Sudan University of Science and Technology

College of Graduate Studies

Clinical Evaluation of Laser Application Versus Conventional Surgery in Functional Crown Lengthening

التقييم السريري لتطبيق الليزر مقابل الجراحة التقليدية في إطالة تاج السن الوظيفي

A Dissertation of Graduation Project for Postgraduate Diploma in Laser Applications in Medicine (Dentistry)

By

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

قال الله تعالى :

{الْحَمْدُ لِلَّهِ الَّذِي أَنزَلَ عَلَىٰ عَبْدِهِ الْكِتَابَ وَلَمْ يَجْعَل لَّهُ عِوَجًا ۜ(1)

قَيِّمًا لِّيُنذِرَ بَأْسًا شَدِيدًا مِّن لَّدُنْهُ وَيُبَشِّرَ الْمُؤْمِنِينَ الَّذِينَ يَعْمَلُونَ

الصَّالِحَاتِ أَنَّ لَهُمْ أَجْرًا حَسَنًا (2)}

صدق الله العظيم

[سورة الكهف الآيات:(2-1)]

Dedication

To my parents,

for installing ethics determination and positive attitude on me. I cannot thank
them enough for the support they have provided to me
To my brothers,
for their positive words of encouragement and support, I

love you all.

thank you to every one gave me support
and positive energy.

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I would like to thank all participants for their valuable time, I really enjoyed my time with them. Their positivity and cooperation really pushed me fore ward. Without them this project is just a dream.

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Abstract

Functional Clinical crown lengthening(FCL) is a periodontal resective procedure aimed at partial removal of supporting periodontal tissues to increase exposure of coronal tooth structure. FCL indicated for functional issues to aid in retention forms for restoration fabrication, by facilitating tooth preparation, margin placement and impression taking. FCL involves various techniques, including gingivectomy or gingivoplasty, apically positioned flap procedure, which may include osseous resection and forced tooth eruption. Laser-tissue ablation results in adequate exposure of tooth structure with minimal or no bleeding, allowing the clinician to place a restoration immediately.

Aim: The aim of this study is to compare between functional crown lengthening (gingivectomy without bone removal) using diode laser versus conventional surgical technique (using scalpel) in the degree of postoperative pain expressed by Visual Analog Scale(VAS) and patient's satisfaction scale and post operative edema.

Materials and method: Fourteen teeth were selected for the study but unfortunately, only 12 teeth were found during study duration (two teeth dropped one in each group) resulted in 6 teeth in each group. Patients were 5 females (41.7%) and 7 males (58.3%) with age ranging from 18- 40 years, who referred for functional crown lengthening from both conservative and fixed prosthodontic departments at Khartoum dental teaching hospital and Omdurman military dental teaching hospital. They were divided into two groups: case group and control group. Case group consists of 7 teeth (one case was dropped) were treated using laser technique (diode laser) with 810nm and 980nm wave length in continuous mode(CW). And control group: consist of 7 teeth who were treated with conventional scalpel technique (one case was dropped).

Results: Postoperative pain and patient satisfaction ranges of each patient were recorded using a VAS after 3 hours (same day), 3 days and 7 days after crown lengthening procedure for both groups. Clinical assessment of post operative swelling was recorded after 3 days.

The obtained results indicated that patients treated with the diode laser had less postoperative pain (same day) with significant result (P value =0.017) and they were more satisfied and required fewer analgesics compared to patients treated with the conventional scalpel technique with significant difference (P value=0.024). No participant suffers from edema at both groups.

Conclusion: From this project, it can be concluded that the application of diode laser appears to be more predictable and comprise the state-of-the-art instrumentation, and effective alternative procedure for the treatment of functionally short clinical crowns.

المستخلص

الهدف :الهدف من هذه الدراسة هو المقارنة بين استخدام ليزرالثنائئ والجراحه التقليدية (بإستخدام المشرط الجراحي) في عملية زيادة طول السن, معبر عنها قياسيا بقياس درجة الألم ما بعد الجراحة بإستخدام مؤشر مقياس التناظر البصري للألم، ورضا المرضى بإستخدام مقياس رضاء المرضى.

الأساليب: تم اختيار أربعة عشر سنا ولكن فقط اثنا عشر سنا وجدوا خلال فترة المشروع.حيث كان عدد المرضى الكلي 5 اناث (41.7%) و7 ذكور (58.3%) تتراوح أعمارهم ما بين (18- 40 سنة) ، والذين تم تحويليهم من اقسام العلاج التحفظي والتركيبات الثابته بمستشفى الاسنان التعليمي- الخرطوم ومستشفى السلاح الطبي -امدرمان ، وتم تقسيمهم إلى مجموعتين مجموعة الحالات ومجموعة التحكم. مجموعة الحالات تتكون من6 اسنان تم علاجهم بالليزر الثنائي بطول موجي nm810 وnm980 بإنبعاث مستمر, مجموعة التحكم: تتكون من 6 اسنان تمت معالجتهم بإستخدام الجراحة التقليدية بالمشرط .

النتائج: تم تسجيل الألم ورضاء المرضى بإستخدام (مقياس التناظر الشفهي للألم ومقياس رضاء المرضى بالتتالي) . وتمت مقارنة نتائج كثافة الألم بين مجموعة الحالات ومجموعة التحكم , بعد3 ساعات وبعد 3 يوم, وبعد 7 يوم من إجراء العملية.ورضاء المرضى بعد 7 أيام.

أشارت النتائج المكتسبة إلى أن المرضى الذين عولجوا با ليزر الثنائي لديهم آلام أقل بعد العملية ب 3 ساعات ويشعرون بالرضاء مع وجود فرق ذو دلالة إحصائية واحتاجوا الي مسكنات أقل, مقارنة بالمرضى المعالجين بتقنية المشرط الجراحي

الاستنتاج: بناء علي النتائج إتضح أن العلاج بالليزر الثنائي المستخدم بإعتباره من احدث الاجهزه المستخدمه لعمليات تطويل السن الوظيفي, يساعد على إدراك نتائج متوقعه ويمكن ان يمثل وسيله واداء بديله لعمليات تطويل السن.

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List of Abbreviations

CL	Crown lengthening
FCL	Functional Crown Lengthening
CLP	Crown Lengthening Procedure
VAS	Visual Analog Scale
PDT	Photodynamic Therapy
PAD	Photoactivated dye disinfection using lasers
CO2	Carbon dioxide
Nd-YAG	Neodymium Yttrium Aluminum Garnet Laser
Er: YAG	Erbium yttrium aluminum garnet
LLLT	Low Level Laser Therapy
CW	Continuous wave

CHAPTER ONE

INTRODUCTION

1.1.Background

The concept of crown lengthening was first introduced by D.W.Cohen (1962)(Chaubey et al.).Crown lengthening (CL) is a surgical procedure used to increase the extent of supragingival tooth structure for restorative or esthetic purposes(Gokulanathan et al., 2014). Crown lengthening involves the surgical removal of soft and/or hard periodontal tissues to gain supracrestal tooth length, allowing longer clinical crowns and reestablishment of the biologic width (figure1.1). CL can be indicated for : functional and aesthetic (CL) according to the purpose of the procedure . CL procedure involves various techniques, including gingivectomy (external or internal bevel gingivectomy) or gingivoplasty, apically positioned flap procedure, which may include osseous resection and orthodontic forced tooth eruption(Arora et al., 2015).

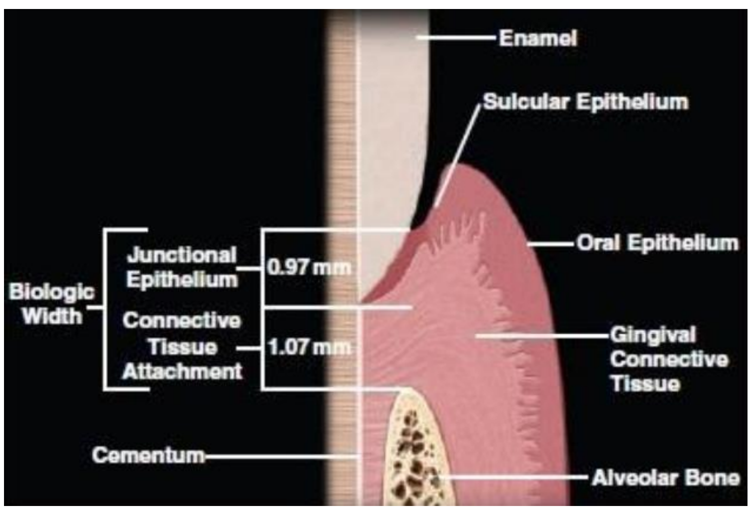

Figure (1.1): Schematic representation of normal biological width (Gupta et al., 2015)

Crown lengthening procedure can be accomplished using scalpel, electrocautery or most recently by the use of lasers (Allen, Wagenberg, Bashetty, McGuire, &Lagdive, 1993; Kalsi, Hussain, &Darbar, 2015), due to its advantages.

Indications of CL (Chaubey et al.):

Can be subdivided into three categories, these are:

1-Functional CL (FCL):

Would be for:

A-Prosthetic:

- Increase crown length.
- Produce ferrule effect.
- Relocate margins of restorations that are impinging on biological width.

B-Restorative:

- Restoration of subgingival caries.
- To access perforations in the coronal third of the root.
- Cervical root resorption.

2-Asthetic CL:

- Altered passive eruption.
- Gummy smile.
- Short teeth.
- Uneven gingival contour.

CL procedures, either for esthetic or functional purposes have one common goal; not to violate the biologic width. Preservation of biologic width is the therapeutic endpoint of both these procedures. Biologic width (BW) is defined as the combined dimension of the epithelial and connective tissue attachments coronal to the crestal bone. Encroachment of the biologic width by placing the margin of restoration within its zone may result in gingival inflammation, pocket formation, and alveolar bone loss(Farista et al., 2016, Dawadi et al., 2021)

Advantages of laser opposite to scalpel (Bhandari et al., 2014):

- Dry surgical field and better visualization.
- Tissue surface sterilization and reduction in bacteremia.
- Decreased swelling, edema and scarring.
- Decreased pain.
- Faster healing response.
- Increased patient acceptance.
- Minimal mechanical trauma.
- Negotiates folds in tissues.

1.2 Research problem and Justification

Numerous clinical situations such as subgingival caries, distorted -badly decayed teeth, fractured teeth, worn out teeth, gummy smile etc. are encountered by dentists in daily clinical practice. Here comes the Interdisciplinary approach, through the procedure of crown lengthening to expose sufficient tooth structure to facilitate proper restoration as well as enhance esthetic appearance. There, the scalpel may not be the ideal method for recontouring, reshaping or sculpting of the gingival margin. This often easier to be accomplished using laser- certainly diode lasers. Moreover, gingival coronal regrowth and rebound effect often less occur in laser compared to traditional crown lengthening. (Ernesto 2017). Moreover, the predictability of achieving biological, aesthetic and functional demands of restorations in both dentition and periodontium may be enhanced by using laser as alternate for conventional procedure.

1.2.Previous studies

In a case study done by Sajay and his colleagues in 2010, they described surgical crown lengthening using semiconductor diode laser for three patients, in all three patients there were no post operative pain mentioned by participants or swelling or bleeding from surgical side. Excellent post operative results were obtained after two weeks and definitive restoration was accomplished after six weeks and the result was esthetically acceptable (Lagdive et al., 2010) .

In 2014 Gokulanathan etal , accomplished also case series at the Department of Periodontics, Vivekanandha Dental College for Women. They described three cases of crown lengthening using diode laser. Patients were prescribed analgesics for use when required. But , no complain of pain or discomfort, during surgery or on following days .Crown lengthening by diode laser was found to be a safe and efficient procedure. Further post-operative patient satisfaction was good. The gingival healing was found uneventful with no infection, pain, swelling or scarring (Gokulanathan et al., 2014). Milavec and colleagues at the same year had a study to compare between laser assisted CL versus conventional surgical therapy, which concluded that laser can be applied in esthetic procedures, such as the recontouring or reshaping of gingiva and in crown lengthening procdure (Milavec and Gaspirc, 2014). At the same year Khashu et al had used scalpels and laser , and they found that healing with laser was faster than scalpel (Khashu et al., 2014). Also post operative discomfort was lesser. Arora and his colleagues in 2015, done a case report also to compare between CL procedure Laser-Assisted versus conventional surgical therapy. In all the three cases, no pain, bleeding was reported. From the non-invasive technique, clinicians can expand esthetic surgery to higher limits. It was mentioned in a study conducted by Bragger, that periodontal tissue response after crown lengthening after six weeks postoperatively, probing depth and attachment level did not change. (Arora et al., 2015).

