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Expedited Removal of Pyogenic Granuloma Using 980nm Diode Laser

A Thesis
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بسم الله الرحمن الرحيم

وأن ليس للإنسان إلا ما سعى

وأن سعيه سوف يرى

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Dedication

- *To the pure soul of my father, who guided me to live for the sake of truth and knowledge to keep alive even if my soul leaves the body.*
- *To my great mother, who taught me to be like a good tree whose root is firm and its branches are in the sky.*
- *To my brothers (Dr. Harith, Dr. Mohammed) & my husband (Dr. Abdelaziz), for their support, guidance, and for always being in my life and study in every respect. I could not have done it without them.*
- *To my lovely girls (Dana & Dema), the sweetest thing in existence.*

I dedicate the fruit of this research faithfully…

Aya

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First and foremost, I thank Allah for his grace & generosity in accomplishing this work & I ask Allah to make it a continuous charity for me and my parents.

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Abstract

Background: The laser has become very effective surgical tool in oral and maxillofacial surgery field. It offers many benefits for soft tissue lesion management including oral pyogenic granuloma not to be seen with conventional surgery.

Objective: Evaluation the therapeutic advantages of diode laser (810-980 nm) in an intraoral pyogenic granuloma treatment compared with conventional surgical technique.

Materials and methods: Forty-two patients with age range between 10 to 65 years. The mean age of studied sample was 27.93±14.44 year, the patients were randomly divided into two groups: experimental group that treated with diode laser (810-980 nm) and control group that treated with conventional scalpel surgery. Laser parameters setting were initiated with a diode laser, a wavelength of 810- 980nm applied 0.8W Power, Continuous Wave mode (CW) and tip diameter was 300 µm with tips length of 4 mm.

Results: nineteen male and twenty-three female had been enrolled in this study. In the current study, the postoperative pain, bleeding & swelling scores showed great disparity according to statistical study, between the groups of study. A great disparity according to statistical study was found between the groups of study in regards to postoperative function &patients satisfaction scores. The function & patients satisfaction scores were higher significantly in laser technique as compared to scalpel technique. P-value less than 0.05.

Conclusion: The application of diode laser (810-980 nm) can be considered an effective and successful therapy option with a many clinical benefit compared with conventional surgery for the excision of pyogenic granuloma as well as the management of soft tissue lesions.

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List of Abbreviations

A	Absorption coefficient
ANSI	American National Standard Institute
C°	Degree celsius (unit of temperature)
cm	Centimeter
CN V	Fifth cranial nerve
Co2	Carbon dioxide
CW	Continuous-wave
DC	Duly cycle
DNA	Deoxyribonucleic acid
E	Energy
Er: YAG	Erbium-doped Yttrium Aluminum Garnet
FDA	Food and Drug Administration
Fig	Figure
fs	Femtosecond
GaAlAs	Gallium Aluminum Arsenide
H2O2	hydrogen peroxide
He-Ne	Helium-Neon
JE	junctional epithelium
K.E.	kinetic energy
M	Meter
Ml	milli litter
Mm	Milli meter
µm	Micrometer
MPE	maximum permissible exposure
Mw	Milliwatt
Nd: YAG	Neodymium-doped Yttrium Aluminum Garnet
Nm	Nanometer
Ns	Nanosecond
PDT	photodynamic therapy
PG	pyogenic granuloma
POD	postoperative day
POW	Post-operative week
Ps	Picosecond
PSS	patient satisfaction score
RNA	ribonucleic acid
ROS	reactive oxygen species
TEM	transverse electromagnetic mode
UV	Ultraviolet
W	watt (unit of power)
1O2	singlet oxygen

Chapter One

Introduction & Basic Concepts

1.Introduction

1.1 Definition & Background

Pyogenic granuloma (PG) is a non-neoplastic inflammatory hyperplasia that develops in response to a variety of triggers, including prolonged local irritation, constant low-grade trauma, bad oral hygiene, certain kinds of drugs, hormonal alterations, pregnancy, vascular malformation, chronic inflammation, bone marrow transplant, and graft reactions. Pyogenic granuloma is a benign vascular proliferation of the skin and mucous membranes that occurs in children and young adults (**Isaacs, 1997; Mueller & Mulliken, 1999; Patrice et al., 1991; Mooney & Janniger, 1995; Requena & Sangueza, 1997; Lin & Janniger, 2004)**.

PG is a common tumor-like growth of the oral cavity. Pyogenic granuloma most commonly affects the marginal gingiva, but it can also affect the palate, buccal mucosa, tongue, and lips. **(Rai et al., 2011; Hammes et al., 2012)**. The gingiva is the most common intra oral site. Pyogenic granuloma occurs mostly on the mucosa of females with high levels of steroid hormones. It is generally believed that female sex hormones play important roles in its pathogenesis **(Yuan et al., 2002)**.

Pyogenic granuloma is a pedunculated hemorrhagic lesion that most commonly appears on the gingiva and has a high proclivity for recurrence following simple resection. **(Glick & Michael, 2015)**.

Clinically, pyogenic granuloma manifests as a smooth or lobulated exophytic lesion that show as small, red erythematous papule on a sessile or pedunculated base, which is usually hemorrhagic and compressible **(Jafarzadeh et al., 2006; Matarese et al., 2013)**.

Clinically, an oral PG exhibit as a tumor-like, exophytic mass, painless. It usually develops rapidly with red papules that tend to bleed easily because of its high vascularity, and sizes ranging from a few mm to a few cm have been reported **(Rai et al., 2011; Neville et al., 2015; Al-Mohaya & Al-Malik, 2016)**.

The size of a pyogenic granuloma is usually between 0.5 and 1 cm, however it can occasionally reach 2.5 cm **(Asnaashari et al., 2014**). Fragile and ulcerated surface surrounded by a fibrous membrane, and the color varies depends upon the age of the lesion from pink to purple. Because young PGs are mostly made up of hyperplastic granulation tissue with prominent capillaries, they are very vascular. Older lesions, on the other hand, are more collagenized **(Neville et al., 2015)**.

Chronic irritation may be difficult to be considered as a cause of these lesions, but the fact that they are usually found near the gingival margin appears to suggest that calculus, food materials, and overhanging margins of dental restorations are important irritants that should be removed when the lesion is resected. Their histologic structure aligns with their friable, hemorrhagic, and usually ulcerated appearance **(Glick & Michael, 2015)**.

PG made up mostly of growing endothelial tissue that has been canalized into dense circulatory network with little collagenous support. Neutrophils, and other cells of chronic inflammation, are found throughout the edematous stroma, resulting in the production of micro-abscesses. Differentiation from a hemangioma is critical histologically. A profuse pus discharge is not evident, despite the conventional term for the lesion; when one does arise, it's most probably a sinus tract caused by a periapical or periodontal abscess, the aperture of which is sometimes characterized by a nodule of granulation tissue (parulis) **(Glick & Michael, 2015)**.

Pregnancy epulis or pregnancy tumor is identical lesion with the same histologic structure that develop in combination with the gingivitis and periodontitis that might complicate pregnancy. Pregnancy epulides are most common near the end of pregnancy (when circulating estrogen levels are maximum), and they appear to diminish following delivary. This shows that hormones have a role in the genesis of the lesion, as angiogenic factor expression increases and granulation tissue apoptosis decreases **(Glick & Michael, 2015)**. These lesions do not arise in mouths that are kept free of even minor gingival irritation, identical to pregnancy gingivitis, and local irritation is certainly a significant causative component. Both pyogenic granulomas and pregnant epulides can grow into fibrous epulides by becoming less vascular and more collagenous. Small and isolated pregnancy tumors in a mouth with otherwise good gingival health may be left alone until after delivery, but the size of the lesion or the presence of widespread pregnancy gingivitis or periodontitis confirms the necessity for treatment during pregnancy **(Glick & Michael, 2015)**.

Hullihen published the first description of pyogenic granuloma in English literature in 1844. Poncet and Dor, two French surgeons, recognized and called this lesion botromycosishominis in 1897. Other names for it include granuloma pediculatum benignum, benign vascular tumor, pregnancy tumor, vascular epulis, Crocker's disease, and Hartzell's illness. Crocker gave it its current name in 1903. Pyogenic granuloma has been retained in the literature since coined by Hartzell in 1904 because of its historic significance. However, some researchers believe that the term “Pyogenic granuloma” or “granuloma pyogenicum” was introduced by Hartzell in 1904 that is widely used in the literature, although, it does not express accurately the clinical or histopathologic features **(Hartzell, 1904)**.

Angelopoulos AP coined the name "hemangiomatous granuloma" which appropriately describes the histopathologic appearance (hemangioma-like) and inflammatory nature (granuloma) of oral pyogenic granuloma. Because the blood vessels in oral pyogenic granuloma are so abundant, Cawson et al proposed the term granuloma telangiectacticum as an alternative nomenclature **(Cawson et al., 1998)**.

Pyogenic granulomas were discovered in 44.4 percent to 83 percent of oral cavity gum. It has also been described to occur in the lingual, buccal, and palatal mucosa in the literature **(Eversole, 2011**; **Neville et al., 2015)**. It can be found in a variety of places outside of the mouth, including the lips, nose, fingers, and toes. Patients of any age can develop PG; however, it is most frequent in those between both the ages of 10 and 40. It is more common in young adult females in their second decade of life. The vascular impacts of female sex hormones could be one cause for this **(Esmeili et al., 2005; Asnaashari et al., 2014; Adusumilli et al., 2014)**.

The peripheral ossifying or cementifying fibroma only appears on the gingiva; it does not appear anywhere else in the oral mucosa. It ranges in color from pale pink to cherry red in appearance and is usually seen in the interdental papilla region. The presence of calcifications in a hypercellular fibroblastic stroma on histology gives this reacting proliferation its name. Peripheral ossifying or cementifying fibromas are more prevalent in females and emerge in adolescence and young adults. The presence of these lesions suggests that a periodontal consultation is required, and treatment should involve the removal of subgingival irritants and gingival pockets throughout the mouth, and resection of gingival growth **(Glick & Michael, 2015)**.

