectively and efficiently. Its absorption by hydroxyapatite, regard the efficiency in cutting enamel and dentin creating surfaces that appear similar to acid-etched surfaces. Thus bonding composite to the tooth by Er:YAG will bond strongly equal to or better than acid etching alone(Cozean et al., 1997).

2.4.3 Chemical Laser:

Chemical lasers are a type of liquid laser that depend on the emission properties of organic dyes to supply lasing wavelengths. The available laser dyes can produce variable laser light over a large range of wavelengths, typically 50–100 nm wide. Variation of wavelength over the visible is made possible by selecting different dyes for different wavelength ranges. Because of their versatility and tunability, liquid dye lasers were widely applied for many years (Potter and Simmons, 2021).

2.4.4 Semiconductor Laser:

The latest supplement to the laser family are the semiconductor lasers, reported, by Hall, et al, also by Nathan, et al (Yariv and Gordon, 1963) Semiconductor lasers also known as quantum well lasers, are smallest, cheapest, can be produced in mass, and has the potential to develop . They are basically p-n junction diode, which produces light of certain wavelength. It is very similar to the light-emitting diodes (LEDs). LEDs possess spontaneous emission, while laser diodes emit radiation by stimulated emission. The active medium in a semiconductor diode laser is in the form of n-p junction, the end faces are cleaved, and parallelism as feedback mechanism. If laser made from a single type of semiconductor material is known as homojunction, while that obtained from two different semiconductors is termed as heterojunction (Singh et al., 2012). The semiconductor diode laser is emitted in continuous- wave or gated-pulsed modes, and is usually operated in contact mode using a flexible fiber optic delivery system. It is poorly absorbed in water at 800 to 980 nm, but highly absorbed in hemoglobin and other pigments. Accordingly, the laser is an excellent soft tissue surgical laser, indicated for cutting and coagulating gingiva and oral mucosa, and for soft tissue curettage or sulcular debridement (Sagar et al., 2015).

Distinguishing from the other laser sources, free electron lasers (FELs) have an active medium consists of a beam of free electrons, propagating at relativistic velocities .If an accelerated charged particle moving with relativistic velocity emits spontaneous radiation, the emitted spontaneous radiation interacts with the electron beam in order to stimulate laser radiation (Singh et al., 2012).

Laser can be classified according to output power into continuous wave laser (CW), pulsed laser, mode-locked laser, and free-running pulse laser. For example, diode laser and many CO_2 emit photons on a continuous basis, as long as the laser is energized, a continuous stream of photons can be emitted. Continuous wave lasers produce the same number of photons in each microsecond. Pulse laser produce pulses output power with duration at some repetition rate. The most important characteristic of a pulsed laser is the ability to store and release energy rapidly. This creates very high peak powers. For instance, Q-switched lasers with pulse widths in the nanosecond range can produce peak powers that are several 100 times greater than the average output.

Other parameter is laser power. It is the number of joules created in each second of time, measured by watt. Accordingly, laser can be classified as low and high power laser.

2.5 Laser Matter Interaction

Laser beam can be reflected, transmitted, scattered or absorbed by the target tissues (See figure 2.4). Reflected light recoil from the tissue surface and directed outward, so it limits the amount of energy that enters the tissue, therefore dose not damage the surrounding tissue much. Scattering occurs when the light energy transfers between the molecules of the tissue. It is affected by the degree of absorption thus high absorption leads to minimum scattering. Scattering disseminate the energy over a larger volume of tissue, limiting the thermal effects. While absorption occurs after a characteristic amount of scattering and is responsible for the thermal effects within the tissue (Dederich, 1991).