Farista and colleagues in 2016 had a clinical study to evaluate the effectiveness of diode laser and to Compare Laser and Scalpel for soft tissue CL in Fourteen patients including males and females, aged 20- 40 years and were divided into two equal groups to undergo crown lengthening either using scalpel or laser. Results of the intergroup analysis for both groups for pain scale showed that there was a significant difference (P<0.002) in (VAS) scores of pain on the 3 rd day as well as on the 7th day (P<0.044), with patients in the laser group displaying significantly lower VAS scores compared to the scalpel group, but when both the groups were compared on the 10th day, there was no significat difference (P<0.14)(Farista et al., 2016).

1.3.Objectives of the Thesis

1.4.1General objectives:

To evaluate the effectiveness of using diode semiconductor laser on Functional clinical crown (FCL)lengthening procedure in comparison to conventional(scalpel) surgical technique.

1.4.2 Specific objectives:

1-To assess pain intensity and quality on case and control group using visual Analogue Scale of pain(VAS).

2-To assess patient satisfaction on both case and control groups.

3- To assess post operative swelling(edema) on case and control groups .

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Laser

The term LASER is an acronym for 'Light Amplification by the Stimulated Emission of Radiation'. first application of laser in dentistry was accomplished by Miaman, in 1960 (Verma et al., 2012).Or, it may describe the laser device(=device for generation of coherent electromagnetic waves by stimulated emission of radiation(Renk, 2012, Bhandari et al., 2014).Historically, the foundation of laser was in 1917 by Albert Einstein. His experiments laid to the invention of the laser and its predecessor, the Maser, by theorizing that photoelectric amplification could emit a single frequency, or stimulated emission and was first introduced to the public in 1959, in an article by a Columbia University graduate student, Gordon Gould(Verma et al., 2012). The microwave laser (maser) makes use of microwave amplification by stimulated emission of radiation(Renk, 2012).. Theodore Maiman, at the Hughes Research Laboratories in Malibu, CA, built the first functioning laser, by using a mixture of Helium and Neon. In 1961, laser generated from crystals of Neodymium yttrium-aluminum-garnet (Nd: YAG) was accomplished. In 1962, the argon laser was developed. After that came the first medical laser, Ruby laser at 1963which used in ophthalmology for coagulation of retinal lesions. In1964, Patel at Bell Laboratories developed the CO2 laser. Recently, diode lasers are being extensively used in the field of dentistry(Verma et al., 2012).

1.1.1. Properties of Laser

The laser light exhibits some peculiar properties compared with the conventional light which make it unique(Vogel, 2012). These are:

- Monochromaticity
- Directionality
- Coherence
- Highly Intense or Brightness

1.1.1.1. Monochromaticity

Monochromaticity means the generated light wave is a single specific color (one single wave length). The light emitted from ordinary light sources have different energies, frequencies, wavelengths, or colors. But laser light has a single wavelength or color. Laser light covers a very narrow range of frequencies or wavelengths. This can be due to the stimulated characteristics of laser light. The bandwidth of the conventional monochromatic light source is 1000 Å. But the bandwidth of an ordinary light source is 10 Å. For a highly sensitive laser source it is 10^{-8} [Å=10^{-10}meter].

1.1.1.2. Directionality

The light ray coming from an ordinary light source travels in all directions, but laser light travels in a single direction. For example, the light emitted from torchlight spreads 1km distance it spreads 1 km distance. But the laser light spreads a few centimeters distance even it travels lacks kilometer distance. The directionality of the laser beam is expressed in terms of divergence.

1.1.1.3. Coherence

A predictable correlation of the amplitude and phase at any one point with another point is called coherence. That means if two or more waves of same frequency are in the same phase or have constant phase difference then these waves are said to be coherent in nature (figure 2.1).

In the case of conventional light, the property of coherence exhibits between a source and its virtual source whereas in the case of laser the property coherence exists between any two or more light waves. There are two types of coherence. Temporal coherence and Spatial coherence.

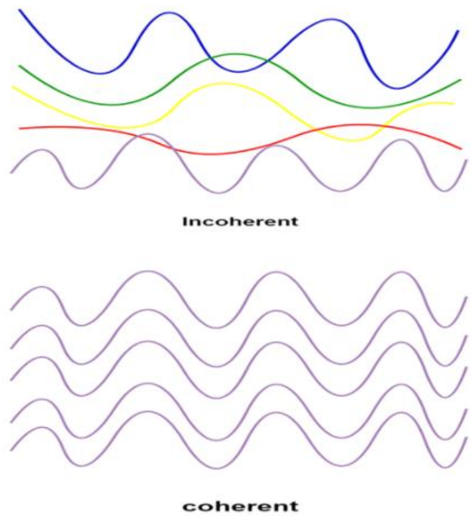

Figure 2.1: Difference between coherent electromagnetic wave and in coherent wave

1.1.1.4. Highly Intense or Brightness

Laser light is highly intense than conventional light. The intensity of a wave is the energy per unit time flowing through a specific area. A one mill watt He-Ne laser is more intense than the sun intensity. This is because of the coherence and directionality of the laser.

1.1.2. Elements of Laser

laser has the following parts(figure 2.2) (Renk, 2012):

I. **Active medium**(gain medium or laser medium): The active medium is able to amplify electromagnetic radiation. The active medium, located inside a resonator, fills out a resonator partly or completely. Active medium could be: Solid, gas or liquid medium.

II. **Pumping system**: It pumps the active medium. Methods of pumping are:

-optical pumping with another laser or a lamp

-pumping with a gas discharge

-pumping with a current through a semiconductor or a semiconductor;

-chemical pumping.

III. **Laser resonator**: The laser resonator has the task to store a coherent electromagnetic field and to enable the field to interact with the active medium - the active medium experiences feedback from the coherent field. Here, we will describe resonators that consist of two mirrors - one is a high reflector mirror with about 100% of reflectivity also known as (Rear mirror), and the other is a partial reflector serving as output couple with reflectivity of <100%.Each type of laser requires its own resonator design.

In dental lasers, the laser light is delivered from the laser to the target tissue via a fiberoptic cable, hollow waveguide, or articulated arm. Focusing lenses, a cooling system, and other controls complete the system(Coluzzi and Parker, 2017). The wavelength and other properties of the laser are determined primarily by the composition of an active medium, which can be a gas, a crystal, or a solid-state semiconductor(Verma et al., 2012).

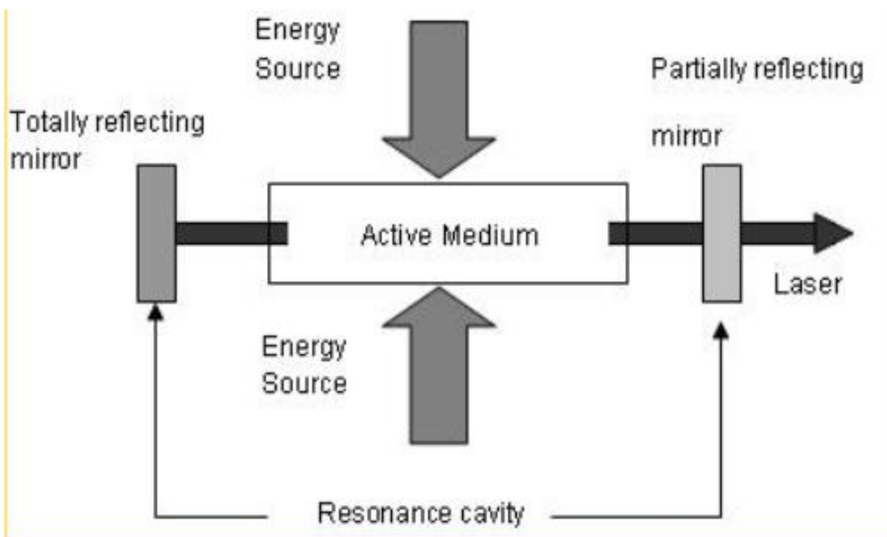

Figure 2.2: Main components of laser (Engineering Physics,2015)

1.1.3. Operation of laser (Lasing Action)

1.1.3.1. Emission and absorption

Spontaneous Emission

In 1913, Niels Bohr, a Danish physicist, developed his model of an atom, applying the quantum principle of plank. He proposed distinct energy orbits or levels of energy around the nucleus of that atom. Bohr found that an electron could «jump» to a higher (and unstable) level by absorbing a photon and then the electron would return to a lower (more stable) level while releasing a photon. He termed this spontaneous emission the emitted photon will likely have a random direction and phase (Vogel, 2012).

Stimulated Emission

In 1916 Albert Einstein postulated the theory of lasers .Using Bohr's model, he postulated that during the process of spontaneous emission, an additional photon, if present in the field of the already excited atom with the same excitation level, would stimulate a release of two quanta. These would be identical in phase, direction, and wavelength. In addition, these emission photons would share monochromatic and coherent properties-thus a laser is born (Vogel, 2012)

Let us assume that the atom is initially lying in level 1 (Fig. 2.3). If this is the ground level, the atom will remain in this level unless some external stimulus is applied to it. This stimulus may be electric current or flash lamp from an incident photon(quanta of energy).

In this case there is a finite probability that the atom will be raised to level 2. The energy difference E2-E1 required by the atom to undergo the transition is obtained from the energy of the incident photon. This is **the absorption process.**

In thermal equilibrium state, numbers of atoms(N) at the ground state are more in the first energy level (E1) than in the second level(E2). We thus have N2<N1. According to, the material then acts as an absorber of energy. This is what happens under ordinary conditions. If, however, a non-

equilibrium condition is achieved for which N2 >N1, then the material will act as an amplifier. In this case we will say that there exists **a population inversion.**

Population inversion cannot be achieved for a two level system under continuous irradiation. Three or four level systems are needed, with a long lifetime of the upper laser level. Obviously a laser system operates correctly when the process of stimulated emission is stronger than the other two processes: absorption and spontaneous emission soon as some atoms are excited into the upper levels, spontaneous emission starts emitting photons in various directions.

Assume one photon propagates to the right exactly along the optical axis of the resonator; it will be reflected on the mirror back into the optical amplifier where it interacts with atoms in the excited states. Stimulated emission yields the number of photons in this propagation direction from 1 to 2 to 4 to 8 to 16 and so on. The number of photons in this direction grows exponentially with the propagation length in the optical amplifier (as long as no saturation occurs). The beam exits the amplifier at the left side, gets reflected by the left mirror and propagates back in the optical amplifier. Therefore, a strong light beam builds up, which goes back and forth between the two mirrors. The mirror on the left side has an almost 100% reflectivity and is therefore called high reflector, while the mirror on the right side, called output coupler, has slight transmission, for example 2%. In this case 2% of the resonator internal beam intensity is coupled to the outside and used for experiments or material processing. A much higher intensity remains in the resonator to ensure that stimulated emission is stronger than spontaneous emission (Vogel, 2012).

Amplification:

Amplification is part of a process that occurs inside the laser. Once stimulated emission occurs, the process should theoretically continue as more photons enter the field both to excite the atoms and to interact with the excited photons returning to their ground state. One could imagine a geometric progression of the number of emitted photons, and, at some point, a population inversion occurs, meaning that a majority of atoms are in the elevated rather than the resting state. As Bohr implied, there can be several potential levels of energy available in most atoms. Having multiple levels (more than two) would aid in maintaining a population inversion because there would be no possibility of equal rates of absorption back into the ground state and stimulated emission. Thus amplification effect can only occur if there is a constant and sufficient source of energy, which is supplied by a pumping mechanism (Vogel, 2012).