Pyogenic granuloma may occur in all ages. The peak age of incidence is usually the second decade of life, although a preference for children has been reported by some investigators. It is also more common in young adult females, possibly because of vascular effects of female hormones **(Jafarzadeh et al., 2006)**.

The color of the lesion depends on the vascularity of the growth, so it can be red, purple or pink **(Fekrazad et al., 2014)**. Younger PGs exhibit increased vascularity and hyperplastic granulation tissue, whereas older PGs have a greater collagen content (**Jafarzadeh et al., 2006)**. It is currently believed that this lesion represents a benign neoplasm, a form of capillary hemangioma, rather than a reactive infectious or traumatic process.

The differential diagnosis of PG includes peripheral giant cell granuloma, peripheral ossifying fibroma, hemangioma and inflammatory gingival hyperplasia. Final diagnosis is mainly based on biopsy and histopathological examination**. (Jafarzadeh et al., 2006 & Neville et al., 2015)**.

Traditional granulation tissue, hemangioma, peripheral giant cell granuloma, hyperplastic gingival inflammation, bacillary angiomatosis, peripheral odontogenic fibroma, peripheral ossifying fibroma, Kaposi's sarcoma, angiosarcoma, and metastatic cancers are all differentiated by differential diagnosis. Histopathology can be used to make a precise diagnosis of PG. The severity of the symptoms determines the treatment for PG. Clinical monitoring and follow-up are recommended when the lesion is tiny, painless, and not bleeding. The most basic treatment is surgical removal of the lesion. Irritating elements like plaque, calculus, poor restorations, foreign substances, and trauma causes should be eliminated during the excision. Electrodessication, cryosurgery, sclerotherapy, intralesional steroids, sodium tetradecyl sulfate, monoethanolamide oleate ligation, cauterization, (Nd: YAG) laser, CO2 laser, Er: YAG laser, and diode laser are some of the additional treatment options **(Matsumoto et al., 2001; Ichimiya et al., 2004; Parisi et al., 2006; Gupta, 2007; Lindenmüller et al., 2010; Alomar., 2011; Kocaman et al., 2014; Fekrazad & Chiniforush, 2014)**.

For the patient to obtain the most accurate and suitable treatment, the correct differential diagnosis is required to prevent unnecessary extra examinations and invasive procedures. The terminal diagnosis is primarily depended on examination of biopsy and histopathology **(Neville et al., 2015)**.

1.2 Embryology

The oral mucous membrane includes most of the gingiva, develop from ectoderm and mesoderm during embryonic development, is composed of a surface epithelium and a deeper connective tissue layer which is the lamina propria or corium. The epithelial layer is of either ectodcrmal or endodermal origin, depending on its relation to the oral membrane in embryonic life. The lamina propria is of mesodermal origin. **(Ross et al., 1990)**.

1.2.1 Oral mucosal development

The ectoderm derived structures such as (lips, cheeks, palate, gums, and oral cavity floor) and endoderm derived structures like (tongue) are the primary sources of the oral mucosal epithelium. In the beginning of pregnancy, during first two weeks, a layer of epithelial cells lines the mouth cavity. Between weeks 5 and 6, two cell layers form, and by 10^{th} week, a multilayered epithelium is developed. Surface elements of the mucosa of the mouth, for example tongue papilla on anterior 2/3 and the palatal rugae, start to emerge during this time. The epithelium of mouth has differentiated into stratified keratinized epithelium of palate and gingiva, and epithelium (stratified nonkeratinized type), which lines the lips, cheeks, soft palate, and mouth floor, by around week 23 in utero (**Winning & Townsend, 2000)**.

1.2.2 Dento-gingival junction development

The dento-gingival junction is remarkable in that it includes teeth moving through to the epithelium of gingiva and connective tissue without producing epithelial damage or breach. The junctional epithelium, sulcular epithelium, and underlying connective tissue are all involved in the creation of this complex. When a tooth comes into contact with the oral cavity's epithelial lining, the connective tissue among the mucosa of the mouth and tooth breaks down, and the oral epithelium's basal layer begins to proliferate. Following that, the fusion between the reduced enamel epithelium and oral epithelium with the central part of the epithelial surface breaking down. When the tooth's tip descends into the oral mucosa, this development ensures epithelial continuity **(Winning & Townsend, 2000)**.

1.3 Histology &histopathology

In the underlying connective tissue, a stratified squamous epithelium forming rete ridges, according to histopathology. Many endothelium-lined channels, both small and large, are plumped up with blood components can be seen in connective tissue. There was also a moderate infiltration of mixed inflammatory cells. These lesions were identified as PG in the histopathology report **(Rashmi et al., 2011)**.

1.4 Anatomy of gingiva

The gingiva is the keratinized mucosa with pink color that surrounds and support the teeth. It is supplied with blood via a network of tiny arteries that branch off the carotid artery. Nerves generated from trigeminal nerve by its mandibular and maxillary divisions innervate it. **(Clark & Clark, 2018)**.

The periodontium, which encompasses the teeth's investing and supporting structures, includes the gingiva. Furthermore, oral indications of systemic diseases are common, and poor oral gingival health can exacerbate several systemic disorders. **(Clark & Clark, 2018)**.

1.5 Structure and Function

The periodontium is in charge of keeping teeth healthy and supporting them. The gums, periodontal ligament, alveolar bone, and cementum are the four elements. The gingiva (gum), is a specialized epithelial tissue surrounds the teeth via specialized cells known as the junctional epithelium. The gingival sulcus contains this junctional epithelium, which is advantageously positioned at the base of the sulcus where that acts as a physical and microbial barrier. The gum is responsible for sensating in the mouth and micronutrient absorption, in addition to its defensive function. Finally, the gingival epithelium is important in the periodontal tissue's innate immune response to viral inflammation. As a result, it plays a vital role in the onset of periodontal disease **(Fujita et al., 2018)**.

The gingival connective tissue is made up of collagen fibers, cells, and ground substance. Gingival connective tissue is made up of five percent cells, sixty percent collagen fibers, and thirty-five percent ground substance, respectively. Fibroblasts, mast cells, macrophages, and inflammatory cells are among the cell types found in gingival connective tissue. Fibroblasts are the most common cell type in connective tissue and are accountable for the synthesis of fibers of collagen and ground matrix **(Chavrier, 1990)**.

Collagen is an important component of the gingival connective tissue's structural stability. Tropocollagen is comprised of three polypeptide chains that form a triple helix, is the most basic unit of collagen. Translation, hydroxylation, glycosylation, and peptide cleavage are all processes in the formation of collagen. Once tropocollagen is created, crosslinks among each staggered tropocollagen molecule cause the molecules to assemble into fibrils. Collagen's tensile strength is derived from fibrils coalescing into fibers. Type I collagen is the main type in the gums, and it can be present in all layers of the gingivalconnective tissue. Type III collagen is found mostly beneath the epithelium of gingiva, while type IV collagen is found in the gingival basement membrane and gingival mucosal blood vessel.

Proteoglycans and glycoproteins make up the ground substance present in of gingival connective tissue. Proteoglycans are large molecules that govern fluid movement and diffusion in the tissue matrix. Polysaccharides are covalently linked to proteins to form them. Glycoproteins are essential for maintaining connective tissue's structural integrity. In gingival connective tissue, fibronectin is a glycoprotein that directs fibroblasts to collagen and gives sufficient points of attachment for adhesion of cells to the matrix of connective tissue **(Chavrier, 1990)**.

1.6 Oral Mucosa

The oral mucosa has a lot of structural variety in different parts of the mouth. The three zones of the oral mucosa are as follows, according to their primary function:

1. The masticatory mucosa covers of the gum and the hard palate.
2. The tongue's dorsum is coated by specialized mucosa.
3. The mucous membrane that lines the rest of the mouth cavity **(Carranza, 2019)**.

   Lining mucosa makes up the majority of the mucosa, accounting for around sixty percent of the total area, with the masticatory and specialized mucosa comprising minor portions. (25%, 15% respectively) as shown in Fig (1-1) **(Nanci, 2003)**.

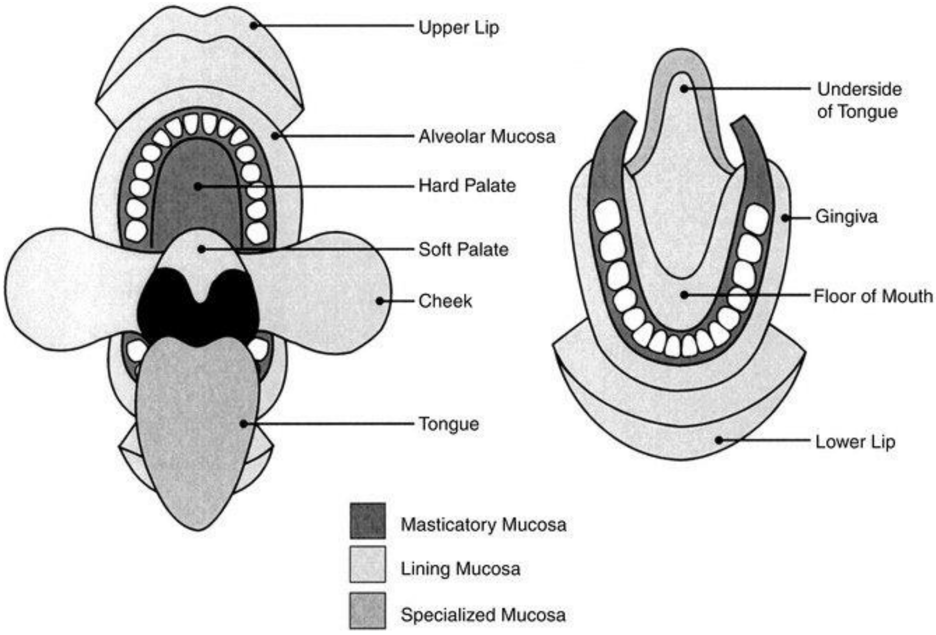


Figure (1-1) Oral mucous organization **(Nanci,2003)**.