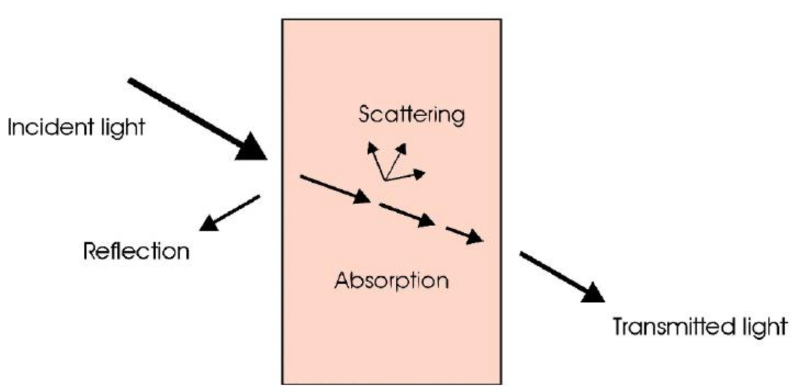

Figure 2.4. Geometry of reflection , refraction, absorption ,scattering (Niemz, 2007).

However, the effect of laser on tissue defined as laser tissue interaction, which depends on the absorption of wavelength by the target tissue. Generally, five categories of interaction types are classified namely photochemical interactions, photothermal interactions, photoablation, plasma-induced ablation, and photodisruption. All these interaction types are within specific range of energy density from 1.0 J/cm^2 to 1000 J/cm^2. The exposure time to laser beam plays a significant role in these different categories of interactions (Niemz, 2007).

2.5.1 Photothermal interaction:

For example, when applying Neodymium-Doped Yttrium Aluminium Garnet (Nd: YAG) laser or Carbon Dioxide (CO_2) laser on biological tissue, multiple photo-thermal effects such as coagulation, vaporization, carbonization or melting can be observed. These effects depend on different factors such as wavelength and power of the laser as well as the thermal properties of the biological tissues. In temperature range between 40-50 ^{o} C some molecular bonds and membrane of the tissues are significantly affected and can be altered. This is known as hyperthermia effect. However, the effects of temperature within this range are reversible. At temperatures of 60 ^{o}C, denaturation of proteins and collagen occurs which leads to the coagulation of tissue and hence it can necrotize cells. Protein denaturation involves breaking of weak bonds with in the protein molecule, modifying its native structure state in to an (partially) unstructured state. Denaturation can be induced by temperature, denaturants (chemical denaturation) and freezing. At 100 ^{o}C, temperature of the tissue remains constant and gas bubbles are expected to form. This can be attributed to vaporization of water phase. The alteration in the volume of the formed bubbles causes thermal decomposition of tissue fragments. After vaporization of all water molecules a carbonization occurs. This blackened the adjacent tissues and smoke rises from the skin. Beyond 300 ^{o}C melting might occur (Ansari et al., 2013).

2.5.2 Photochemical interaction:

Photochemical changes occur through particular long interaction times (10 secs–1000 sec) and low-power densities (10^{-3} –1 W/cm^2). Applying laser beam on tissue injected with photosensitizers initiate a cytotoxic process and tissue destruction.

Photodynamic therapy is a method used in the diagnosis and treatment of tumors. It required injecting the tumors by synthetic photosensitizer (Knappe et al., 2004). Laser applications in biology have been widely studied. This offered a new perspective for healing, reducing pain, and tissue engineering through photobiomodulation. Photobiomodulation explained through the absorption of photon by the chromophores ; primarily enzyme cytochrome c oxidase, which is located at unit IV of the mitochondrial respiratory chain, resulting in the activity of various molecules such as nitric oxide (NO), ATP, calcium ions, reactive oxygen species (ROS), and numerous other signaling molecules (Dompe et al., 2020).

Photochemical effect has significant effect in the antimicrobial action. When certain molecules absorb light, highly reactive moiety can cause microbial cell death by several mechanisms, including lipid peroxidation, enzyme system inhibition, and protein agglutination (Andersen et al., 2007)

2.5.3 Photoablation and Photodisruption interactions:

Exceeded power density beyond 107 W/cm^2 causes non-linear effects and generates strong electric fields, leading either to a breaking of the intracellular structures or to an ionization of the tissue material involved. In this case laser beam is converted into kinetic energy. However, photoablation effect occurs when energy densities exceed a certain threshold. This effect associated with a combination of tissue evaporation and expulsion of liquified material by hydrodynamic mechanisms. It can be achieved in the ultraviolet region using excimer lasers (108 W/cm^2 with 10 nano sec) or in the mid-infrared region by using solid-state lasers with wavelengths range of 2–3 μm. Photodisruption is used in ophthalmology in microsurgical interventions and Keratotomy, also it can be used for lithotripsy (Knappe et al., 2004).