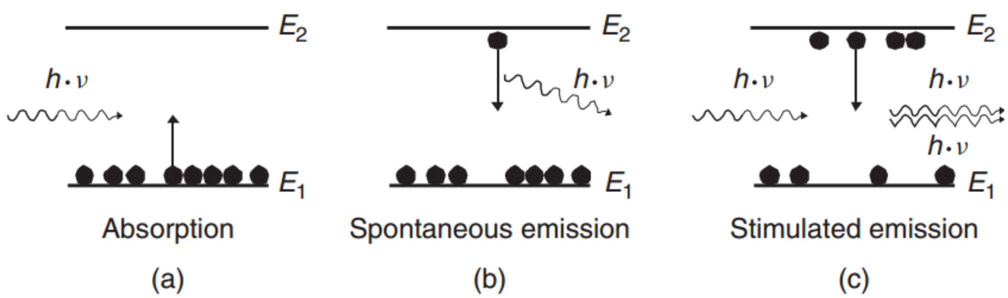

Figure 2.3: Interaction of light with a two level system (Vogel, 2012)

1.1.4. Types of Lasers

Lasers used in dental practice can be classified by various methods:

- According to the lasing medium used, such as:

  Gas laser, solid laser and liquid laser

- according to tissue applicability:

  Hard tissue and soft tissue lasers

- according to the range of wavelength of laser emission into: Infra-red laser, visible light lasers and Ultraviolet light lasers(UV) (Figure 2.4)

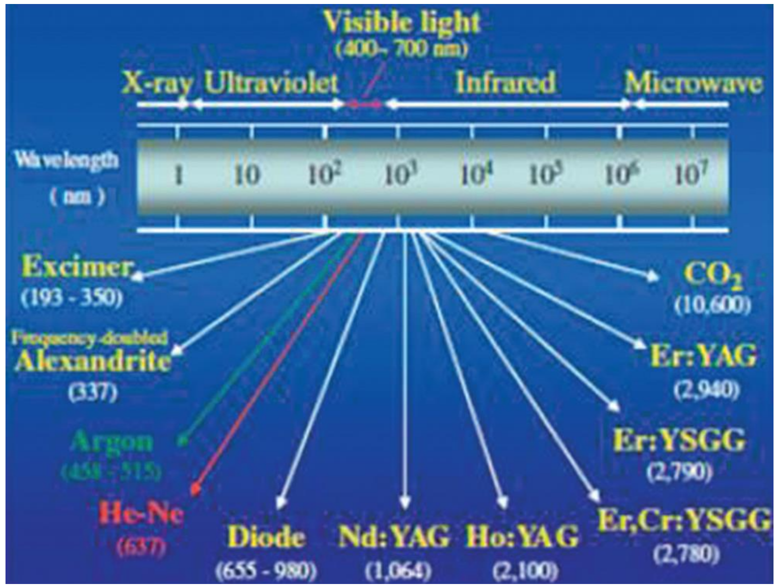

Figure 2.4: Various types of lasers and their corresponding wavelengths(Verma et al., 2012)

All available dental laser devices have emission wavelengths of approximately 0.45 microns, or 450 nanometers to10.6 microns or 10,600 nanometers. This places them in either the visible or the invisible nonionizing portion of the electromagnetic spectrum

- According to possibilities of Operating a Laser:

  Lasers can operate as continuous wave lasers, as pulsed lasers or as femtosecond lasers.

  There are continuous wave lasers and different types of pulsed lasers(Renk, 2012):

  • The CW *(*continuous wave) laser: Continuous pumping maintains the laser oscillation.

  • Pulsed laser: Each laser that delivers pulses is a pulsed laser .Here, A pump pulse generates a population inversion.

  • Q-switched laser: In the Q-switched laser, the quality factor Q of the laser resonator varies with time. The Q factor is small for most of the time and large for a short time. During the time of small Q, population in the upper laser level is collected. During the time of large Q, laser oscillation occurs and the population of the upper laser level is strongly reduced (de-population)

• Giant pulse laser: This is a Q-switched laser with an upper laser level that has a very long lifetime (for instance 1 ms); pumping leads to a large concentration of atoms in the upper laser level.

• Femtosecond laser :The pumping is continuous. For most of the time, the Q factor of the resonator is small but it is large during short time intervals that follow each other periodically. The laser generates ultrashort light pulses with a duration between about 5 fs and 100 fs.

- 1 ms (1 millisecond) = 10^{3} s
- 1 s (1 microsecond) =10^{6} s
- 1 ns (1 nanosecond) = 10^{9}s
- 1 ps (1 picosecond) = 10^{12} s
- 1 fs (1 femtosecond) = 10^{15} s

s=second

1.1.5. Laser in Dentistry

The first experiment with lasers in dentistry was reported in a study about the effects of a pulsed ruby laser on human caries(Husein, 2006). With the recent advances and developments of wide range of laser wavelengths and different delivery systems, lasers could be applied for the dental treatments including periodontal, restorative and surgical treatments (Bhandari et al., 2014).There are several types of lasers used in dentistry depending on their wavelength range and their absorption by biological chromophores, e.g., water, hemoglobin, melanin.

Most commonly used lasers in dental field:

1.1.5.1. Carbon dioxide Laser (CO_2)

The CO2 laser is a gas laser .It has a very high affinity for water, resulting in rapid soft tissue removal and hemostasis with a very shallow depth of penetration (Verma et al., 2012). Although it possesses the highest absorbance of any laser, disadvantages of the CO2 laser are its relative large size and high cost and hard tissue destructive interactions.

1.1.5.2. Neodymium Yttrium Aluminum Garnet Laser (Nd: YAG)

The Nd: YAG wavelength is highly absorbed by the pigmented tissue, making it a very effective surgical laser for cutting and coagulating dental soft tissues, with good hemostasis (Verma et al., 2012). Moreover, there has been researches on using the Nd: YAG laser for nonsurgical sulcular debridement in periodontal disease control and on Laser Assisted New Attachment Procedure (LANAP).

1.1.5.3. Erbium Lasers

The erbium 'family' of lasers has two different wavelengths: Er, Cr: YSGG (Erbium, Chromium doped yttrium scandium gallium garnet) lasers and Er: YAG (Erbium yttrium aluminum garnet) lasers. The Erbium wavelengths have a high affinity for hydroxyapatite crystals and has the highest absorption of water in any dental laser wavelengths (Verma et al., 2012). Thus it is the laser of choice for treatment of dental hard tissues. Further, Erbium can be used in soft tissues, because the dental soft tissue also contains high percentage of water.

1.1.5.4. Diode Laser

The active medium of the diode laser is a solid state semiconductor made of aluminum, gallium, arsenide, and occasionally indium, which produces laser wavelengths, ranging from approximately 810 nm to980 nm. All diode wavelengths are absorbed primarily by tissue pigment (melanin) and hemoglobin. Conversely, they are poorly absorbed by the hydroxyapatite and water present in the enamel. Diode laser can be applied for specific procedures include: aesthetic gingival recontouring, soft tissue crown lengthening, exposure of soft tissue impacted teeth, removal of inflamed and hypertrophic tissue, frenectomies, and photostimulation of the apthous and herpetic lesions.

1.1.5.5. Advantages and disadvantages of using laser (Bhandari et al., 2014):

Advantages:

- Dry surgical field and better visualization.
- Tissue surface sterilization and reduction in bacteremia.
- Decreased swelling, edema and scarring.
- Decreased pain.
- Faster healing response.
- Increased patient acceptance.
- Minimal mechanical trauma.
- Negotiates folds in tissues.

Disadvantages:

- They are relatively high in cost.
- Operations of lasers require specialized training.
- Dental instruments mainly used are both sided and end cutting thus; a modification of clinical technique is required.
- No single wavelength will optimally treat all dental diseases.
- There is inability to remove metallic and cast-porcelain defective restorations by erbium family lasers.
- Harmful to eyes and skin

1.1.6. Application of laser in dentistry

Depending on application on various tissues, laser application in dentistry can be categorized as: soft tissue applications and hard tissue applications (Verma et al., 2012)

1.1.6.1. Soft Tissue Applications

Soft tissue applications of laser in dentistry at different branches(Bhandari et al., 2014)**:**

Applications in oral surgery:

- Hemostasis.
- Malformations.
- Preprosthetic surgeries.
- Precancerous lesions.
- Cysts.
- Benign tumors.
- Scar corrections.
- Low Level Laser Therapy.

Applications in periodontics:

- Gingivectomy.
- Frenectomy.
- Removal of granulation tissue.
- Removal of melanin pigmentation and metal tattoos.
- Subgingival debridement and curettage.
- Osseous recontouring as well as in implant surgery.
- Maintenance of implants.
- Low Level Laser Therapy.

Applications in orthodontics:

- Aesthetic gingival recontouring.
- Soft tissue crown lengthening.
- Exposure of soft-tissue impacted teeth.
- Removal of inflamed and hypertrophic tissue.

- Frenectomy.
- Tissue removal at the site for mini screw.
- Low Level Laser Therapy(LLLT).

Applications in conservative dentistry & endodontics:

- Dentinal Hypersensitivity.
- Pulp Capping & Pulpotomy.
- Cleaning of root canals.
- Sterilization of the root canals.

1.1.6.2.Hard Tissue Applications(Verma et al., 2012):

1-Photochemical effects

2- Laser fluorescence

3- Cavity preparation, caries, and restorative removal

4- Etching

5- Treatment of dentinal hypersensitivity

1.1.6.3.Diagnostic application

Example: for 3-D Laser scanner for e-model preparation.

1.1.7. Laser safety

While most dental lasers are relatively simple in use, certain precautions should be taken to ensure their safe and effective operation. First and foremost is protective eyewear by anyone in the vicinity of the laser, while it is in use. This includes the doctor, chairside assistants, patient, and any observers such as family or friends. It is critical that all protective eye wear worn is wavelength-specific. Additionally, accidental exposure to the non-target tissue can be prevented through the use of warning signs and labels posted outside the Nominal Hazard Zone(NHZ), limiting access to the surgical environment, minimizing the reflective surfaces, and ensuring that the laser is in good working order, with all manufacturer safeguards in place. Also for prevention of possible exposure to infectious pathogens, such as HIV (Human immunodeficiency virus) and HBV (Hepatitis B virus) pathogens, high volume suctions should be used to evacuate any vapor created during tissue ablation, and normal infection protocols should be followed. Each office should have a designated Laser Safety Officer (LSO) to supervise the proper use of the laser, coordinate staff training, oversee the use of protective eyewear, and be familiar with the pertinent regulations (Verma et al., 2012).

1.2. Laser tissue interaction

1.2.1. How matter acts on light

The light energy produced by a laser can have four different interactions with a target tissue: Reflection, Transmission, Scattering, and Absorption (Figure 2.5). Only non reflected and non absorbed or forward scattered photons are transmitted by the slice and contribute to the intensity detected behind the slice. The ratio of transmitted and incident intensities is called transmittance. Which of the losses of reflection, absorption, or scattering is dominant primarily depends on the type of material and the incident wavelength. In laser surgery, knowledge of absorbing and scattering properties of a selected tissue is essential for the purpose of predicting successful treatment.

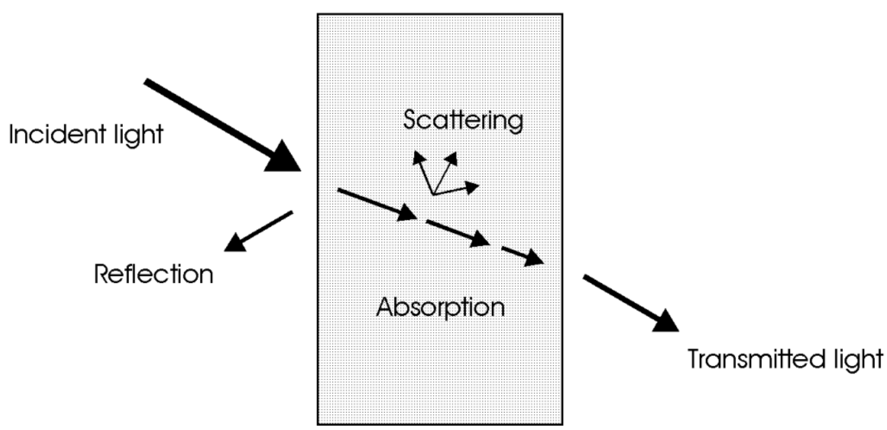

Figure 2.5: Geometry of reflection, refraction, absorption, and scattering (Niemz, 2007)

1.2.2. How light acts on matter

A general classification scheme is developed with the exposure duration by laser being the main physical parameter. Five different types of interaction mechanisms are presented: photochemical interaction, photothermal interaction, photoablation, plasma-induced ablation, and photodisruption..