1.6.1 Functions of the Oral Mucosa

The oral mucosa provides a different of purposes. The primary function is to protect the mouth cavity's deeper tissues, as well as to serve as a sensory organ and a place for glandular activity and secretion **(Squier & Finkelstein ,2003)**.

- **Sensation**

  This function is significant since it gives a lot of information about what's going on inside the mouth, whereas the lips and tongue sense stimuli from outside the mouth. Temperature, touch, and pain are all sensed by receptors in the mouth; the tongue also has taste buds that aren't found anyplace else in the body. Water-tasting receptors in the oral mucosa are thought to respond to thirst and convey contentment. Oral mucosa receptors also reflex triggering such as swallowing, gagging, retching, and salivation **(Nanci, 2003)**.

- **Protection**

The mucosa of the mouth isolates and support tissues and organs that rest deeply in the oral region from the oral cavity's surroundings as a surface lining. The soft tissues of the mouth are exposed to mechanical forces as well as surface abrasions when biting food and chewing it. To overcome these damages, oral mucosal epithelium and connective tissue have developed a number of adaptations. Furthermore, the oral cavity has a resident population of germs that may consider as cause of infection if they got access to the tissues. Several of these kinds also produce toxins that injure the body's tissues. The oral mucosa epithelium serves as the primary defense against these dangers **(Nanci, 2003)**.

- **Secretion**

Saliva, that is secreted via the salivary glands and assists to the preservation of a wet surface, is a major secretion linked with the oral mucosa. The primary salivary glands are located away from the mucosa, and their fluids flow through the mucosa via long ducts; nonetheless, the oral mucosa is home to a large number of tiny salivary glands. The presence of sebaceous glands in the oral mucosa is common, but their discharges are likely minor **(Nanci, 2003)**.

- **Thermal Regulation**

The human oral mucosa has almost no function in regulation of body temperature, and there are no clear blood vessel specializations for regulating heat transfer, such as arterio-venous shunts. In certain animals (for example the dog) large amount of heat of body is lost through the mucosa of the mouth. **(Nanci, 2003)**.

1.6.2 Oral Mucosa Structure

The oral mucous membrane, like the skin, is composed of a surface epithelium and a deeper connective tissue layer which is the lamina propria or corium. The epithelial layer is of either ectodcrmal or endodermal origin, depending on its relation to the oral membrane in embryonic life. The lamina propria is of mesodermal origin. The epithelium of the oral mucosa is lubricated and protected by the secretion of mucus. The mucus is produced either by small glands which lie immediately deep to the mucous membrane in the submucosa or by the large submandibular and sublingual glands which are placed some distance from the mucosa. Mucus is a combination of the glycoprotein, mucin, and water as shown in Fig (1-2) **(Ross et al., 1990)**.

Figure (1-2): Oral mucous membrane layers **(Bhaskar, 2003)**.

1.7 Gingiva

1.7.1 Clinical Features

In an adult, gum only surrounds the tooth root and alveolar bone to a coronal level to the cement-enamel junction. Anatomically, the gingival is separated into three areas: marginal, attached, and interdental. Regardless of how each kind of gingiva varies in differentiation, histology, and thickness based on its functional demands, all forms are supposed to protect from harms (microbial and mechanical) (**Ainamo & Talari, 1976**). In other word, the structure of several forms of gingiva, reflects the effectiveness in preventing germs and harmful chemicals from penetrating deeper into the tissue **(Carranza, 2019)**.

1.7.2 Marginal Gingiva

The terminal edge or border which surrounds the teeth in a collar-like pattern is known as marginal or unattached gingiva (**Ainamo & Loe, 1966**). A shallow linear depression named the free gingival groove separates it from the adjacent attached gingiva in about 50% of the cases (**Ainamo & Leo, 1966**). The gingival sulcus' soft-tissue wall is formed by the marginal gingiva, which is usually about 1 mm wide. A periodontal probe can be used to detach it from the tooth surface. The gingival zenith is the most apical point of the marginal gingival scallop. Its apico-coronal and mesiodistal measurements range from 0.06 to 0.96 mm as shown in Fig (1-3) **(Mattos & Santana, 2008; Carranza, 2019)**.

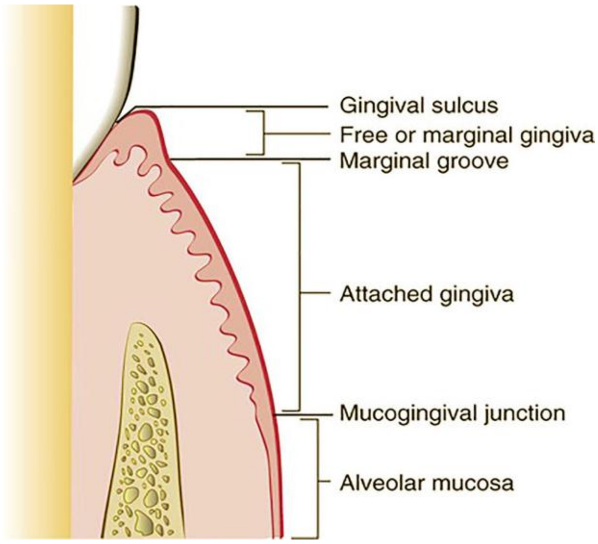


Figure (1-3) Diagram illustrates the landmarks of anatomy of the gingiva **(Carranza,2019)**.

1.7.3 Gingival Sulcus

The sulcus of gingiva is a shallow crevice around the tooth that is confined on one side by the tooth's surface and on the other side by the epithelium lining the free margin of the gingiva. It's V-shaped and just big enough for a periodontal probe to fit through. The depth of the gingival sulcus can be measured clinically and is an essential diagnostic parameter. The depth of the gingival sulcus is 0 millimeter or near to 0 millimeter in totally normal or optimum conditions (**Gottlieb & Orban, 1933)**. These rigorous normality circumstances could only be experiment worked in germ-free animals or after extensive and long-term plaque management **(Attstrom et al., 1975; Caffesse et al., 1980)**. A sulcus of certain depth can be detected in clinically normal healthy gums. The depth of this sulcus has been documented to be 1.8 millimeters in histological sections, with differences ranging from 0 to 6 millimeter. **(Orban & Kohler, 1924)**; other studies have reported 1.5 and 0.69 millimeter **(Gargiulo et al., 1961)**. The introduction of a metallic instrument and measurement of the distance it penetrates, are utilized in the clinical assessment to determine the depth of the sulcus (i.e., the probing depth). The sulcus histological depth does not seem to be completely identical to the penetration depth of probe. The probe's penetration depth determined by a number of factors, including diameter of probe, force of probe, and the extent of inflammation **(Garnick et al., 1989)**. As a result, the probing depth does not always match the histologic depth of the sulcus. In humans, a clinically normal gingival sulcus has a probing depth of two to three millimeters **(Carranza, 2019)**.

1.7.4 Attached Gingiva

The attached gingiva is continuous with the marginal gingiva. It's firm, resilient, and tightly attached to the alveolar bone periosteum. The mucogingival junction separates the facial aspect of attached gingiva from relatively loose and moveable alveolar mucosa. Another essential clinical parameter is the width of the attached gingiva. The distance between the muco-gingival junction and the projection on the external surface of the gingival sulcus or the periodontal pocket. It's not to be confused with the keratinized gingival width, which includes also the marginal gingiva. In different areas of the mouth, the diameter of the attached gingiva on the facial aspect varies (**Bowers, 1963)**. It's greatest in the incisor area (3.5 to 4.5 mm in the maxilla, 3.3 to 3.9 mm in the mandible) and narrowest in the posterior segments (1.9 mm in the maxillary first premolars and 1.8 mm in the mandibular first premolars) **(Ainamo & Loe, 1966)**. Since the mucogingival junction does not change during adult life, **(Ainamo, 1978)** modifications in the position of the attached gingiva's coronal part produce changes in its width. By the age of four years and supra-erupted teeth, the attached gingiva increases in width **(Ainamo & Ainamo, 1978)**. The attached gingival on the lingual aspect of the mandible ends at the lingual alveolar mucosal junction, which itself is continuous with the mucous membrane that lines the floor of the mouth. The palatal surface of the attached gingiva in the maxilla blends imperceptibly with the equally firm and strong palatal mucosa **(Carranza, 2019)**.

Figure (1-4): Normal gingiva in young adult.Mucogingival line between the attached gingiva and the darker alveolar mucosa **(carranza, 2019)**.

1.7.5 Interdental Gingiva

The interproximal region beneath the region of tooth contact, the gingival embrasure is occupied by the interdental gingiva. The gingiva of interdental region can be either pyramidal or "col" shaped. The papilla tip locates just under the point of contact in the former; later, a valley-like depression that connect facial and lingual papilla and that conforms to the shape of the interproximal point of contact **(Cohen, 1959)**. The existence or lack of a point of contact between adjacent teeth, as well as the distance between the point of contact and the osseous crest, determine the morphology of the gingiva in a specific interdental area **(Tarnow et al., 1992)**, and the presence or absence of some recession degree depicts the differences in normal interdental gingiva. The interproximal contact area is tapering on the facial and lingual sides, while the surfaces at the mesial and distal ends are somewhat concave. The adjacent teeth's marginal gingiva forms the lateral margins and tips of the interdental papillae. Attached gingiva makes up the space between the teeth as shown in Fig (1-5).

Figure (1-5): Interdental papillae with a central portion formed by the attached gingiva. The papillae shape varies depending on the gingival embrasure dimension **(Carranza, 2019).**

If there is a diastema, the gingiva is tightly bonded over the interdental bone, resulting in a smooth, rounded surface devoid of interdental papillae as shown in Fig (1-6) **(Carranza, 2019)**.

Figure (1-6): An absence of interdental papillae and col where the proximal tooth contact is missing **(Carranza, 2019)**.

1.7.6 Microscopic Features

The overlaying epithelium (stratified squamous type) and the underlying central core of connective tissue make up gingiva. The epithelium is mostly cellular, whereas the connective tissue is mainly formed of collagen fibers and ground material and is less cellular. **(Carranza, 2019)**.