Laser therapy depends on all these mentioned effects which are significantly affected by many factors such as laser's output power, energy, and pulse repetition rate as well as tip-to-tissue distance.

Tip-to-tissue distance, must be considered because it affects the density of photons delivered to the target cell. The applied energy is distributed over an increasing area as the tip-to-tissue distance increases, power density can be diminished by 95 percent with only 5 mm of tip-to-tissue distance (Coluzzi et al., 2017).

2.6 Laser Hazards

Classification of Lasers regarding to the expected potential damage are extending from Class I lasers, which may create no implicit risk, to Class IV lasers for which all safety procedures are recommended to be applied.

Class I lasers produces output power of 40 μW in blue color, it can be considered eye-safe, follow by Class IM has possible risk with magnified beam with power 400 μWatts in red.

Class II with power output 1.0 milli Watt, it has a possible risk with direct viewing, class IIM, has a significant risk with magnified beam.

Class IIIR can be either visible with output of 5.0 milliWatts or invisible with power output 2.0 milliWatts , they cause eye damage. Class IIIB lasers produce output power of 0.5 Watt. This high output power may pose slight fire and skin risk.

Class IV lasers are considered the most dangerous type of lasers. It can cause eye and skin damage, non-target tissue damage, fire hazard and plume hazard.

However, with the increased use of magnification devices such as loupes and microscopes, lasers beam can be focused on the target area.

Hazards of using laser can be minimized by following all the recommended safety procedure such as using appropriate laser eyewear which is not to be taken off until the laser is switched off. Avoid glass mirrors because they absorb heat from the laser energy and may shatter, also to minimize possible unwanted reflection. The possible risk to human tissue is assessed with regard to the Maximum Permissible Exposure (MPE). This is a value of exposure limit above which tissue damage may occur. Protective measures must be taken within this area, called the Nominal Hazard Zone (NHZ). (Caroline Sweeney et al., 2009).

Chapter three

Experimental Part

3.1 Study Design

The study was clinical trial using split –mouth design, for an observation period of one week.

3.2 Study Area

Clinical work was conducted at AlModather Dental Clinic –Sudan

3.3 Study Population

Only teeth diagnosed with dentine hypersensitivity.

3.4 Inclusion Criteria

Only teeth with non-carious cervical lesion such as tooth wear or teeth with gingival recession were considered suitable for the study. Further, the patients should have not received any desensitizer agents for the last 2 months.

3.5 Exclusion Criteria

Teeth with carious lesion, defective restoration were excluded from the study. Some patients were excluded from the study due to active periodontal disease, periodontal surgery within the last 6 months, using analgesics or anti-inflammatory drugs, pregnancy and lactation.

3.6 Study Variables

Back ground variables were age and gender of the patients.

Independent variable was a 980 nm diode laser.

Dependent variables were dentine hypersensitivity and VAS.

3.7 Clinical Test

Each included tooth was received a tactile and thermal stimulation. The tactile stimulus was performed by scratching the suspected tooth with the tip of dental probe. The thermal stimulation was achieved by the application of a jet of air using a dental air unit syringe perpendicular to the tooth surface for 3 seconds. The adjacent teeth were isolated with cotton rolls to prevent false-positive results. Then level of dentin hypersensitivity was measured by the VAS on a scale from 0 to 10. Range of the pain on VAS was evaluated according to the standard assessment as 0(no pain), 1-3 (mild), 4-6(moderate), 7-9(severe) and 10 (worst pain).

The VAS measurements were performed before laser treatment (base line), after 15 minute of laser treatment and after one week.

Laser Treatment

Laser treatment was performed by a diode Laser-Quick Lase (810+980 nm). After the first measurement, by using tossing coin the involved teeth were randomly divided into two experimental groups namely group A and group B.