1.2.2.1. Photochemical interaction

The light can induce chemical effects and reactions within macromolecules or tissues. One of the most popular examples is photosynthesis. In the field of medical laser , photochemical interaction mechanisms play a significant role during photodynamic therapy (PDT). and, biostimulation. Photochemical interactions take place at very low power densities (typically 1W/cm2) and long exposure times ranging from seconds to continuous wave.

PDT:

During PDT, chromophores are injected into the body. Monochromatic irradiation may then trigger selective photochemical reactions, resulting in certain biological transformations. A chromophore compound which is capable of causing light-induced reactions in other nonabsorbing molecules is called a photosensitizer. After excitation by laser irradiation, the photosensitizer performs several sequential decays which result in intramolecular transfer reactions. At the end highly cytotoxic reactants are released causing an irreversible oxidation of essential cell structures. Today, the idea of photodynamic therapy has become one of the major pillars in the modern treatment of cancer (Niemz, 2007).

Biostimulation:

The potential effects of extremely low laser powers (1–5 mW) on biological tissue have been a subject of controversy, since they were first claimed by the Hungarian surgeon, Mester at the end of the 1960s. Wound healing and anti-inflammatory properties by red or near infrared light sources such as helium–neon lasers or diode lasers were reported. Typical energy fluences lie in the range 1–10J/cm2. At low doses (e.g., 2 J/cm2), laser application stimulates proliferation, while at high doses (e.g. 16 J/cm2) it is suppressive (Verma et al., 2012). Low-level laser treatment (LLLT) of gingival fibroblasts in the culture has been shown to induce transformation in myofirbroblasts (useful in wound contraction) as early as 24 hours after laser treatment. LLLT promotes healing and dentinogenesis following pulpotomy(Verma et al., 2012)

Photoactivated dye disinfection using lasers (PAD):

Low power laser energy is useful for photochemical activation of oxygen-releasing dyes, causing membrane and DNA damage to the microorganisms example diode laser. Photoactivated dye can be applied effectively for killing Gram-positive bacteria (including Methicillin-resistant Staphylococcus aureus (MRSA)), Gram-negative bacteria, fungi, and viruses. The major clinical applications of PAD include disinfection of root canals, periodontal pockets, deep carious lesions, and sites of peri-implantitis(Verma et al., 2012).

1.2.2.2.Thermal Interaction

When a laser is absorbed, it elevates the temperature and produces photochemical effects depending on the water content of the tissues. While photochemical processes are often governed by a specific reaction pathway, thermal effects generally tend to be nonspecific according to Parrish and Deutsch (1984)(Niemz, 2007). When temperature of 100°C is reached, vaporization of the water within the tissue occurs, a process called ablation. At temperatures below 100°C, but above approximately 60°C, proteins begin to denature, without vaporization of the underlying tissue (coagulation). Conversely, at temperatures above 200°C, the tissue is dehydrated and then burned, resulting in an undesirable effect called carbonization(Verma et al., 2012*)*. Absorption requires an absorber of light, termed chromophores, which have a certain affinity for specific wavelengths of light. The primary chromophores in the intraoral soft tissue are melanin, hemoglobin, and water, and in dental hard tissues, hydroxyapatite crystals. Different tissues have different components and then different absorption coefficient for certain wave length, making the laser selection procedure tissue dependent. Depending on the duration and peak value of the tissue temperature achieved, different effects like coagulation, vaporization, carbonization, and melting may be distinguished (table 2.1).

Coagulation:

In coagulation, tissues appear darker in color than adjacent tissues.

Vaporization:

thus leading to vaporization within these layers. The induced increase in pressure- water tries to expand in volume as it vaporizes-leads to localized micro explosions which is as demonstrated as enlargement.

In the literature, vaporization is sometimes also referred to as a thermomechanical effect due to the pressure build-up involved. The resulting ablation is called thermal decomposition and must be distinguished from photoablation. At temperatures above approximately 100◦C, the tissue starts to carbonize, i.e. carbon is released, leading to a blackening in color. For medical laser applications, carbonization should be avoided in any case, since tissue already becomes necrotic at lower temperatures. Thus, carbonization only reduces visibility during surgery.

Melting:

Obviously, the pulse duration of a few microseconds is still long enough to enable a sufficient increase in temperature.

The spatial extent and degree of tissue damage primarily depend on magnitude, exposure time, and placement of deposited heat inside the tissue. The deposition of laser energy, however, is not only a function of laser parameters such as wavelength, power density, exposure time, spot size, and repetition rate. It also strongly depends on optical tissue properties like absorption and scattering coefficients. For the description of storage and transfer of heat, thermal tissue properties are of primary importance such as heat capacity and thermal conductivity.

Parameters of thermal effect:

Heat generation: is determined by laser parameters and optical tissue properties-primarily irradiance, exposure time, and the absorption coefficient-with the absorption coefficient itself being a function of the laser wavelength.

Heat transport: is solely characterized by thermal tissue properties such as heat conductivity and heat capacity. Heat effects, finally, depend on the type of tissue and the temperature achieved inside the tissue.

For thermal decomposition of tissues, it is important to adjust the duration of the laser pulse in order to minimize thermal damage to adjacent structures. By this means, the least possible necrosis is obtained.

Heat effects:

These can be manifold, depending on the type of tissue and laser parameters chosen:

can be summarized at the following table (table 2.1):

Table 2.1: Thermal effects of laser radiation (Niemz, 2007)

Temperature	Biological effect
37°C	Normal
45°C	Hyperthermia
50°C	Reduction in enzyme activity, cell immobility
60°C	Denaturation of proteins and collagen, coagulation
80°C	Permeabilization of membranes
100°C	Vaporization, thermal decomposition (ablation)
> 100°C	Carbonization
> 300°C	Melting

Laser radiation acts thermally if power densities ≥ 10W/cm2 are applied from either CW radiation or pulse durations exceeding approximately 1 μs.

Typical lasers for coagulation are Nd:YAG lasers or diode lasers. CO2 lasers are very suitable for vaporization and the precise thermal cutting of tissue.

Carbonization and melting can occur with almost any type of laser if sufficient power densities and exposure durations are provided.

In most applications, only one specific effect is aimed at. Therefore, careful evaluation of the required laser parameters is essential. Reversible and irreversible tissue damage can be distinguished.

Carbonization, vaporization, and coagulation certainly are irreversible processes, because they induce irreparable damage. Hyperthermia, though, can turn out to be either a reversible or an irreversible process, depending on the type of tissue and laser parameters. Since the critical temperature for cell necrosis is determined by the exposure time as shown in (Fig 2.6), no well-defined temperature can be declared which distinguishes reversible from irreversible effects. Thus, exposure energy, exposure volume, and exposure duration together determine the degree and extent of tissue damage. The coincidence of several thermal processes is illustrated on (Fig. 2.6).

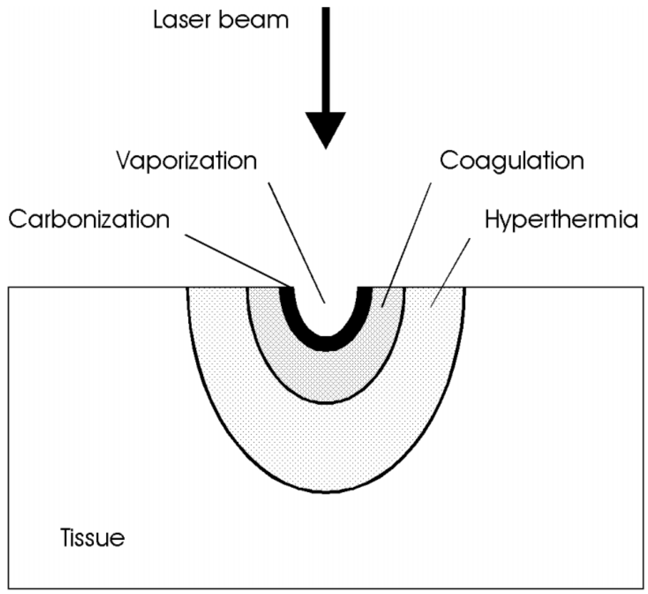

Figure 2.6: Location of thermal effects inside biological tissue (Niemz, 2007)

Laser-Induced Interstitial Thermotherapy (LITT)

The possibility of localized tissue coagulation has formed the basis of a novel tumor treatment technique called laser-induced interstitial thermotherapy. The principal idea of LITT is to position an appropriate laser applicator inside the tissue to be coagulated, e.g. a tumor, and to achieve necrosis by heating cells above 60◦C. It was recently introduced to the treatment of various types of tumors such as in retina, brain, prostate, liver, or uterus, and has already become a well established tool in minimally invasive surgery (MIS). Due to the associated coagulation of blood vessels, severe hemorrhages are less likely to occur than in conventional surgery. This is of particular importance in the case of tumors, because they usually are highly vascularized. Either Nd: YAG lasers at 1064nm or different types of diode lasers at 800–900 nm are applied, since light deeply penetrates into tissue at these wavelengths. Typical parameters of the procedure are 1–5W of CW laser power for a period of several minutes and coagulation volumes with diameters of up to 40mm. In order to achieve a safe LITT procedure, knowledge of the final damage zone is essential. Especially in neurosurgery, it is very important to prevent injury of adjacent healthy tissue and sensitive structures. The laser applicator usually consists of a flexible fiber and a transparent catheter through which the fiber is moved into the tissue. the catheter is placed inside the tumor assisted by qualified monitoring. either ultrasound or magnetic resonance imaging (MRI) can be also used. The same target may be treated several times by LITT to increase the spatial extent of tissue necrosis. The whole procedure can be performed either intraoperatively or percutaneously. For the treatment of very large tissue volumes with diameters of up to a few centimeters the application of several fibers is strongly recommended according to Klingenberg et al.

Following three laser tissue interactions interactions will be summarized, as:

2.2.2.3 Photoablation:

- Main idea: direct breaking of molecular bonds by high energy Ultra Violet (UV) photons
- Observations: very clean ablation, associated with audible report and visible fluorescence
- Typical lasers: excimer lasers, e.g. ArF, KrF, XeCl, XeF
- Typical pulse durations: 10 ... 100ns
- Typical power densities: 10^7 ... 10^{10} W/cm^2
- Special applications: refractive corneal surgery

2.2.2.4 Plasma-Induced Ablation:

- Main idea: ablation by ionizing plasma formation
- Observations: very clean ablation, associated with audible report and blueish plasma sparking
- Typical lasers: Nd:YAG, Nd:YLF, Ti:Sapphire
- Typical pulse durations: 100fs … 500ps
- Typical power densities: 10^{11} ... 10^{13} W/cm^2
- Special applications: refractive corneal surgery, caries therapy

2.2.2.5 Photodisruption

- Main idea: fragmentation and cutting of tissue by mechanical forces
- Observations: plasma sparking, generation of shock waves cavitation, jet formation
- Typical lasers: solid-state lasers, e.g. Nd:YAG, Nd:YLF ,Ti:Sapphire
- Typical pulse durations: 100fs . .. 100ns
- Typical power densities: 10^{11} ... 10^{16} W/cm^2
- Special applications: lens fragmentation, lithotripsy

2.3 Crown lengthening (CL):

The concept of crown lengthening was first introduced by D.W. Cohen (1962) and is presently a procedure that often employs some combinations of tissue reduction or removal, osseous surgery, and / or orthodontics for tooth exposure(Gupta et al., 2015)**.**

The crown lengthening (CL) of the clinical crown of a tooth, is one of the most common procedures in periodontal practice according to a survey by the American Academy of Periodontology (AAP) 2003,forming about 10% of periodontal surgical procedure(Dawadi et al., 2021). CL aims at increasing the length of the supragingival tooth structure and is performed for variety of problems and conditions, including the need to improve esthetics (esthetic crown lengthening) and/or to facilitate restorative treatment (functional crown lengthening).CL can treat esthetic problems which occurred due to: altered passive eruption, excessive gingival display - also known as “gummy smile”, or to improve the esthetic outcomes of definitive restorations. Ernesto proposed classification of aesthetic CL (table 2.2). Also, CL is indicated in the management of restorative challenges(functional) when access to subgingival tooth structure is required (e.g., subgingival caries, crown or root fractures, cervical root resorptions, short abutment). The biological basis for the crown lengthening procedure is the reestablishment in a more apical position of the supracrestal tissue attachment , previously described as biologic width(Jepsen et al., 2018)