1.7.7 Gingival Epithelium

General Aspects of Gingival Epithelium Biology

Previously, it was considered that the epithelium compartment served only as a physical barrier between infection and underlying gingival attachment. Epithelial cells, consider as apart of innate host defense by responding to bacteria in a cooperative manner **(Dale, 2002)**, this suggests that the epithelium actively participates in response to infection, signaling subsequent host responses, and integrating innate and acquired immune responses. Epithelial cells, for instance, may behave to bacteria by increasing multiplication, altering cell signaling events, changing differentiation and death of cells, and, finally, altering tissue homeostasis **(Dale, 2002**). Know the fundamental structure and function of the epithelial innate defense mechanisms, as well as the involvement of the epithelium in gingival health and disease, is crucial shown in the next table. **(Carranza, 2019)**.

Functions	**Constant Renewal**
Mechanical, Chemical, Water and	Replacement of damaged cells
Microbial barrier	**Cell-cell attachment**
Signaling functions	Desmosomes
Architectural integrity	Adherens junctions
Cell-cell attachment	Tight junctions
Basal lamina	Gap junctions
Keratin cytoskeleton	**Cell-Basal lamina**
Major cell type	Synthesis of basal lamina
Keratinocyte	components
Other cell types	Hemidesmosome
Langerhans cells	
Melanocytes	
Merkel cells	

Table (1-1): Functions and features of gingival epithelium **(Dale, 2002; Carranza, 2019)**.

A continuous lining of stratified squamous epithelium lines the gingival epithelium. The oral or outer epithelium, the sulcular epithelium and the junctional epithelium are the three areas that can be denied from a morphologic and functional standpoint. The keratinocyte is the most common cell type in the gingival epithelium, as well as other stratified squamous epithelia. Clear cells, also known as non-keratinocytes, are found in the epithelium and include Langerhans cells, Merkel cells, and melanocytes. The gingival epithelium's major job is to protect the deep tissues while permitting selective interaction with the oral environment. Keratinocyte proliferation and differentiation are used to accomplish this. Keratinocytes multiply by mitosis in the basal layer and far less commonly in the supra-basal layer; a limited number of cells persist in the proliferative fraction while the majority ascend to the surface **(Carranza, 2019)**.

1.7.8 Gingival Connective Tissue

Collagen fibers (sixty percent by volume), fibroblasts (five percent), arteries, nerves, and matrix are the major components of gingival connective tissue (about 35 percent). The gingival connective tissue made up of two layers: (1) Papillary layer subjacent to the epithelium, consists of papillary projections between epithelial rete pegs, and (2) a reticular layer is continuous with the alveolar periosteum **(Carranza, 2019)**.

A cellular compartment exists in connective tissue, as well as an extracellular compartment, connective tissue is made up of fibers and ground substance. As a result, the connective tissue of gingiva is mostly a fibrous with elements derived directly from the oral mucosal connective tissue and some fibers (dento-gingival) derived from the growing dental follicle (**Bartold et al., 2000).** The amorphous ground substance covers the space between fibers and cells and has a high-water content. It is made up of glycoproteins and proteoglycans (mostly hyaluronic acid and chondroitin sulfate) (mainly fibronectin). Glycoproteins are responsible for the ground substance's faint periodic acid–Schiff–positive reaction **(Engel, 1953; Carranza, 2019)**.

Fibronectin helps to mediate cell adhesion and migration by binding fibroblasts to fibers and many other intercellular matrix components. Another glycoprotein found in the basal lamina, laminin, is responsible for attaching it to epithelial cells. Collagen, reticular, and elastic fibers are the three types of connective tissue fibers. Type I collagen makes up the majority of the lamina propria and gives the gingival tissue its tensile strength. Between the type I collagen bundles, type IV collagen (argyrophilic reticulum fiber) branches and is continuous with basement membrane and blood vessel wall fibers **(Löe & Karring, 1969; Carranza, 2019)**.

Oxytalan, elaunin, and elastin fibers are interspersed between collagen fibers to form the elastic fiber system **(Chavier, 1990)**; The connective tissue attachment is formed by bundles of collagen that are firmly packed attached into the acellular extrinsic fiber cementum right below the junctional epithelium's terminal point. The durability of this connection is a significant component in limiting junctional epithelium movement **(Cho & Garant, 2000; Carranza, 2019)**.

1.8 Gingival Fibers

The marginal gingival connective tissue is heavily collagenous, with a notable system of collagen fiber bundles known as gingival fibers. Type I collagen makes up these fibers. **(Romanos & Bernimoulin, 1990)**. The gingival fibers have the following functions **(Carranza, 2019)**:

1. To brace the marginal gingiva firmly against the tooth.
2. .To provide the stiffness required to sustain mastication forces without deflecting away from the tooth surface .
3. To unite the free marginal gingiva with the cementum of the root and the adjacent attached gingiva.

The gingival fibers are arranged in 3 groups: gingivodental, circular, and trans-septal **(Kronfeld, 1939)**. On the facial, lingual, and interproximal surfaces, gingivodental fibers can be found. They're embedded in the cementum beneath the epithelium, near the base of the gingival sulcus. They extend externally to the periosteum of the facial and lingual alveolar bones, terminating in the attached gingiva or blending with the periosteum of the bone on the facial and lingual surfaces, they protrude in a fan-like pattern towards the crest and outer surface of the marginal gingiva, where they end short of the epithelium. The gingivodental fibers extend interproximally toward the crest of the interdental gingiva **(Carranza, 2019)**.

Circular fibers go through the marginal and interdental gingival connective tissue and encircle the tooth in a ring-like pattern. The inter-proximally positioned trans-septal fibers form horizontal bundles between the cementum of the adjacent teeth into which they are implanted. They lie in the point between the epithelium at the bottom of the gingival sulcus and the crest of the interdental bone, and often, they are considered as one of the main fibers of the periodontal ligament **(Carranza, 2019)**.

Page and colleagues (**Page et al., 1972**) described a collection of semicircular fibers which they connect at the proximal surface of a tooth directly just under cement-enamel junction, go around the tooth's facial or lingual marginal gingiva, and connect on the other proximal surface of the same tooth; they also discussed the transgingival fibers group which bind at the proximal surface of one tooth, traverse the interdental space diagonally, and connect on the other proximal surface of next tooth. The tension in the collagen is thought to be caused by tractional forces in the extracellular matrix produced by fibroblasts. This maintains the teeth firmly attached to each another as well as to the alveolar bone **(Carranza, 2019)**.

1.9 Blood Supply and Lymphatics

Gingiva is supplied by a system of arteries that branch off from the carotid artery. Buccal artery and posterior superior alveolar artery give arterial supply for the entire buccal mucosa. The greater palatine artery, a branch of the descending palatine artery that originates from the maxillary artery, supplies blood to the palate. The sublingual and submental arteries supply blood to the floor of the mouth as well as the mandibular lingual gingiva. Finally, tiny branches from the inferior alveolar artery perfuse the labial gingiva that covers the jaw (incisive and mental artery). Branches of the anterior superior alveolar artery perfuse the labial gingiva that covers the maxilla. **(Shahbazi et al., 2019)**.

-Three sources of blood supply to the gingiva are as follows (Carranza, 2019):

1. Supra-periosteal arterioles along the facial and lingual surfaces of the alveolar bone from which capillaries extend along the sulcular epithelium and between the rete pegs of the external gingival surface **(Egelberg, 1967; Hansson et al., 1968; Ambrosini et al., 2002)**. Arterioles travel through the alveolar bone to the ligament of periodontium on rare occasions, or pass over the alveolar bone crest.

2. Periodontal ligament vessels that extend into the gingiva and anastomose with capillaries in the sulcus.

3. Arterioles, which emerge from the crest of the interdental septa **(Folke & Stallard, 1967),** and extend parallel to the crest of the bone to anastomose with the periodontal ligament vessels, with capillaries in the gingival crevicular areas and vessels that run over the alveolar crest, as shown in Fig (1-7)

2

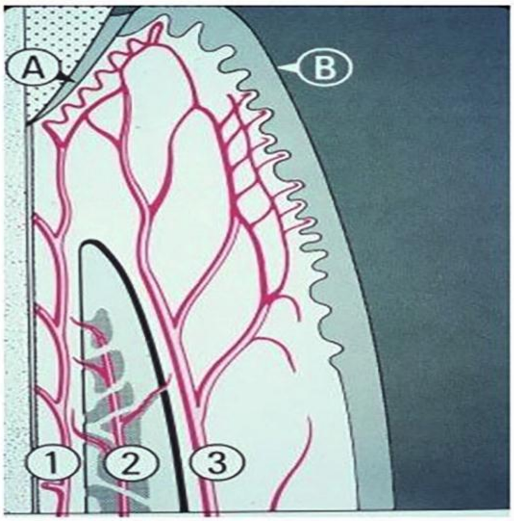


Figure (1-7): Blood supply and peripheral circulation of the gingiva.**A:** vascular plexus adjacent to junctional epithelium **B:** vascular plexus adjacent to oral epithelium **1**. Blood supply from periodontal ligament.**2**. Blood supply from aleveolar process **3.** supraperiosteal blood supply **(Sueng, 2007)**.

Capillaries penetrate the connective tissue of papilla beneath the rete pegs of epithelium on the outer gingival surface in the form of terminal hairpin loops comprising efferent and afferent branches, spirals, and varices (**Carranza et al., 1966; Hansson et al., 1968)**. Cross-communications can connect the loops (**Forsslund, 1959**), and flattened capillaries act as reserve vessels when circulation is boosted in response to irritation **(Glickman & Johannessen, 1950; Carranza, 2019)**.

Controlling diffusion and inflammatory processes resolution require the lymphatic system to remove excess liquids, cellular and protein debris, bacteria, and other components **(Marchetti & Poggi, 2002)**. It then goes to the regional lymph nodes, particularly the submaxillary group, via the collecting network external to the alveolar process periosteum. In addition, lymphatics penetrate into the periodontal ligament immediately beneath the junctional epithelium and accompany the blood vessels **(Carranza, 2019)**.

1.10 Nerves

The trigeminal nerve by its divisions, mandibular and maxillary feed all of the nerves that innervate the gingival mucosa, the innervation of the oral gingiva is unique (CN V) **(Adam & Amit, 2020)**.