Group (A) was treated by the diode laser with high power of 1.0 W in continuous emission mode, the selected wavelength was 980 nm and the exposure time was 60 seconds in non-contact mode on the exposed dentine. Group (B)was treated by the same parameters as group (A) except the power was changed to 500 mW.

Both groups were subjected to one session of laser for treatment of dentin hypersensitivity. During laser treatment, both the researcher and patient were wearing protective goggles.

The patients were instructed to brush their teeth with non-desensitizing dentifrices throughout the study.

3.9 Statistical Analysis

Data were collected in forms of clinical history sheet and numerical VAS scale for the measurement pain of dentine hypersensitivity. Then the results of VAS data were transformed to micro-soft Excel sheet. Software Statistical Package for the Social Sciences (SPSS) version 26 was used for data analysis.

Descriptive analysis was performed using mean ± standard deviation (SD) for numerical variables. A Comparison between the study groups was analyzed by paired sample T-test.

For all statistical tests P value < 0.05 was considered statistically significance.

3.10 Ethical Considerations

The study submitted to the research committee at Institute of Laser.

All data were safely preserved to protect the privacy and confidentiality of the patient's information.

3.10.1 Consent

Aims and study information were explained to the patients before participating in the study and they agreed to sign the informed consent. The consent was written in Arabic language.

Chapter Four

Results and Discussion

In this study 12 teeth associated with DH were considered for the investigation.
Only teeth that observed the inclusion and exclusion criteria, reported in the material and methods section, and that shown a VAS score in at least 2 different quadrants of mouth, were selected for the analysis.
The mean and standard deviation (SD) results of the VAS scores for group A are shown in Table 4.1. The obtained results are for each time point of the therapeutic protocol particularly before laser treatment, 15 minutes after laser session and after one week of laser treatment.

Table 4.1. Comparison between Means and Standard deviations of VAS scale for Group A before laser treatment, after 15 minutes and after one week.

Comparison	Mean	SD	*P* value
Before laser versus after 15 min	1.5	0.837	0.007
After 15 min versus after one week	0.167	0.753	0.611
Before laser versus after one week	1.667	0.516	0.001

The results show a significant reduction in VAS after one-week laser treatment *p* value 0.001, although *p* value increase when compared between before laser versus after 15 minute (0.007) and after 15 minute versus after one-week p value = 0.611.
Table 4.2 shows VAS reading for group B for each time point of the therapeutic protocol as before laser treatment, 15 minutes after laser session and after one week of laser treatment.
A significant increase in *p* value when comparing VAS scale before applying the laser versus after 15 minutes (*p* value = 0.141) with the VAS after 15 minutes versus after one-week treatment (*p* value = 0.328). However, there is a significant reduction in *p* value in the VAS scale before laser versus after one week (*p* value = 0.007).

Table 4.2. Comparison between Means and Standard deviations of VAS scale for Group B before laser treatment, after 15 minutes and after one week

Comparison	Mean	SD	*P* value
Before laser versus after 15 min	0.833	1.169	0.141
After 15 min versus after one week	0.667	1.095	0.328
Before laser versus after one week	1.5	0.753	0.007

The comparison between *p* values for both groups from table 4.1 and 4.2 shows a significant reduction in *p* values in group A after 15 minutes of laser treatment (0.007), while in group B no significant reduction was observed (0.141). Whilst, both groups show no reduction when comparing the *p* values after 15 minutes versus after one week, despite of its reduction in group B than group A (0.328) and (0.611) respectively.

Both group show a significant result in the *p* values before laser versus after one week, with group A has a significant reduction.

Figure 4.1 shows the number of teeth that have VAS scale and its ranging from mild to severe in group A and B. The VAS with sever mark is despaired in both group after 15 minutes of laser treatment and after one week as well. This is showing in figure 4.2 and figure 4.3 respectively.