2.3.1 Indications for crown lengthening(Gokulanathan et al., 2014):

a. Functional crown lengthening:

• To access subgingival caries

• To increase the clinical crown height reduced by tooth wear, caries or fracture extending subgingivally

• Correcting the position of the restorative margin when there has been invasion of the biologic width.

b. Aesthetic crown lengthening:

• Correction of short clinical crowns due to wear or altered passive eruption

• Creating gingival symmetry in the smile line

• Correcting irregular/uneven gingival margins

• Correcting for hyperplasic tissue overgrowth

2.3.2 Contraindications of CL(Khashu et al., 2014):

• Inadequate crown-to-root ratio

• Non-restorability of caries or root fracture

• Esthetic compromise

• High furcation

• Tooth arch relationship inadequacy

Therapeutic classification of CLP by Michael Sonick 1997(Baghele, 2021):

I -Gingival reduction only-bone removal not required

A Gingivectomy

B Gingival flap surgery

II- Mucoperiosteal flap with ostectomy-bone removal required

A. One-stage procedure that requires one of the following:

(1) Flaps, ostectomy, apical positioning

(2) Flaps, ostectomy, gingivectomy, positioning

(3) Gingivectomy, flaps, ostectomy, positioning

B. Two-stage procedure, which requires:

A. Flaps, ostectomy, and repositioning,

B. 4 to 6 weeks later—gingivectomy

Table 2.2: Ernesto classification for aesthetic Cl (Lee, 2004):

CLASSIFICATION	**CHARACTERISTICS**	**ADVANTAGES**	**DISADVANTAGES**
TYPE I	Sufficient soft tissue allows gingival exposure of the tooth without exposure of the alveolar crest and violation of the biologic width.	May be performed by the restorative dentist. Provisional restorations of the desired length may be placed immediately	
TYPE II	Sufficient soft tissue allows gingival excision without Requires osseous contouring. May require a surgical referral.	Will tolerate a temporary violation of the biologic width. Allows staging of the gingivectomy and osseous contouring procedures. Provisional restorations of the desired length may be placed immediately	Requires osseous contouring. May require a surgical referral.

TYPE III	Gingival excision to the desired clinical crown length will expose the alveolar crest.	Staging of the procedures and alternative treatment sequence may minimize display of exposed subgingival structures. Provisional restorations of desired length may be placed at second stage gingivectomy	Requires osseous contouring. May require a surgical referral. Limited flexibility.
TYPE IV	Gingival excision will result in inadequate band of attached gingiva		Limited surgical options. No flexibility. A staged approach is notadvantageous. May require a surgical referral.

2.3.3 Normal Anatomy:

The basic functional unit that supports the teeth is the periodontium, which includes the alveolar bone, periodontal ligament, cementum, junctional epithelium, and gingiva (Lee, 2007). The gingiva is comprised primarily of connective tissue, which is covered by an epithelial that provides a protective barrier against bacterial, mechanical, and immunological challenges. Collagen fibers within the gingival connective tissue insert into the periosteum of the alveolar process and into the root cementum. The junctional epithelium constitutes the attachment interface of the epithelial layer to the tooth surface. It extends in an apical direction from the bottom of the sulcus to the level of the gingival connective tissue attachment(Lee, 2007).

2.3.4 Biological width:

The term biological width , recently replaced by the term supracrestal tissue attachment in the 2018 classification of periodontal diseases and conditions(Jepsen et al., 2018), refers to the combined junctional epithelium and supracrestal connective tissue coronal to the alveolar crestal bone(figure 2.7). Both histologic animal studies and human clinical studies provide evidence that infringement of a restorative margin within the zone of the supracrestal tissue attachment results in inflammation, loss of periodontal supporting tissues, and apical migration of the junctional epithelium and the underlying connective tissue(Xenoudi and Karydis, 2019, Jepsen et al., 2018). It is therefore generally accepted that preservation of a sufficient band for the supracrestal tissue attachment is of critical importance in maintaining periodontal health after subgingival placement of restorative margins and during crown lengthening procedures.

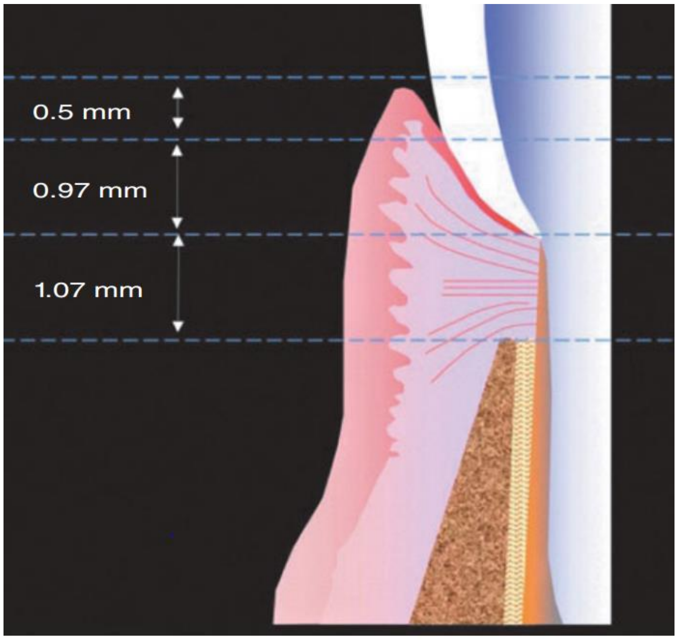

Figure (2.7): Normal Biological width (Sarfati and Tirlet, 2018)

The dimension of biologic width is found to be 2.04 mm, 0.97 mm for the junctional epithelium (average range 0.71–1.35 mm, overall range 0.08–3.72 mm) and 1.07 mm for the connective tissue (average range 1.06–1.08 mm, overall range 0– 6.52 mm), and an additional 0.69 mm for the gingival sulcus (average range 0.61–1.76 mm) (Figure 2.7).These findings agree with the dimensions reported by Vacek et al., overall width 1.91 mm, 1.14 mm for the junctional epithelium (range0.32–3.27 mm) and 0.77 mm for the connective tissue (range 0.29–1.84mm),in addition to1.32mm for the gingival sulcus (range 0.26–6.03 mm) (Vacek et al., 1994). While the biologic width does not include the gingival sulcus dimension, it is suggested in the literature to preserve at least 3 mm of tooth structure between the alveolar crest and the restorative margin in order to include 1 mm of sulcus and avoid close contact with the coronal part of the junctional epithelium due to the association of restorative margins with crestal bone loss. Thus, does not take into consideration the variability in the range of the biologic width dimensions between patients and teeth and different sites on the same tooth. In a systematic review on biologic width dimensions, Schmidt et al. reported that the tooth type, site, presence of restoration, and periodontal status often affect these dimensions. Vacek et al. reported >1 mm wider junctional epithelium at interproximal sites as well as wider junctional epithelium around restored teeth(Vacek et al., 1994), while Novak et al. observed that the biologic width of teeth with attachment loss up to2 mm in patients with untreated periodontitis was significantly wider (average 5.35 mm) than the biologic width in sites with attachment loss >6 mm (average 3.05 mm).

Due to the large variability in the supracrestal attachment dimensions between patients and periodontal conditions, types, and sites of teeth, a careful evaluation of the patient's periodontal status and phenotype is required prior to any treatment planning for crown Clinical and radiographic examinations are necessary prior to any crown lengthening procedure for the assessment of the restorability of the involved tooth or teeth, assessment of supportive bone and the prognosis of both the involved and the adjacent teeth. Clinical assessment involve examination of gingival biotype/periodontal

2.3.5 Gingival Biotype/Periodontal Phenotype

According to the 2018 classification system of periodontal diseases and conditions, the term biotype has been replaced by the term periodontal phenotype, since biotype may imply the patient's genotype while phenotype indicates effect of the combination of genetic traits and environmental(Jepsen et al., 2018)

Gingival phenotype this includes gingival thickness and keratinized tissue width. The bone morophotype (thickness of the buccal bone plate).

Three different methods have been proposed for the assessment of the gingival thickness: transgingival probing (Ronay et al., 2011), ultrasonic measurement(Eger et al., 1996), and periodontal probe visibility through the facial gingiva after the probe's placement in the facial aspect of the sulcus.

The gingiva is thin if ($\leq$ 1 mm) when the probe is visible/shining through the gingival tissues after being inserted in the facial sulcus and thick (> 1 mm) when the probe is not visible(Kan et al., 2010).

The keratinized tissue width is easily measured with a periodontal probe positioned between the gingival margin and the mucogingival junction. The periodontal phenotype has been described by Zweers et al. who classified it in three categories (Zweers et al., 2014):

-Thin scalloped phenotype: associated with narrow triangular crown, a narrow zone of keratinized tissue, thin gingiva, and a relatively thin alveolar bone. In these situations, the interproximal contacts seem to be close to the incisal edge

-Thick flat phenotype: associated more with square shaped tooth shape, a wide zone of keratinized tissue, thick gingiva, and thick alveolar bone. The interproximal contacts are positioned more apically.

-Thick scalloped phenotype: associated with a thick gingiva, narrow teeth, narrow zone of keratinized tissue, and a distinct gingival architecture/ scalloping.

Keratinized tissue width: It has been reported that keratinized tissue width ranges from 2.75 to 5.44 mm in a thin phenotype and from 5.09 to 6.65 mm in a thick phenotype, whereas the gingival thickness ranges from 0 .63 to 1. 79 mm (Cortellini and Bissada, 2018). In addition, the thin phenotype has a mean buccal bone thickness of 0.34 mm while the thick and average phenotype has a mean buccal bone thickness of 0.75 mm(Cortellini and Bissada, 2018).

Sequence Of Treatment (Allen, 1993)

Clinical and radiographic evaluation:

1- Caries control

2- Removal of defective restorations

3- Placement of provisional restorations:

a. Control of inflammation

b. Better assessment of crown lengthening required

c. Improved surgical access, especially interproximally

d. Enhanced predictability of margin placement post surgically

4- Endodontic therapy:

a. Precedes surgery

b. If not possible, then completion is 4 to 6 weeks post surgically

5- Control of gingival inflammation

a. Plaque control

b. Scaling and root planing

6- Re-evaluation for:

a. Orthodontic treatment

b. Surgical therapy

7- Surgery

2.3.6 Techniques for crown lengthening:

2.3.6.1 Surgical:

A- Crown Lengthening Surgery Using External Bevel Gingivectomy

Indicated in the presence of excess keratinized gingiva and an underlying bone crest at 3 mm or more from the level of gingival resection. Adequate apicocoronal height of keratinized gingival tissues of at least 3 mm should remain after surgery in the presence of subgingival restorations(Majzoub et al., 2014).Gingivectomy can be performed using conventional scalpels or a Kirkland knife , electrosurgery, radiosurgery or laser. The incisions are started apical to the point of tissue that is desired to be removed. The incisions are directed coronally beveled approximately 45 degrees to the tooth surface. Discontinuous or continuous incisions may be used and should recreate, as far as possible, the normal festooned pattern of the gingiva(Gupta et al., 2015).

B- Crown Lengthening Surgery Using Internal Bevel Gingivectomy with or Without Ostectomy (Undisplaced Flap)

C- Crown lengthening Using Apically Positioned Flap with or without Ostectomy

These last two methods, are beyond the objectives of this project.

2.3.6.2 Orthodontic Tooth Extrusion

Indications to orthodontic extrusion include:(Xenoudi and Karydis, 2019):

-Tooth fractures

-Deep caries

-Inadequate axial height for retention.

-External root resorption that does not extend past the coronal third of the root.

- In any case that surgical CL would compromise the esthetics of the tooth of interest and/or the prognosis of the adjacent teeth.

Contraindications to orthodontic extrusion include:

-Ankylosis

-lack of adequate anchorage

-Vertical root fracture

-Root proximity, short toots, and potential exposure of the furcation.