The lingual, inferior alveolar, and buccal nerves are all branches of the mandibular division of the trigeminal nerve that innervate the mandibular gingiva. After going through the foramen ovale and reaching the infratemporal fossa, the mandibular division splits into two trunks: the anterior trunk and posterior trunk **(Shahbazi et al., 2019)**. The anterior trunk carries afferent sensory fibers that make up the buccal nerve. The buccal nerve, which innervates part of the lower oral gingiva. The lingual and inferior alveolar nerves emerge from the posterior trunk. After that, the lingual nerve goes anteriorly into the oral cavity, providing sensory innervation to the lingual oral gingiva. **(Fagan & Roy, 2019)**.

The inferior alveolar nerve branches into the mylohyoid nerve and the mental nerve as it descends further into the lower jaw. The mental nerve innervates the lower gingival mucosa with sensory innervation, whereas the mylohyoid nerve innervates the anterior belly of the digastric muscle and the mylohyoid muscle with motor innervation **(Fagan, & Roy, 2019)**.

The nasopalatine, greater palatine, and superior alveolar nerves, which originate from the maxillary division of the trigeminal nerve, innervate the maxillary gingiva. The greater and lesser palatine nerves pass through the palatine canal. The greater palatine nerve innervates the oral gingiva and runs along the inferior surface of the hard palate. The nasopalatine nerve, which is the longest of the nasal branches, innervates the oral gingiva through the incisive canal on the top of the oral mucosa.Finally, buccal gingival innervation is provided by the anterior, middle, and posterior superior alveolar nerves **(Shafique & M Das, 2020).**

1.11 Treatment Modalities

There are various treatment modalities for treating the oral PGs, the surgical excision is considered the standard treatment. However, the recurrence rate of the lesion after surgical excision is still high **(Frumkin et al., 2015)**. Due to incomplete excision, failure to remove etiologic factors, or repeated trauma contributes to recurrence of these lesions **(Gomes et al., 2013)**. A careful excision of the lesion may minimize its recurrence but cannot prevent it. Although traditional surgical excision can be employed, several difficulties may arise, affecting the dynamics of the healing process like intra-operative bleeding, difficulties in wound healing and maintenance of sterility during surgery, and postoperative infection **(Asnaashari et al., 2013)**. During the past year's other treatment modalities like scalpel, cryosurgery, and laser surgery were being implemented **(Rai et al., 2011; Al-Mohaya & Al-Malik, 2016)**.

For pyogenic granuloma, a variety of therapeutic options have been outlined. The most common treatments are surgical excision and removal of the irritant or source of damage. Also recommended as treatment possibilities include cryosurgery, silver nitrate cauterization, sclerotherapy, Nd: YAG (Neodymium-Doped Yttrium Aluminium Garnet) and CO2 (Carbon Dioxide) lasers, and laser photocoagulation **(Jafarzadeh et al., 2006; Rai et al., 2011)**.

Pyogenic granuloma is one of common benign vascular lesion that is frequently diagnosed. Excision, curettage, cryotherapy, chemical, electric cauterization, and the use of lasers are all options for treatment **(Chan et al., 2000; Raulin et al., 2002)**.

The conventional treatment for pyogenic granuloma is surgical excision or electrocoagulation. But the side effects are the scarring and the possibility of bleeding, particularly in big granulomas or when the excision is near to the lesion, so, this modality is not preferable form of treatment. Excision by laser may be the best option for treating these types of lesions **(Powell et al., 1994; Raulin et al., 2002)**.

Despite the possibility of early postoperative bleeding, which appears to be a minor complication, biopsy is the preferred technique of intervention. For diagnosis and treatment, an excisional biopsy was conducted **(Safak et al., 2012)**.

Excision method necessitates the excision of the entire lesion with a margin of at least 2 to 3 mm on all sides. This method is best for oral lesions that are smaller than 1 cm in diameter, as well as mild, solid, and exophytic lesions. Lasers are used to remove localized discrete lesions such as fibroma, papilloma, mucocele, and pyogenic granuloma **(Sawisch et al., 2015)**.

When applied for excision, the laser acts as a "light scalpel," allowing for precise cuts without the bleeding associated with traditional surgical technique.

The laser spot size must be maintained as small as possible (0.1 to 0.5 millimeter), which would be achieved by maintaining the handpiece at its focal length from the tissue **(Strauss & Fallon, 2004)**. This is known as the focused mode. Each handpiece has a different focal length from the handpiece end to the tissue, ranging from 1 millimeter to 1 cm. Regardless of the laser system employed, the process for removing a lesion stays the same. It is recommended that the beam of laser be set at a lower power in an intermittent, gated, or pulsed mode to outline the intended incision line.This mapping provides superficial guide markings while avoiding deep tissue penetration,allowing the surgeon to adjust the boundaries as necessary. During excisional biopsy procedure, an additional 0.5 mm should be added circumferentially to account for the lateral zone of thermal necrosis caused by the laser **(Catone & Alling, 1997)**.

The laser is changed to continuous-wave mode after the outlining is complete, and the dots are joined to produce the incision. To obtain the necessary depth, several passes may be needed. The surgeons would be able to modify the laser's parameters throughout subsequent passes if mandatory, after evaluating the laser's effect on the tissue during the initial pass, the exposure period must be prolonged, for instance, if the cut depth is just too shallow, the power should be elevated or the handpiece moved at a slower rate **(Strauss et al., 2004).**

The preferable alternative is to increase the power because this will give more time for lateral conduction and consequent lateral thermal damage. The power can be lowered or the handpiece can be running faster if the initial cut is too deep, both of which are good options. Excision of the lesion can be commenced once the outlining incision has reached a sufficient depth. This is done by gently holding the tissue with forceps, using gentle traction, and horizontally undermining the lesion while keeping the tip of laser at the focal length. Hemostasis will be excellent at the site of surgery, and closure will be infrequent.

The only exception is, if permitting, the wound to granulate would result in unsatisfactory aesthetic outcomes (**Strauss et al., 2004)**.

Lasers were introduced into dentistry four decades ago. Since that time, different wavelengths have been used for oral soft tissue dental procedures. The dental laser can provide many advantages such as tissue incision cleaning, immediate coagulation, and less postoperative pain, and swelling **(Al-Mohaya, & Al-Malik, 2016)**.

Laser surgery has been showed to be effective in frenectomies, biopsies (incisional and excisional), reduction of soft-tissue tuberosity, soft-tissue crown lengthening, vestibuloplasty, stage two implant recovery, and other dental soft-tissue procedures involving **(Caroth & Mckenzie, 1985)**. Laser surgery can treat many lesions which occur on the surface of the oral mucosa, this is why it is used in oral and maxillofacial surgeries **(Fitzpatrick, 1992)**.

•The laser use can be minimally invasive compared to conventional modalities.

•The laser energy can aid in hemostasis, for improving visibility during a surgical procedure.

• The laser irradiation can decrease bacteremia.

• The laser use can aid in the healing of wound and can produce other photo-biomodulation effect.

• The laser energy can decrease pain; compared to conventional techniques (**Peter et al., 2010)**.

Pyogenic granuloma has been successfully treated with a variety types of lasers, including Nd:YAG , CO_2 lasers, and Er:YAG **(Al-Mohaya & Al-Malik , 2016**).the newly developed diode-laser systems with different wavelengths have recently become more suitable in surgery. **(Powell et al., 1994)** stated the use of Nd: YAG laser for excision of PG, with lower risk of bleeding compared to other surgical techniques. Diode laser is also introduced as a powerful tool for management of pyogenic granuloma by (**Rai et al., 2011)**.

Lasers have found increasing applications in the majority of surgical specialties including oral and maxillofacial surgery. It introduces a new powerful tool with a bloodless operated field. In contrast to conventional techniques and other adjunctive equipments used to improve surgery, it is necessary that the surgeon has at least a basic understanding of high-quality laser technology and how to operate those lasers which are most useful in clinical practice **(Catone & Alling, 1997; Andrew et al., 1999)**.

A laser is a monochromatic, collimated, coherent, and strong beam of light created by a light source's stimulated emission of radiation. The classification of lasers is based on a variety of variables, including the active medium of the laser (gas, liquid, solid, or semiconductor), which identifies and classifies the type of output laser beam **(Oviya et al., 2021)**. The benefits of lasers include tissue incision, coagulation during surgery, and other postoperative benefits. Diode lasers are small, portable surgical equipment that provide effective and dependable results. **(Markolf & Neimz, 2007; Afrah et al., 2017)**. Lasers are currently recognized as practical and cost-effective equipment with unique qualities that have been successfully applied in a variety of fields. Because of its advantages, lasers are utilized in medical, dental, biological, and a range of chemical and physical studies **(O'shea, 1978; Beesly, 1978)**. Lasers are new potent instruments in oral and maxillofacial surgery that are characterized by a bloodless and painless field and can be used to treat both soft and hard tissues **(Strauss, 2000)**.

, From the initial discovery of the ruby laser in the 1960s, medical applications of the laser systems were developed and approved for procedures of soft tissue management **(Lewis et al., 1997; bsten, 1990)**.

A diode laser is a semiconductor device with an active medium of aluminum, gallium, arsenide, or indium. In the visible or infrared spectrum, the laser unit emits coherent radiation (waves with the same frequency and phase). (**Al-Mohaya, & Al-Malik, 2016)**.

As a result, pigmented tissue, which comprises melanin and hemoglobin, absorbs all wavelengths effectively. However, calcified tissue, such as tooth enamel which composed of hydroxyapatite and water; absorbs them weakly (**Al-Mohaya, & Al-Malik, 2016)**.

Diode lasers produce light that ranges from the near-infrared to the visible red spectrum. The main benefits of semiconductor lasers are their compactness, simplicity, and effectiveness; they need so little auxiliary equipment and can be easily connected to optical fibers, allowing them to be employed for medical applications **(Miserendino & Pick, 1995;Strauss, 2000;Aldelaimi & Khalil, 2015; Afrah et al., 2017)**.