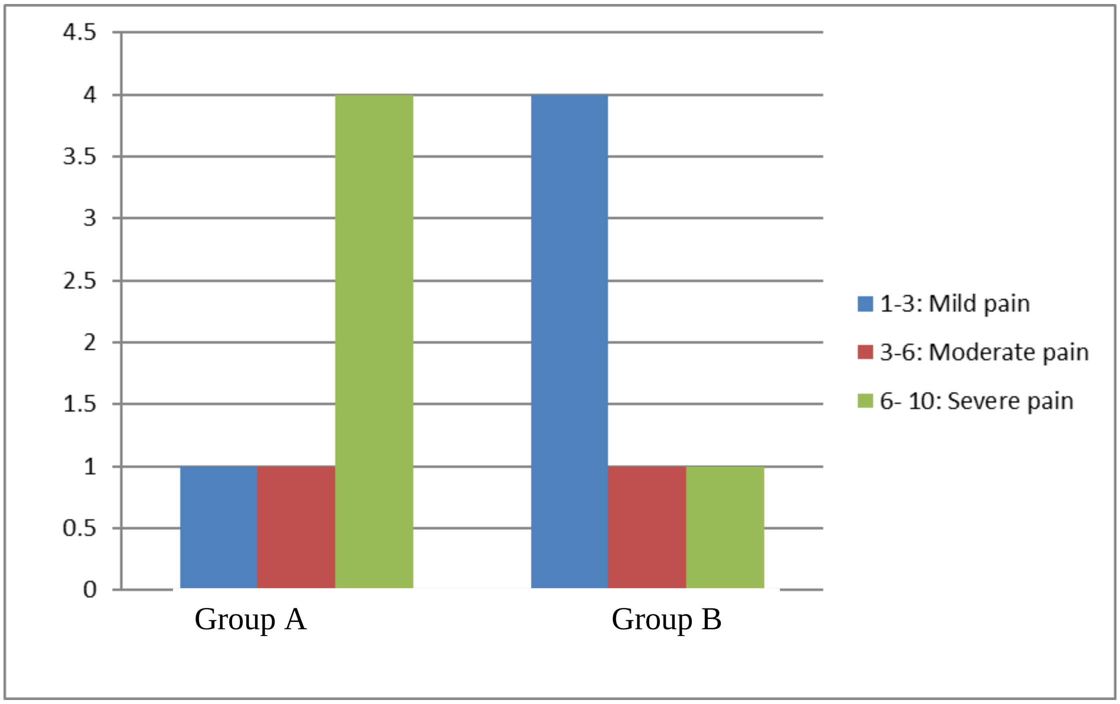

Figure 4.1. Numbers of teeth have readings of VAS scale before laser in both groups.