Orthodontic tooth extrusion is characterized by the coronal movement of the tooth utilizing traction forces via orthodontic appliances(Xenoudi and Karydis, 2019). Due to the unique environment of the periodontium, as the tooth transverses coronally, the gingival tissues and bone will follow along. It has been reported that the main determinant of the movement of the bone depends on the rate of the tooth movement. If the tooth moves 1 to 2 mm per month, then the whole complex of tooth, periodontal ligament, and bone will migrate (Low Orthodontic Force). If the tooth moves on a faster rate, 3 to 4 mm per month, the extra tension on the periodontal ligament may lead to “tear” of the periodontal ligament fibers and movement of the tooth separately from its surrounding bone and soft tissues (Rapid Orthodontic Extrusion). A single fiberotomy has been proposed at the end of the procedure to minimize soft tissue rebound(Gupta et al., 2015).

Orthodontic extrusion is a conservative procedure that allows retention of the tooth and preservation of the adjacent soft and hard tissues. The clinician needs to consider and inform the patient that orthodontic movement is time-consuming.

Laser-Assisted CL Gingivectomy/Gingivoplasty:

The use of lasers for gingivectomy or gingivoplasty in CL procedures, for the excision of gingival tissues in sites with sufficient band of keratinized gingiva, provides many advantages when compared with the traditional scalpel, including hemostasis, smooth surgical margins, decreased morbidity, accelerated healing, and increased patient comfort, as well as the ability to perform restorative procedures at the same visit (Lee, 2017).

The laser wavelength determines the absorption of the energy by different physical elements and consequently its properties. Diode and Nd: YAG lasers are primarily absorbed by chromophores (e.g., melanin, hemoglobin), whereas the Erbium family lasers and the carbon dioxide (CO2) are absorbed by water and hydroxyapatite, and have very shallow depth of penetration since all tissues have high concentration in water. Diode lasers with initiated tips are used for incision and tissue ablation/vaporization, while the Nd: YAG lasers are used for disinfection, removal of diseased epithelium, and hemostasis. The Erbium type of lasers is effective in removing both soft and hard tissues whereas the CO2 and diode lasers are primarily used for soft tissue removal and are not appropriate for procedures that include osseous resection or tooth structure removal (Lee, 2017). Moreover, diode lasers, once initiated, concentrate the energy at the tip, which leads to heat generation. This makes them very effective and time efficient in soft tissue removal, allows precision of soft tissue ablation and sculpting of the gingival contour, and provides coagulation and safety as it does not interact with restorative materials and tooth structures(Lee, 2006).

In CL procedures where both soft and hard tissue removal is necessary, erbium lasers are very advantageous for "flapless crown lengthening" tentatively without the need to raise a flap.

The application of dental lasers in CL procedures has significant advantages including: enhanced gingival sculpting, accuracy and precision of the incisions, and, depending on the laser, hemostasis or coagulation. On the other hand, tissue handling with the laser is more time-consuming while the use of scalpel allows the operator to control the speed of the incision. When an initiated diode, Er and/or CO2 laser is utilized incision should be done in layers, allow time between the laser pulses for the tissue to absorb the energy, and recover from the temperature increase. It is therefore of critical importance that the laser operator has sufficient training and experience(Xenoudi and Karydis, 2019).

CHPTER THREE

MATERIALS AND METHODS

3.1 Introduction

Surgical Functional crown lengthening(FCL) procedure is performed to assist in the retention of prosthesis by allowing tooth preparation, impression taking and placement of restorative margins. Thus, it is important to prepare the periodontium before restorative treatment to ensure good form, function and aesthetic as well as patient comfort. The present project, evaluates the FCL by means of using semiconductor laser diode laser as alternative for conventional surgical crown lengthening.

3.2 Materials

3.2.1 Study Design:

Case control study design. Control group comprises (scalpel group) and case group comprises (laser group).

3.2.2 Study Population:

Both sexes, males and female patients aged between 18 to 40 years.

3.2.3 Study Area:

Khartoum teaching dental hospital and Omdurman Military dental hospital and Elmmudathir dental clinic (private clinic).

3.2.4 Study duration: January 2022- March 2022

3.2.5 Sample Size:

Sample size was calculated according to previous study. 14 teeth (7 teeth as case or test group and 7 teeth as control group). Unfortunately, only 12 teeth were found during study duration (two teeth dropped one in each group) resulted in 6 teeth in each group.

3.2.6 Sample Size Technique:

Convenience (All subjects who satisfied the inclusion criteria and who were present at the study area during the period of data collection were included in the study).

3.2.7 Inclusion Criteria

1- Systemic healthy patients

2-Patients with adequate keratinized gingival tissues(>3mm).

3- Bone sounding revels distance from proposed restorative margin and bone level (≥3mm).

3.2.8 Exclusion Criteria

1-Patients with systemic disease

2-Patients under medications

3-Patients who previously underwent any surgical procedures in the same area.

4-Smokers

5- Pregnant and lactating mothers.

6-Patients with narrow zone of keratinized tissues(<3mm) (appendix II)

7- Bone sounding revels distance from proposed restorative margin and (<3mm) bone level.

3.3 Method:

The present clinical study is aimed to assess the clinical effectiveness of a diode laser for functional crown lengthening procedure and to compare it with the conventional procedure using the scalpel. Twelve teeth of males and female patients, aged 18 to 40 years were referred from conservative and fixed prosthesis departments at Khartoum dental teaching hospital and Omdurman military teaching dental hospital to periodontal departments at mentioned hospitals, for the purpose of functional CL. They were divided into two groups with simple randomization to undergo crown lengthening either with the scalpel or the diode laser.

CL procedure was properly explained to the patients and a signed consent was taken from them, and Oral prophylaxis was accomplished to both groups before CL procedure by author.

3.3.1 Conventional Soft Tissue Crown Lengthening Procedure(scalpel):

The area around the teeth which were to undergo the procedure was sufficiently anesthetized with 2%lignocaine and 1:80,000 adrenalines. Initially the probing depth was measured and once sufficient anesthesia was achieved, biologic width calculation was done by the transgingival probing method using a William's periodontal probe.

Once the biologic width was calculated and the amount of gingival tissue to be excised was demarcated to attain a proper exposure of the tooth structure, an internal bevel incision was performed and the gingival tissues were excised. An internal bevel incision can preserve the maximum amount of attached gingiva while thinning the margin of the gingiva to a knife-edge contour. It is more comfortable for the patient than external bevel gingivectomy, because of healing by primary intension in the former. Left out tissue tags and any granulation tissue were removed to attain a smooth surface Patients were given all the post operative instructions and were prescribed analgesics if needed. Adequate plaque control measures involving rinsing with 0.12% Chlorhexidine gluconate twice daily for about one week was prescribed.

3.3.2 Laser Assisted Soft Tissue Crown Lengthening Procedure:

A soft tissue Diode laser (British Quicklase) (appendix II), emitted in continuous wave mode (CW) was used for the case group. The diode laser unit was pre adopted at energy settings 2 watts(W) operated in contact mode using flexible fiber optic delivery system with wavelength 810 and 980 nm 400 micrometer fiber tip diameter, as adjusted by the laser device. Safety glasses were worn by the operator, patient and assistant. Plastic instruments were used to avoid reflection of the laser beam as proposed by FDA laser safety rules (Gokulanathan et al., 2014). No anesthesia was used before the procedure. Laser therapy was started from the base of bleeding point created by the laser light itself, with small brush like strokes -back and forth with deeper progression along the same initial laser incision to remove the gingival tissues and tip was kept in continuous motion.

Remnants of the ablated tissues were removed using sterile gauze soaked in saline. Recontouring of marginal gingiva and interdental papilla to recreate of normal contour.

Patients were prescribed analgesics for use when required and postoperative instructions were given.

3.3.3 Method of scoring:

Using Visual Analog Scale (VAS)(figure(3.1)).The VAS is recognized as a sensitive and reliable instrument for evaluating an individual's subjective feeling of pain level quantitatively (Gurumoorthy Kaarthikeyan et al., 2012).

The VAS scale comprised of a 10 scale with 0 indicated as "no pain" on the left and 10 representing "worst pain" on the right. Patients were instructed to make a vertical mark between these two end points on the pain separately on the first day (after 3 hours), 3th day, 7th day. The first day participants were asked by phone call and were asked to rate their pain.

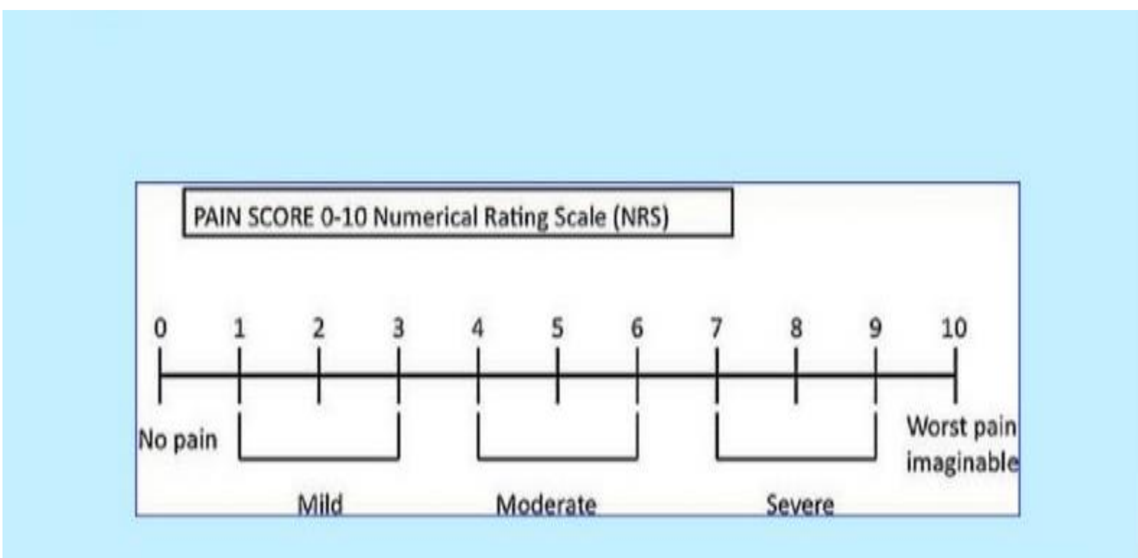

Figure (3.1): visual analog scale(VAS)

VAS:

0: No pain

1-3: Mild pain

3-6: Moderate pain

6-10: Severe pain

Satisfaction is one of the outcome measures used at the present project. Satisfaction of the subjects about the procedure was assessed using Likert-Type Scale (Vagias, 2006).

Level of Satisfaction

A. Not at all satisfied.
B. Slight satisfied.
C. Moderate satisfied.
D. Very satisfied.
E. Extremely satisfied

Also, patient satisfaction and post-operative swelling after 3days were taken for both groups (appendix I questionnaire).

3.4 Statistical Analysis

A statistical analysis was performed using a Statistical Package for Social Sciences (SPSS) software version 26. One way ANOVA test was used to compare between VAS and patient's satisfaction for both groups to statistically highlight the significant of results obtained. Value of 0.05 or less was taken at significant level (P value≤0.05). The presentation of the data is in the form of tables, graphs. Consultation with statistical analyzer was done.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

FCL is aimed at exposure of sufficient crown structure accomplished by a gingivectomy, an apically positioned flap with/or without osseous resection or by the use of lasers. Our present project is aimed to assess the clinical effectiveness of a diode laser for functional crown lengthening procedure and to compare it with the conventional procedure using the scalpel
The grossly decayed teeth often pose problems to the restorative dentists during their treatment due to unavailability of sufficient clinical crowns. Hence a crown lengthening procedure prior to restorative treatment (FCL) is mandatory during management of such teeth. Clinical crown lengthening refers to procedures designed to increase the extent of supragingival tooth structure for restorative or esthetic(Saurabh et al.).
CL involves the surgical removal of periodontal tissues to gain supracrestal tooth length, allowing longer clinical crowns and reestablishment of the biologic width (Gokulanathan et al., 2014). Crown lengthening can be done by scalpel, electrosurgery and laser. However, the use of lasers provides many advantages compared to other methods.

Lasers have increasingly been used in modern dentistry for more than 30 years. A wide range of lasers such as CO2, Nd: YAG, and Er: YAG are used in the field of periodontology for soft and hard tissue ablation and various surgical approaches. Laser soft-tissue surgery has been shown to be well accepted (Khashu et al., 2014).In the present project, diode laser was used, because it is more affordable and small in size with good control.
The fine tip of a diode laser offers good control during soft tissue sculpting procedures and can be easily manipulated to precisely create the gingival margin contours required. Placement of the tip directly in contact with the surgical site, however, enhances tactile feedback while providing the operator with a sense of familiarity relative to other dental cutting or drilling procedures(Lee, 2017).