The coherent laser beam at the specific wavelengths penetrates deep into the mucosa while being weakly absorbed by the dental hard tissues, allowing surgery to be accomplished safely. Fibroblast growth can be also induced by low-energy lasers **(Chaya & Pankaj, 2015)**.

Beginning in 1995, the FDA approved the use of diode safely in soft tissue surgical procedures. Among 800 and 1064 nm, four distinct wavelengths of semiconductor diode lasers are available as follows **(Convissar & Robert, 2015)**:

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

In continuous-wave or gated-pulse mode, the delivery system uses optical fibers of various diameters, which are frequently employed in contact with tissues. Pigmented tissues, which contain melanin and hemoglobin, absorb the diode laser very well **(Convissar & Robert, 2015)**. However, calcified tissue, such as hydroxyapatite and water in the enamel, absorbs them weakly. Because of the tissue interaction of diode laser, it is extremely safe and well-suited for soft oral tissue surgery in areas close to dental structures **(Asnaashari et al., 2015)**. the little penetrating coefficient of the diode laser; create high amount of heat, and deep coagulation (showing surface carbonization) **(Convissar & Robert, 2015)**. the common applications for diode lasers include incision, excision, and coagulation of soft tissues, as well as the control of bacterial development in open wounds **(Nussbaum et al., 2003)**.

Depending on the procedure, diode lasers sometimes apply fiberoptics for energy delivery in contact or noncontact mode **(Convissar & Robert, 2015)**. Diode lasers can be applied in continuous-wave or gated-pulse mode in contact or non-contact with biological tissue. since the pigmented tissue absorbs most wavelengths of diode laser, the laser tip must be "initiated" in normal mucosa by touching the fiber tip of diode to a pigmented item (articulating paper) to pick up some pigment, which subsequently absorbs the beam to yield a thermal effect .Unlike other diode wavelengths, which are predominantly absorbed by pigments with optical penetration of less than 300μm, the 980-nm diode laser has a substantially higher absorption in water than other diode wavelengths, permitting it to cut more optically than thermally **(Convissar & Robert, 2015)**.

When comparing to other laser wavelengths, Romanos and Nentwig discovered that the 980-nm diode laser provided more exact incisional margins **(Romanos & Nentwig, 1999)**.

Lasers have been used in a number of surgical operations for a long time. The chosen option of 810 nm diode laser excision resulted in entirely healed lesions for pyogenic granuloma patients, suggesting that laser excision may be the best therapy choice for these types of lesions. diode laser with wavelength of 810-980 nm have been used for soft tissue cutting procedures in pediatric patients. The benefit of laser in removal of soft tissue lesions in pediatric patients includes less bleeding and less post-surgical pain and discomfort **(Ghadimi et al., 2012)**.

The diode laser is a semiconductor. Gallium, arsenide, aluminum, and indium are state elements that convert electrical energy into light energy. Soft tissue absorbs a large portion of the light energy from the diode, while teeth and bones absorb only a small portion **(Aras et al., 2010)**. As all wavelengths are weakly absorbed by hard dental tissue, diode laser is safe and well indicated for soft oral tissue surgical procedures in regions near the dental structures **(Asnaashari et al., 2015)** and for cutting, vaporization, curettage, coagulation of blood, and oral region hemostasis **(Akbulut et al., 2013)**.

Because of the wavelengths of (810-980 nm) are absorbed not just by water (although less so than the Co2 laser wavelength), but also by other chromophores such as melanin and, in special, oxyhemoglobin, diode lasers are effective for oral soft tissue surgery. Furthermore, the exclusive use of this laser by contact or at a very close distance prevents damage in an open field owing to 'beam escape,' making it far safer than conventional laser sources. Moreover, diode lasers have a larger capacity for ablation of tissue and appropriate bleeding hemostatic properties in comparison with other types of laser, and also the attempt to cut tissue to accomplish coagulation and hemostasis **(Saetti et al., 2008; Desiate et al., 2009; Genovese et al., 2010; Akbulut et al., 2013)**.

Clinical evidence suggests that diode lasers have many benefits like a low intra-operative bleeding, a low postoperative edema, a significant better coagulation, healing without suture, a short surgical time, and a minimal post-operative pain **(D'Arcangelo et al., 2007; Ortega- Conception et al., 2017)**.

The Food and Drug Administration (FDA) authenticated the usage of diode lasers in oral surgery. Lasers have been used in a number of surgical operations for a long time. Certain authors, such as **(Goharkhay et al., 1999; Gontijo et al., 2005; Akbulut et al., 2013)** had succeeded in the treatment of oral soft tissue lesions using a diode laser.

1.12 Laser light

The initial letters of "light amplification by stimulated emission of radiation" form the acronym "laser." The amplification of microwave by stimulated emission of radiation "maser" principle was developed into the laser principle. When Einstein derived Planck's law of radiation in 1917, he used the concept of stimulated emission. It took over 40 years to realize that this process might be employed in a device to generate coherent microwaves and a new type of light - laser light **(Haken, 1985)**.

Light produced by a laser allowed measurements of unique precision due to its temporally and spatially coherent beam, monochromatic and collimated. Laser radiation is characterized by an extremely high degree of coherence. A coherent light beam means spatial and temporal overlap of the waves of the beams. This overlap in space and time leads to the capability of producing very unique light signals that have monochromatic, directional and bright feature **(Niemz, 2007)**.

1.12.1 Basic Elements of laser devices

Tee main conditions must be met in order to operate most laser devices:

a) Active medium: This is a group of atoms, molecules, or ions in solid, liquid, gaseous, or semiconductor form. Light waves are amplified inside this medium. The medium must be kept in a population inversion state for amplification, which means that the atoms number in the upper energy state must be more than the atoms number in the lower energy state. The output of wavelength and laser name are determined by the nature and composition of the lasing medium **(Keye, 1990)**.

b) Pumping source: The energy source for pumping the laser medium. When the active medium is pumped, a laser beam emerges from the optical cavity and exits via the partially transmissive mirror, causing a population inversion inside the active medium **(Cember, 1987)**. (light, electric current, chemical or nuclear reaction) provides for obtaining such a state of population inversion between energy states of the atomic system.

c) Optical resonator: (optical cavity) which composed of a pair of parallel mirrors opposite to each other around the active laser medium which provides feedback of light. This system then performs as an oscillator creating light rather than just amplifying as shown in Fig (1-8) **(Thyagarajan & Ghatak, 2011)**.

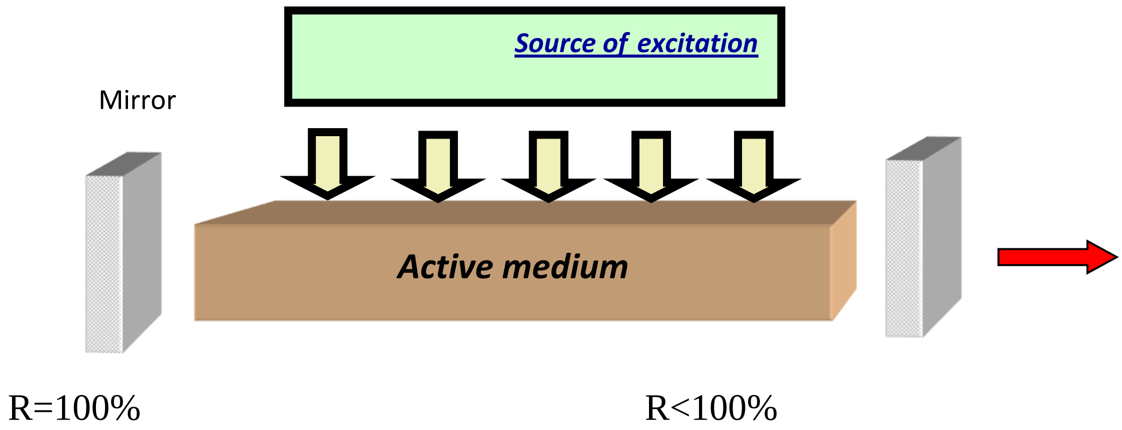


Figure (1-8) Primary laser components **(Chopra & Chawla, 1992)**.

1.12.2 Laser light properties

- Coherence

In both space and time, the light rays of electromagnetic waves are in phase with each other, which is referred to as coherence. The coherent nature of laser light had been taken from the fact that it is produced via stimulated emission, this indicates that the photon released is in phase with the stimulating photon **(Moseley, 1988)**. There are two kinds of coherence spatial and temporal **(Powell, 1992)**. All waves have crests and troughs that coincide with lines perpendicular to the rays, which is known as spatial coherence. In temporal coherence, the frequency, wavelength, and speed of motion all seem to be identical **(Wright & Fisher, 1993)**.

The most fundamental property of a laser is coherence, which separates it from other types of light. As a result, a laser can be characterized as a coherent light source.

- Brightness or intensity

This feature is due to the laser light's parallelism or collimation as it traverses through space, preserving its concentration and consequently the distinctive brightness. When the laser is focused in a narrow spot, the brightness translates to large energy concentrations **(Powell, 1992)**.

- Monochromaticity

This means that the wavelength of all photons is just the same. The light emitted by a specific laser will have a specific wavelength **(Mercer, 1996)**. This is in contrast to a conventional incandescent light bulb, which releases wavelengths across the full spectrum, often from UV (ultraviolent) to visible light and then into the IR (infrared) region or more **(Powell, 1992)**.

- Directionality

The laser beam has extremely low divergence when it departs the laser device, and it has the potential to traverse a great distance with minimal variation from parallelism. Laser light retains brightness across distance but it does not diverge **(Powell, 1992; Mercer, 1996)**.

The photon can be emitted in one of two different methods **(Tarasov, 1986; Mosaad, 1997)**:

a) **Spontaneous emission**: Thus, in the absence of any stimuli, level E2 atoms likely to decay to level E1. Different atoms decay at different rates, and the orientation of the emitted photons, as well as their polarization, are all random amounts at the time of transition.

b) Stimulated emission: The same incident photon may operate as a trigger if the atom is in the higher energy level, causing the transition from E2 to E1, which results in the emission of a photons. Both the inducing and induced photons have the same energy, direction, and polarization as the inducing photon.