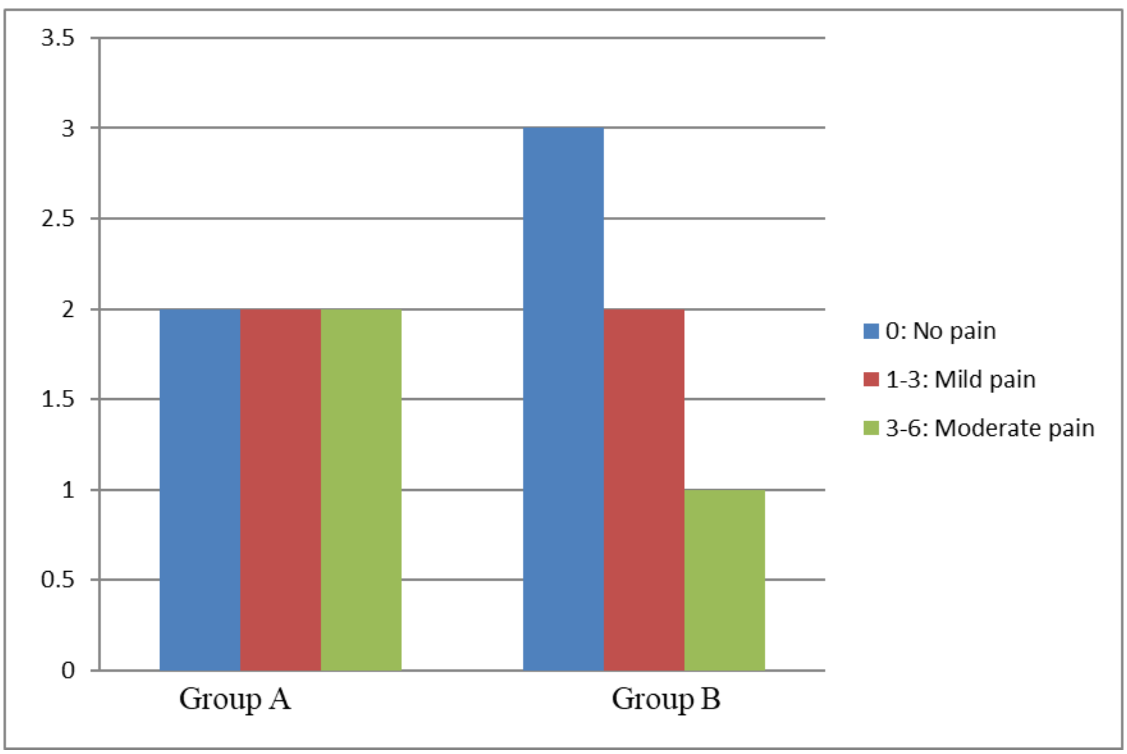

Figure 4.2. Numbers of teeth have readings of VAS scale after 15 minutes in both groups

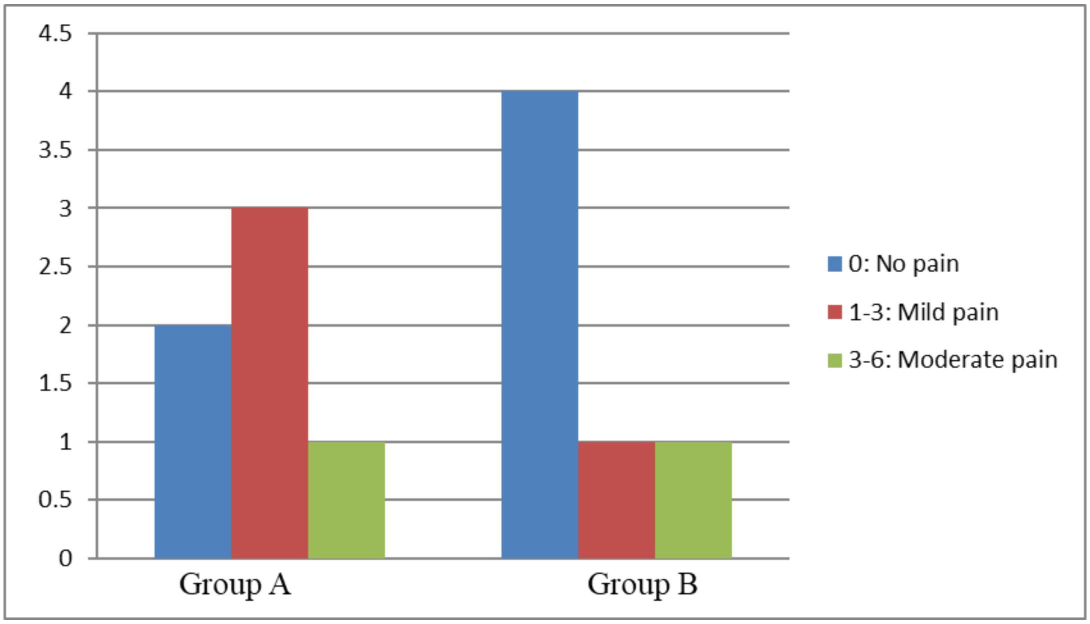

Figure 4.3. Numbers of teeth have readings of VAS scale after one week in both groups.

In this study 980 nm diode laser was used to treat DH. The treatment was performed by using only diode laser without desensitizing agent.

This study involved an evaluation for the effectiveness of using two different laser powers (low and high). A significant pain reduction was observed. Furthermore, presented teeth with sharp stimulated pain before laser treatment, showed an immediate decreasing of painful sensation after 15 minutes of the first session of diode laser (980 nm), even one week after initial irradiation in both study groups with best obtained results in group A (high power 1W). This can be attributed to a mechanism through which high power induce photo- thermal effect that melts the hard tissue on the surface with the smear layer occluding the tubules. Therefore, laser blocks the movement of the fluids in the dentinal tubules, which cause DH pain. The present result agree with other clinical studies, such as , Oliveira Lopes and Aranha study (Lopes and Aranha, 2013) and Femiano et al study (Femiano et al., 2020).