4.2 Results

A case control study was conducted at Khartoum Dental teaching hospital and Omdurman Military dental teaching hospital and Elmmudathir dental clinic, to assess the effectiveness of Diode Laser for (FCL) procedure.

The study involved 12 teeth (2 teeth drop), and were sub divided into two equal groups; control group (conventional scalpel surgery) and case group as (laser surgery). 5 of the participants were females and 7 were males (table 4.1) (figure 4.1), with mean age 35.08 years old for both groups.

Table(4.1): Shows the Gender distribution among both groups:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	7	58.3	58.3	58.3
	Female	5	41.7	41.7	100.0
	Total	12	100.0	100.0	

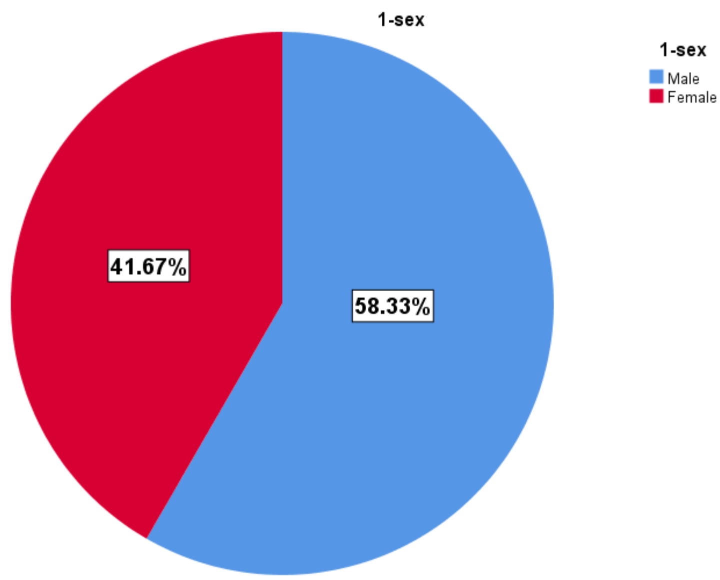

figure (4.1): Gender distribution

Clinical Parameters before surgery:

Before performing both CL procedures (scalpel or laser), clinical parameters (WKT, SD/PD, BW) were measured for all participants to exclude other techniques for CL, example apically positioning flap and bone removal (osteoctomy and/or osteoplasty) (table (4.2) and table (4.3))

Table (4.2): Clinical Parameters before surgery for control group:

Control Group	Tooth Number	Width of keratinized tissue(WKT) (mean)	Sulcular/Pocket depth(SD/PD) (mean)	Bone sounding(BS) (mean)	Biological width (BW) (mean)
	22	7	3	5	2
	22	7	3	5	2
	23	7	3	5	2
	11	8	4	6	2
	35	7	3	5	2
	45	7	3	5	2

Table (4.3): Clinical Parameters before surgery for case group:

Case Group	Tooth Number	Width of keratinized tissue(WKT) (mean)	Sulcular/Pocket depth(SD/PD) (mean)	Bone sounding(BS) (mean)	Biological width (BW) (mean)
	25	6	3	5	2
	26	6	3	5	2
	35	7	3	5	2
	38	7	4	7	3
	45	7	3	5	2
	48	7	4	7	3

Analysis showed that pain perception at the same day of surgery (after 3 hours), in control group (scalpel): 2 participants had severe pain, 3 had moderate pain and one had mild pain. In case group (laser): 4 patients had no pain and 2 had moderate pain. Intergroup comparison between both groups showed significant difference result (P value=0.017) (table (4.4) and (4.5) and (figure (4.2)). After 3 days and 7days, VAS in both groups showed that there was no pain forming 0 score in both groups. Two cases of laser group used analgesic while 5 cases in scalpel group used analgesics -two of them used analgesics for 2 days.

Table (4.4): Pain perception using VAS:

Groups	Same day				Total
	0: No pain	1-3: Mild pain	3-6: Moderate pain	6- 10: Severe pain	
Control group(scalpel)	0	1	3	2	6
Case group(laser)	4	0	2	0	6
Total	4	1	5	2	12

If P value ≤ 0.05 (significant)

P value=.017 (Correlation is significant)

Table (4.5): shows the comparison of same day reading between two groups:

Variable	**Control group**		**Case group**		**P value**
	Mean	**±SD**	**Mean**	**±SD**	
Reading same day	3.17	0.753	1.67	1.033	0.017

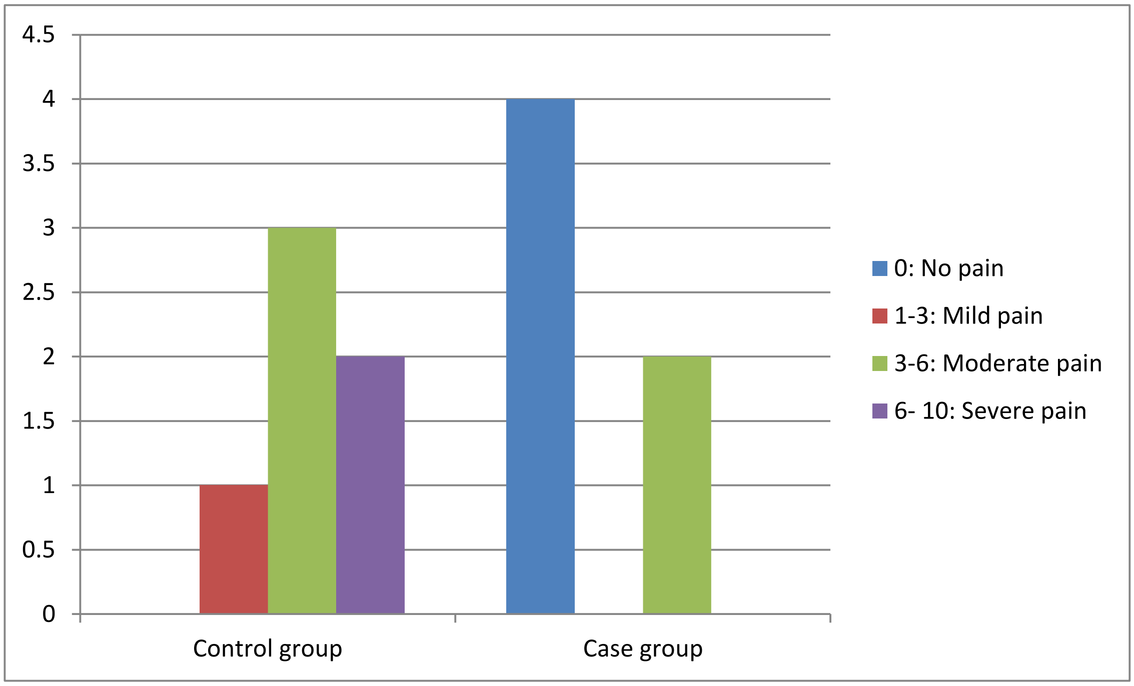

Figure (4.2): VAS (same day)

Regarding patient's satisfaction, in control group only 1 participant was extremely satisfied, 1 very satisfied ,1 moderately satisfied and not all satisfied. In case group 4 participants were extremely satisfied and 2 were very satisfied. No participant in case group was not satisfied at all with laser technique for crown lengthening. And there was significant difference between both groups (table (4.6) and table (4.7)) (figure (4.3)).

Table (4.6): Patient's Satisfaction :

Groups	5-Patient Satisfaction				Total
	Extremely satisfied	Very satisfied	Moderate satisfied	Not at all satisfied	
Control group	1	1	2	2	6
Case group	4	2	0	0	6
Total	5	3	2	2	12

If P value ≤ 0.05 (significant

P value=0.024 (Correlation is significant).

Table (4.7): shows the comparison of patient satisfaction between two groups:

Variable	Control group		Case group		P value
	Mean	±SD	Mean	±SD	
Patient satisfaction	3.17	1.602	1.33	.516	.024

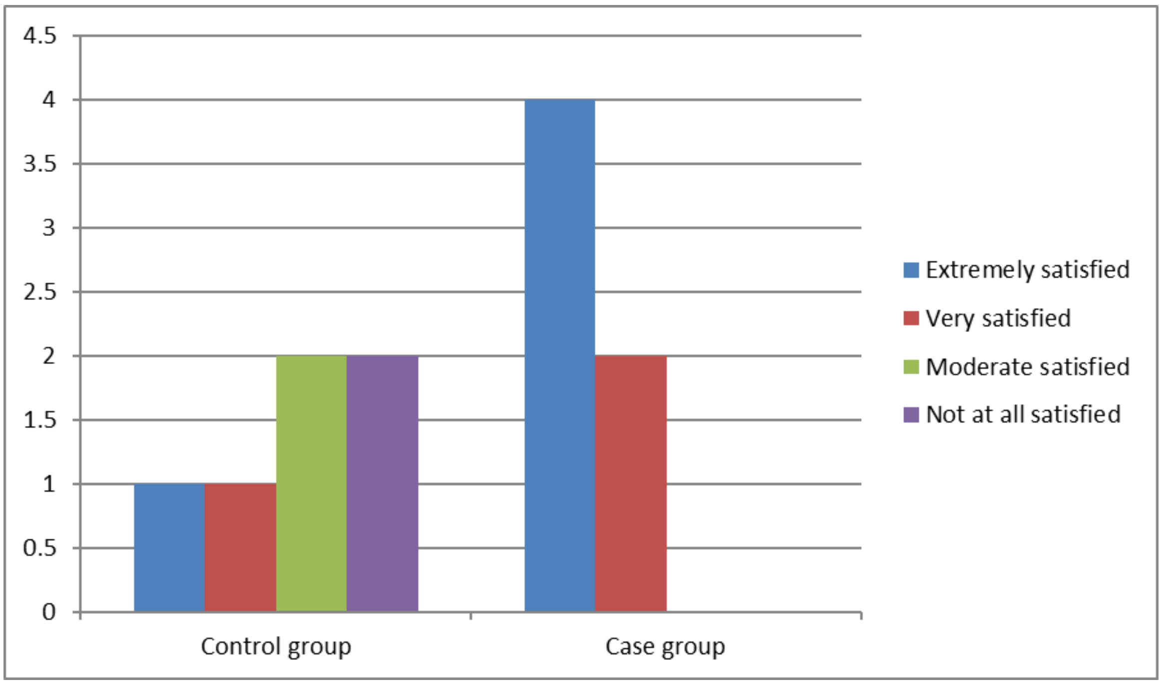

Figure (4.3): Patients satisfaction.

For the last parameter-patients post operative edema (swelling), both groups recorded 0 score. So, all participants had no swelling post operatively in conventional scalpel surgery and laser surgery (figure (4.4)

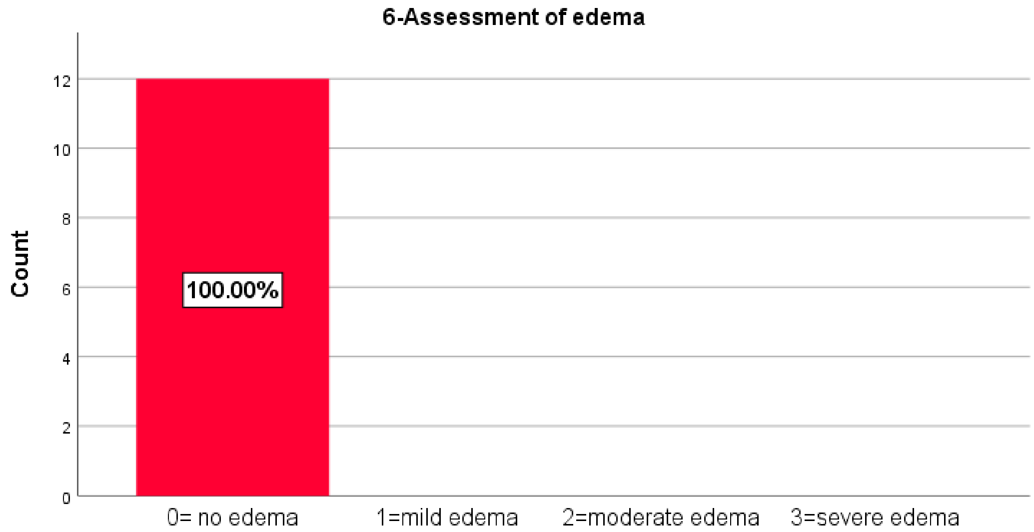

Figure (4.4): post operative swelling.