As a result, if a large number of photons with the same energy pass through an excited state, this process is quite likely to occur, and the lifetime of stimulated emission can be significantly shorter than the lifetime of spontaneous emission. This is known as "amplification," and it is the crucial mechanism that allows a laser to operate **(Elliott, 1995)**.

To produce a laser action, it is essential to ensure that further atoms in the lasing medium are in an excited energy level than in a lower-energy level. When this requirement is met, a population inversion in the medium is said to occur. This condition can be achieved by pumping energy into the lasing medium **(Oshea et al., 1978; Tarasov, 1986; Mosaad, 1997)**. A single stray photon of the correct wavelength, created spontaneously, is now enough to start a stimulated emissions chain.

The medium of laser found between two mirrors, one mirror is completely high reflective and the other one is partial reflective. As they exit through the partially reflecting mirror, photons can bounce off each other, enhancing more atoms to create photons and so quickly increase the intensity **(Oshea et al., 1978)**.

The population inversion is maintained if the pumping energy is applied continually, and fresh excited atoms recuperate the exhausted atoms, resulting in a continuous wave laser. When the energy of pumping is delivered sporadically, as in a pulsed laser, the stimulated emission fades as the excited atoms develop and lose their extra energy, thus erasing the population inversion **(Mosaad, 1997)**.

1.12.3 Types of Laser

There are different types of lasers, which are based on their active medium such as solid-state lasers (Nd-YAG), semiconductor lasers (diode lasers), liquid lasers (dye lasers) and gas lasers (CO2).

In the current study a diode laser was used**.** The diode laser is based on Gallium arsenide p-n semiconductor junction.

Diode lasers are the most widespread between all laser types because it is small size, not expensive require less maintenance and durable. The laser is created by the junction of two different types of semiconductor, and the light emerges from the edge of the block, coming directly from the junction. Semiconductors composed of ternary or quaternary elements; the bandgap energy depends on the relative concentration of different elements. The ternary semiconductor gallium aluminum arsenide (GaAlAs) has a bandgap energy corresponding to photons from 900 to 620 nm. That is, the wavelength of a GaAlAs laser can be changed by varying the relative amounts of gallium, aluminum and arsenic in the crystal. Shorter wavelengths (in the blue and even the ultraviolet) are obtainable with gallium-nitride compounds **(Hitz et al., 2001)**.

1.12.4 Types of laser mode operation

The main modes for lasers operation are:

1- Continuous mode (CW)

If the partially transmitted mirror lets a fraction energy of light which hit it to escape, and pumped energy into the active medium of laser at a level that keeps the laser output stable, we can produce a continuous laser beam. The lasing medium in most Continuous wave lasers is gas. **(Seckel, 1996)**.

2- Chopped mode

A shutter which "chops" the beam into trains of brief pulses can disrupt the output of a CW laser. So, every pulse's maximum power output is identical to that produced in CW mode. When the shutter is open, the period of the pulse is restricted by the shutter's speed, which is normally 100 to 500ms. The duly cycle is the beneficial percentage of the laser beam in which the transmition of light occur by the chopped laser **(Al-Qalamjy, 2001)**.

3- Pulsed mode

Gas lasers, for example carbon dioxide laser, can be electronically pulsed. The gating allows the pulse duration to be compressed, resulting in a substantially higher peak power than it is commonly available in the Continuous wave mode **(Dederich, 1993)**.

1.12.5 Laser-tissue interaction

If a beam of laser hits biological tissue, a specific distribution for the light of laser inside the irradiated volume is noticed. Part of the radiation is absorbed by the biological tissue and, consequently, may be therapeutically active. Based on the layer thickness, another part will be transmitted either directly at or after multiple scattering **(Brlien & Müller, 2003)**.

- Reflection and refraction, absorption, and scattering are three phenomenons that can obstruct its propagation.

1- Reflection & Refraction

Fresnel's laws show that reflection and refraction are closely linked**.** Reflection is defined as the returning of electromagnetic radiation by surfaces upon which it is incident. In general, a reflecting surface is the physical boundary between two materials of different indices of refraction such as air and tissue. Refraction plays a significant role only when irradiating transparent media like corneal tissue. In opaque media, the effect of refraction is usually difficult to measure due to absorption and scattering. Reflection, Absorption, or Scattering is dominant primarily depends on the material type and the incident wavelength **(Niemz, 2007)**.

2- Absorption

The structures of the biological tissue that absorb the photons are known as chromophores **(Fodor et al., 2011)**. Absorbing molecular components of the biological tissue are H_2O, porphyrin, hemoglobin, melanin, nuclear acids, deoxyribonucleic acid (DNA)/ribonucleic acid (RNA), and reduced nicotinamide adenine dinucleotide, where electronic transitions are excited leading to separate and intense absorption bands. absorption spectra of water, hemoglobin, melanin and proteins together with scattering in tissue shown in Fig (1-9) **(Steiner, 2011)**.

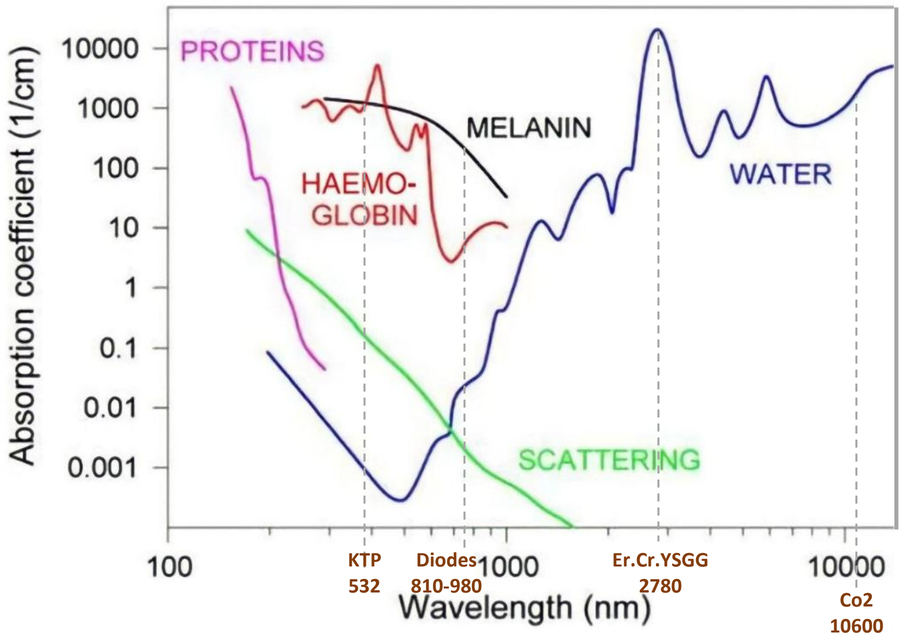


Figure (1-9): Absorption spectra of water, hemoglobin, melanin and proteins together with scattering in tissue **(Peng et al., 2008)**.

3- Scattering

The scattering performance of biological tissue is also neccesary due to it determines the distribution volume of light intensity in the biological tissue. A photon's Scattering results in a change in direction without an energy loss. Muscle fibers, skin layers, and dentin tubules are examples of macroscopic scattering biological structures; cells or intracellular structures are examples of microscopic scattering structures; and macromolecules or nanoparticles are examples of sub-microscopic scattering structures **(Steiner, 2011)**.

As light of laser hits a biological tissue surface, this can be reflected and refracted, scattered, absorbed, or transmitted **(Love, 1995)**. The fractional intensity that goes into each of these processes is determined by the tissue's optical properties, such as coefficients of absorption, reflectivity, scattering, and size of particle **(Chopra & Chawla, 1992)**, and the parameters of laser such as wavelength, energy, duration of pulse, mode of operation and output spectral profile **(Bedry, 1997)**.

Refraction plays very important role in medical laser applications specially when irradiating transparent media such as corneal tissue. while in opaque material, refraction is difficult to evaluate because of absorption and scattering effects **(Markolf, 1996)**.Several scattering mechanisms turn laser light travelling through biological tissue from a narrow-collimated beam into a broad diffuse beam **(Mosaad, 1997)**.Ultraviolet light is scattered more than infrared light because the scattering coefficient rises as the wavelength rises **(Markolf, 1996)**.The absorption of electromagnetic radiation is the starting point for all of light's effects **(Elliott, 1995**). The incident light intensity is reduced when it passes through such a medium owing to a light energy partial conversion into thermal motion or some vibrations of the absorbing material's molecules during absorption. Internal characteristics such as temperature and concentration, as well as the electronic component of atoms and molecules, the wavelength of the radiation and the thickness of the absorbing layer, all influence a medium's capacity to absorb electromagnetic radiation. Interactions of laser beam with biological tissue will be shown in Fig (1-10).

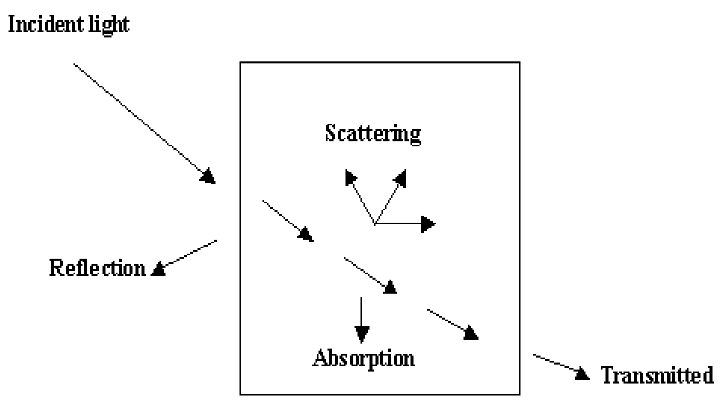


Figure (1-10) Interactions of laser with biological tissue **(Niemz, 2007)**.