The treated group with low laser power also showed a reduction in dentine hyper sensitivity. Oliveira Lopes (Lopes et al., 2015) explained the immediate reduction in DH by using a low-power diode laser with an infrared wavelength based on that light acts on the cell membrane, allowing greater passage and following increase in Ca^{2+}, Na^{2+}, and K^{+} ions. As a result, the endorphin system and the action potential of neural cells increase. In addition, the depolarization of C fiber afferents is blocked hence, not allowing the pain information to reach the central nervous system. The long-lasting effect of low-power lasers can be attributed to the formation of a layer of tertiary dentin.

Rakesh Mittal (Mittal et al., 2014) concluded that medium power 0.5 W of GaAlAs diode laser causes both nerve analgesia and partial occlusion of dentinal tubules.

4.1 CONCLUSION

Many studies have been conducted to assess the beneficial effects of laser in the treatment of DH. This study aimed to evaluate the treatment of DH by deferent laser powers. We made an effort to develop the knowledge of patients about their periodontal health, helped them to understand some details about dentine hypersensitivity and its pain, and they had recognized that the laser could be a new treatment opportunity and a new hope for their illness.

Based on the obtained results in the treatment of 12 teeth. The therapeutic immediate and late effects of the diode laser 980 nm with 60 seconds exposure duration and 1 W power were greater than those of the 980 nm with .5 mW

It can be concluded that laser parameters, (980 nm wavelength, at 0.5 W powers or 1 W power and for duration of 1 minute) that have been used in this study were safe and no adverse effects were observed on irradiated teeth and adjacent tissue.

4.2 Recommendations

Further long-term studies with large sample size are highly recommended for similar study. This can confirm precisely which output power is more effective in treatment of dentine hypersensitivity for long time.

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Clinical examination sheet

Personal Data:

Serial NO: Sex:

Age: Marital status: Occupation:

Address: Telephone No.:

Chief complaint:

History of the chief complaint:

Family history:

Social history:

Smoker: No Yes: Pipe/cigarettes/other Nº.:

Habits:

Past medical history:…………………………….

Past dental history:………………………..

Oral hygiene activity:

Toothbrushing/Miswak:………………..

Other:

Extra oral examination:……………………….

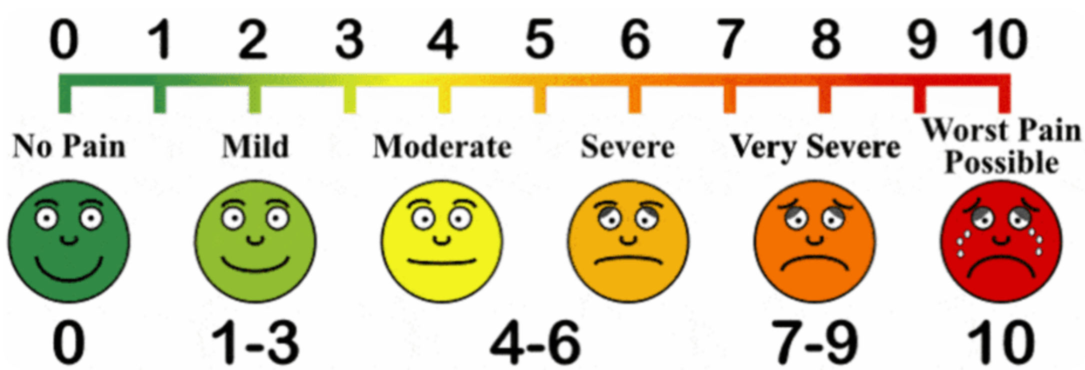
Intra oral examination:

1/gingival recession

2/ caries lesions

3/ tooth wear

4/ tooth fracture



https://rebelem.com/wp-content/uploads/2020/07/Haldol-for-Headache-VAS-Score.png