4.3 DISCUSSION

Few data were found talking about CL especially for gingivectomy cases and laser. Most of data was case reports or case study. Many clinicians advocate avoiding CLPs in favor of implant therapy, the long-term survival of CLP badly distorted teeth has been found to be quite acceptable at 78.4% at 10 years of service. The cumulative success rate of such teeth is found to be 68% for teeth/patients followed for ≥15 years. Furthermore, the reasons for the extraction within this period were nearly unrelated to periodontal weakening (only 11% failures because of periodontal breakdown)(Lee, 2004). Moghaddam et al, also found that a long-term survival rate of multidisciplinary-treated teeth (endodontic, periodontal, and prosthodontic treatment) was 83%–98%, for 245 teeth followed for at least 3 years to more than 10 years (3–5 years 98%, 5–10 years 96%, and ≥10 years 83%). Thus, CLPs can be regarded as valuable and successful treatment modality (Baghele, 2021).

The present project is to evaluate patient perceptions of pain and satisfaction and assess the effectiveness of a diode laser compared with the conventional technique for (FCL).

Functional crown lengthening procedure involves either a gingivectomy or an open flap surgical technique with/or without resective osseous surgery to preserve the normal biologic width of the tooth for restoration and crown placement purposes. Choice between gingivectomy and an open flap surgical technique depends upon several factors, one of which is the width of attached gingiva (Farista et al., 2016) .The current project included only those patients who had a sufficient width of attached gingiva(>3mm) and bone sounding(>3mm) from proposed restorative margin , requiring only gingivectomy procedure either with the laser or the scalpel. Also, if the sulcular depth is>2mm, gingivectomy can be performed especially at the facial surface

Comparing both the laser and the scalpel techniques, indeed both the techniques resulted in sufficient removal of the gingival tissue with adequate exposure of the tooth structure. During laser procedure local or topical anesthesia was not used, but in scalpel surgery profound anesthesia around surgical field must be encountered. This may be infavour for some patients who are afraid from injections and don not like or prefer numbness or heaviness sensation. Patients in the laser group had no or minimal bleeding (due to the coagulation effect of laser) which permitted better visualization of the operative area and better assessment of the necessary tooth structure to be exposed whereas the scalpel wound resulted in unpleasant bleeding with poor visualization of the operative area. this result was in accordance with Lagdive et al.(Lagdive et al., 2010).

A VAS scale was used to assess the patient perceptions for pain of both groups. Patients in the laser group exhibited a reduction in the VAS scores on the first day (3 hours post operatively) compared to the scalpel group, primarily because lasers deposit a protein coagulum sealing the sensory nerves leading to a reduction in inflammation (Hoopingarner, 2008) . Farista et al get same result, in the third and seventh day(Farista et al., 2016). But at the present project at the third day and seventh day there was no pain in both groups. so, the obtained result regarding laser and scalpel in pain perception difference can be noticed only at the first day. Lagdive et al found no swelling or pain or bleeding postoperatively in the their case report on three patients using diode laser for FCL .But they wait up to two weeks to have excellent healing because of delay of laser healing (Lagdive et al., 2010). Gokulanathan et al, in a case report found also that the gingival healing was uneventful with no infection, pain, swelling or scarring (Gokulanathan et al., 2014). Arora et al had also same result(Arora et al., 2015).

Moritiz et al showed that diode laser has bactericidal effect, by crating locally sterile environment (Lagdive et al., 2010).

Various lasers with specific wavelengths were used for soft tissue and hard tissue crown lengthening procedures. There, it was preferred to use diode laser considering them to be compact and cost effective and owing to the fact that these lasers have a better penetration depth with better absorption for melanin and hemoglobin with relatively better hemostasis compared to other lasers. As Diode laser is not interacting with dental hard tissues. so it can be used safely in proximity to root surface. So, diode laser this laser is an excellent soft tissue laser.

The Diode laser exhibits thermal effect through its" hot tip" caused by accumulation of heat at the end of the fiber, forming relatively thick layer of coagulation layer at the treated side- like electrosurgery technique. When the tissue is initially heated by laser beam, it is subjected to warming (37°C to 60°C), protein denaturation, coagulation (> 60°C), welding (70°C to 900°C), vaporization (100°C to 150°C), vaporization and carbonization (>200°C)(Gokulanathan et al., 2014).

Tissue penetration of diode is less than Nd: YAG laser, while heat generation is higher. But the advantages of laser are that it is small in size as well as its the lower financial cost(Lagdive et al., 2010) .

Other advantages of the laser over scalpel include a reduced edema, due to the sealing of lymphatic vessels and less wound contraction as well as scarring(Vescovi et al., 2010).This resulted in no swelling in all laser group participants.

In a study conducted by Bragger showed periodontal tissue response after crown lengthening. They showed that six weeks postoperatively, probing depth and attachment level did not change (Arora et al., 2015). The waiting period after crown-lengthening procedure to fabricate fixed restoration should be at least six months (Chaubey et al.).

4.4 Conclusions

There are different alternative modalities that can be used for the purpose of FCL. The decisive factor is what works best for each individual patient. Laser has indeed shown some advantages compared to scalpel such as: better hemostasis, less inflammation and a sterile wound cut in soft tissue restorative CL. Though there are certain disadvantages such as tissue necrosis and lateral heat damage.

Within the limitations of this present project, it can be concluded that, the application of diode laser appears to be a safe and effective alternative to scalpel for the treatment of functionally short clinical crowns.

4.5 Recommendations

More longitudinal studies with larger sample size and longer period of duration and follow up, are required to confirm the exact efficacy of diode laser over the conventional scalpel technique for FCL procedure, and to study different aspects of healing and tissue regrowth (rebound effect) of laser on gingival tissues and compare it with conventional (scalpel) method.

furthermore, comparison between different techniques for crown lengthening for both functional and ethetic purposes using laser is needed to assist in performing least invasive periodontal microsurgical procedures.

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APPENDIX

Appendix I

جامعة السودان للعلوم والتكنلوجيا

معهد الليزر

أنا الباحثة د/ دلال إدريس عبدالرحيم إختصاصي أمراض اللثه والأنسجه المحيطه بالأسنان أقوم بدراسه لنيل درجة الدبلوم فوق الجامعي في تطبيقات الليزر الطبيه, بعنوان " التقييم السريري لتطبيق الليزر مقابل الجراحة التقليدية في إطالة تاج السن الوظيفي "
يسعى البحث للمقارنه بين إستخدام الجراحه التقليديه باستعمال المشرط/ او السكين اللثوي, والليزر كأدوات لزيادة طول السن.وسيتم التقويم بين الطريقتين بإستخدام (مقياس التناظر البصري للألم).
لقد تم أختيارك لهذا البحث أنت ومعك عدد أخر من المشاركين.
ونتوقع بمشاركتك أنت وبقية المشاركين أن نتحصل على نتائج تمكن أختصاصي أمراض اللثه وأطباء الاسنلن بصفه عامه من معرفة الطريقه الانجع لزيادة طول السن (من غير إزالة عظم) والاقل الما واكثر راحة للمرضى.
خلال هذه الدراسة سأقوم بطرح عدد من الأسئلة عليك وسأقوم بتدوين إجابتك على الأستمارة المرفقة
وسأقوم أيضا بإجراء كشف سريري /إكلنيكي بإستعمال مسبار اللثة وتسجيل القراءات في جداول.
هذه المعلومات ستحفظ بطريقة سرية ولن يظهر أسمك في أي أستمارة ونود أن نشير كذلك أن المشاركة في البحث طوعية وأن رفضك للمشاركة في البحث لاتفقدك الحق في المتابعة والعلاج بالمستشفى ولن تؤثر على نوعية الرعاية الصحية المقدمة لك.
يجب التأكيد على أنه لن يتم منحك أي قيمة نقدية مقابل المشاركة في هذا البحث.
كما نؤكد لك إمكانية الأنسحاب من البحث في أي وقت تشاء ، ودون أبداء توضيح لأسباب الأنسحاب ويتم ذلك بالتوقيع على طلب الأنسحاب ولن يؤثر ذلك أيضا على حقك في المتابعة والعلاج بالمركز ولن تؤثر على نوعية العلاج المقدم لك.
أذا كان لديك أي سؤال أو أستسفار يخص البحث ، أو حقوقك كمشارك أثناء تنفيذ البحث يمكنك الإتصال على: د/ دلال إدريس عبدالرحيم في الرقم0922784073

جامعة السودان للعلوم والتكنلوجيا

معهد الليزر

Consent Form

موافقة على الإشتراك في بحث طبي

Consent Form to Participate in Research

أنا الموقع أدناه .... ، أوافق على مشاركتي في بحث طبي دراسي بعنوان " فعالية ليزر الثنائي كأداة في عملية زيادة طول السن." تقوم به د/ دلال إدريس عبدالرحيم .

البحث سوف يتضمن فحص سريري للثة والسن او الاسنان المراد تطويلها.

لقد تم شرح طبيعة البحث وأهدافه وتفهمت الموضوع كاملا وقد تم إعلامي بأن مشاركتي في هذا البحث خيارية وتطوعية وأنه لن يتخذ ضدي أي إجراء إذا قررت أن لا أشارك أو إذا شاركت في البحث ثم قررت أن أوقف مساهمتي.

توقيع المريض:

شكراً لحسن تعاونكم معنا

Sudan University of Science and Technology
College of Graduate Studies

Institute of Laser
The study Questionnaire

CONTROL GROUP ☐

CASE GROUP ☐

Personal Data:
Code No ( )
(A)Personal items:

1- Sex: ☐

1- male 2- female

2-Age …………………

3-Residence ☐

1- Khartoum state

2- outside Khartoum state

4- Phone No……………………

Clinical Parameters before surgery:

Tooth Number	*Width of keratinized tissue(WKT)	**Sulcular/Pocket depth(SD/PD)	***Bone sounding(BS)	****Biological width (BW)

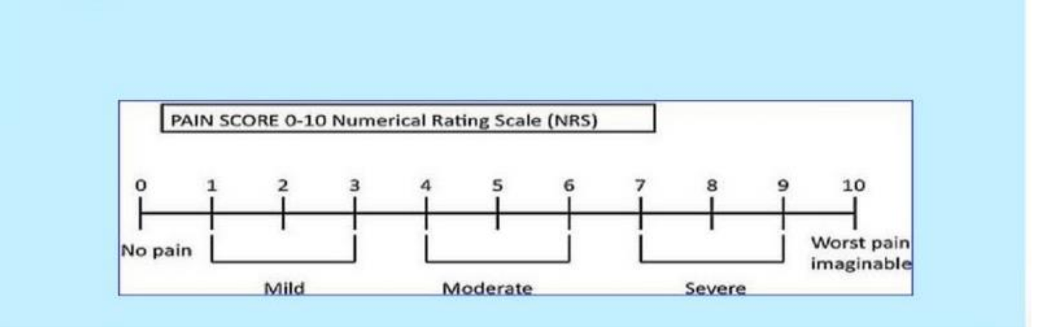
*WKT=Distance from marginal gingiva to mucogingival junction.

**SD= Distance from gingival margin to the bottom of the sulcus

***BS=Distance from gingival margin to crestal bone

****BW=Junctional epithelium and connective tissue attachment= BS-SD/PD

Clinical assessment after surgery/ laser:



Visual Analog Scale(VAS)

Pain perception: using Visual Analogue Scale

0: No pain

1-3: Mild pain

3-6: Moderate pain

6- 10: Severe pain

Patient Satisfaction:

A. Extremely satisfied

B. Very satisfied

C. Moderate satisfied

D. Slight satisfied

E. Not at all satisfied

Assessment of edema:

After 3 days Postoperative Edema Scale:

0= no edema

1=mild edema

2=moderate edema

3=severe edema

Appendix II

Quicklase Laser device

Measurement of WKT

Gingival biotype and Measurement of SD

Bone sounding

Participant of case group (laser group) before procedure

Participant of laser just after laser application

laser group participant after 3 days

laser group participant after 7 days

Scalpel group participant
before surgery

Scalpel group participant
before procedure

Scalpel group participant just
after surgery