The penetration depth of a laser's beam in the biological tissue is the most crucial optical parameter that determines its acceptability for a surgical treatment. The wavelength of the beam of laser has a large effect on the depth of penetration. The depth of penetration can be significantly greater in the red portion spectrum and in the near infrared area. the absorption coefficient is considerably high in spectral areas like at 10.6 nm, a thin layer near the surface absorbs the radiation **(Mosaad, 1997; Julia et al., 1998)**. Water molecules or macromolecules like proteins and pigments are the main targets of absorption in biological tissue. Infrared light is absorbed by molecules of water, whereas ultraviolet and visible light is absorbed by proteins and pigments **(Julia et al., 1998)**.

Depending on the wavelength of the radiation of laser and the type of the tissue, photochemical and/or photothermal impacts can be induced by the absorbed proportion of laser radiation. It has the ability to create fluorescence, which was employed in dentistry to diagnose first dental caries via spot emission fluorescence **(Julia et al., 1998)**.

1.12.6 mechanisms of laser interaction

When laser light is applied to biological tissue, a range of interactions can occur depending on tissue properties as well as the parameters of laser.

1.12.6.1 Wavelength dependent mechanisms

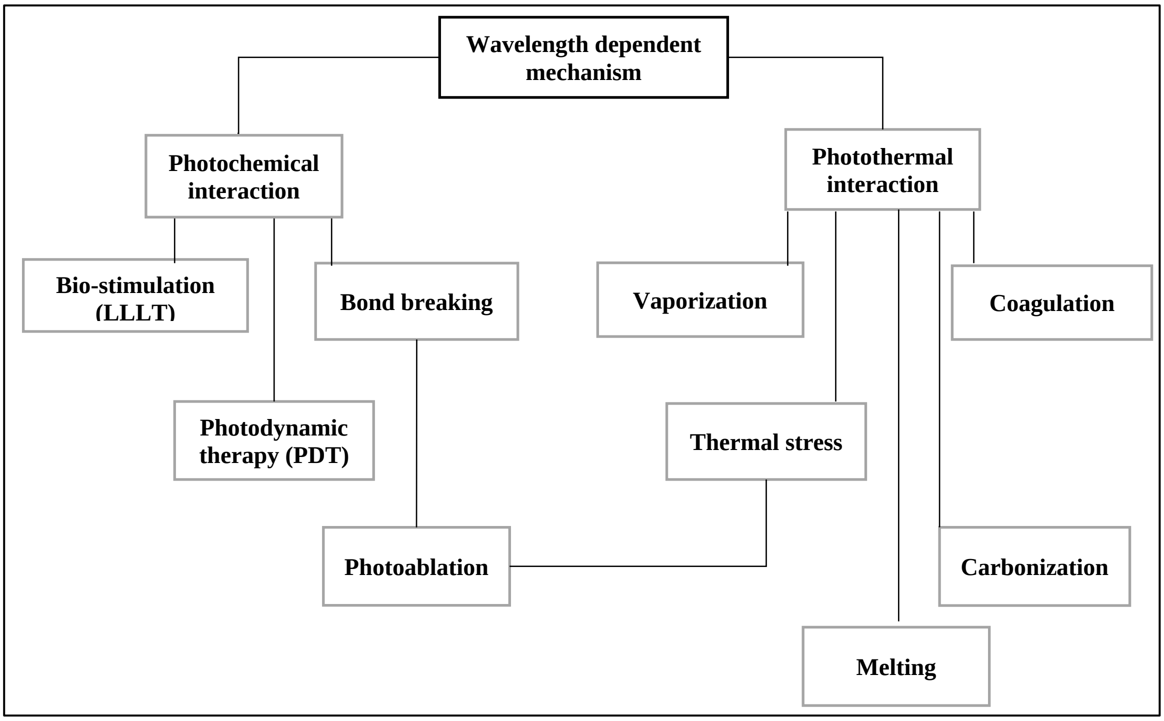


Figure (1-11) Wavelength dependent mechanisms (**Aboud, 2005**).

-Photothermal interaction mechanisms

Through molecular vibrations and collisions, the energy of photons absorbed by chromophores is transformed into heat energy, which could also generate a variety of thermal effects ranging from tissue coagulation to vaporization (**Cox, 2007; Niemz, 2007)**. In medical practice, thermal effect is the most common type of laser-tissue interaction, and one of the first to be studied. Thermal stress causes ablation in photothermal interactions **(Cox, 2007).**

Heating is the most common photon energy conversion method in laser medical treatment. All methods of tissue destruction result in heating of the irradiated sample (coagulation, vaporization, cutting, etc.**) (Karu, 1999)**.

Nonspecific Photothermal effects generated by kinetic excitation are considered to cause biological consequences when photons are absorbed by the biological tissue **(Anders, 1980)**. The targeting molecules' transitional, rotational, and vibrational patterns of movement deposit the outer energy from the photon of laser into the materials of target. The recovered energy from light should be most effective when the incident photons frequency is near to the specific frequencies of vibrational and rotational movement patterns, which are truly characteristics of the temperature or kinetic energy (K.E) of the molecules of target **(Bedry, 1997; Fitzpatrick & Goldman, 2000)**.

Thermal diffusion begins when energy of laser is transformed to heat in the biological tissue. Heat diffusion through the biological tissue is influenced by the irradiated substance thermal properties. The thermal tissue coefficient, the qualities of the surrounding biological tissue or fluids, and the temperature difference among irradiated and non-irradiated biological tissue, all these factors will impact on the thermal relaxation (cooling) phenomenon **(Grundfest et al., 1988)**.

Different effects such as coagulation, carbonization, vaporization, and melting can be identified based on the duration and peak value of the tissue temperature achieved. In order to decrease thermal damage to nearby structures, the laser pulse duration must be adjusted **(Markolf, 1996)**.

Microscopical and biochemical study revealed that as the temperature rises, the massive, uniquely structured molecules required for life are shaken open. All proteins, DNA, RNA, membranes, as well as associated integral structures dissociate or melt at temperatures ranging from 40 to 100 degrees Celsius, resulting in denaturation or function loss as shown in table (1-2) (**Markolf, 1996) (Miscerendino et al., 1997) (Fitzpatrick & Goldman, 2000)**.

Tissue effect	Temperature C°
Hyperthermia (transient)	42-45
Protein denaturation and coagulation	> 65
Tissue welding	70-90
Water vaporization	> 100
Carbonization and charring	> 200
melting	> 300

Table (1-2): Show thermal effect of laser radiation **(Miscerendino et al., 1997)**.

-Photochemical interaction mechanisms

When a molecule absorbs a photon with enough energy, it can transmit that energy to one of the molecule's electrons. Excited molecules are more likely to undergo chemical reactions with other molecules **(Niemz, 2007; Cox, 2007).** The laser energy directly excites electronic bonds, resulting in photochemical reactions **(Grundfest et al., 1988)**. In general, the majority of the biological tissue's molecules bond in the UV frequency range (**Bedry, 1997)**. Tissue components become electronically stimulated at shorter wavelengths, resulting in the breaking of molecular bonds and the molecular fragments creation **(Grundfest et al., 1988).**

Photochemical reactions, throughout most situations, don't really result to an increase in temperature. An electromagnetic field causes an alteration in the course of a biological reaction, or photodecomposition is caused by high-energy photons rupturing molecular bonds, are both examples of photochemical reaction **(Monajembashi et al., 1986; Chopra & Chawla, 1992)**. Photoablation happen in the intensity range of 10^4-10^{10} W/cm^2 and time of interaction in the range of 10^{-3}-10^{-10} second. currently, UV excimer lasers are used for the majority of ablation procedures **(Beesly, 1978)**. laser radiation absorption by molecules known as photo acceptors at low light intensity.

The energy can be transferred from the absorbing molecule to another molecule, which can subsequently drive chemical reactions in the surrounding tissue. This type of reaction is successfully used in the photodynamic therapy (PDT) of tumor; where the photo absorbing molecules are artificially introduced into a biological tissue before irradiation. Irradiation of cells at certain wavelength can also activate some of the native components. In this way specific biochemical reactions as well as entire cellular metabolism can be changed. This type of reaction is believed to form the basis for low power laser effect (Bio-stimulation) (**Karu, 1999)**.

-Bio-stimulation

It's thought to happen at very low irradiances and to be part of the photochemical interactions group **(Niemz, 2007)**. The experiments conducted to clearly show a number of effects on bio-stimulation mediated by this type of laser, including cellular events (fibroblast, endothelial, and epithelial proliferation, high collagen synthesis, differentiation of fibroblasts into myofibroblasts, movement of leukocytes, fibroblasts, and epithelial cells, and increased macrophage phagocytic activity), as well as vascular events (vasodilation and angiogenesis). which play a serious role in acceleration the healing process of injured tissues **(Lins et al., 2010)**.

Helium-Neon laser (He-Ne), diode laser and Nd-YAG lasers, all these lasers have analgesic,anti-inflammatory and bio-stimulation properties. Ablation in photochemical interaction is due to stress of volume which is a result of bond breaking **(Bernardi, et al., 2016)**.

-Photodynamic therapy (PDT)

It is the main tool of the use of photochemistry in medicine. It is widely used for treating the cancers. In photodynamic therapy two ingredients that are non-toxic on their own - a photosensitizer and light - combine in the presence of oxygen to damage the tumor cells **(Cox, 2007)**.

The nature of the photosensitizers, also called PDT drugs, plays a significant role in determining the conditions and effectiveness of PDT. Various applications of PDT, which are very diverse, has emerged as a promising treatment of cancer and other diseases using activation of an external chemical agent, called a photosensitizer or PDT drug, by light (**Prasad, 2003**). The photodynamic impact is depend on the use of visible light and an agent (photosensitizer "PS") that can absorb light energy and transfer it to molecular oxygen, resulting in highly cytotoxic species such as reactive oxygen species, singlet oxygen, hydrogen peroxide, peroxide anion radical, and hydroxyl radical **(Alves et al., 2014; Bartolomeu et al., 2016)**. These reactive cytotoxic species can cause irreversible damage to molecular cell constituents or even its destruction (**Bartolomeu et al., 2016)**. A photosensitizer should ideally have other characteristics such as photostability, amphiphilicity, selectivity for the target cells, solubility, and absence of dark toxicity at lower concentrations.

1.12.6.2 Wavelength independent mechanisms

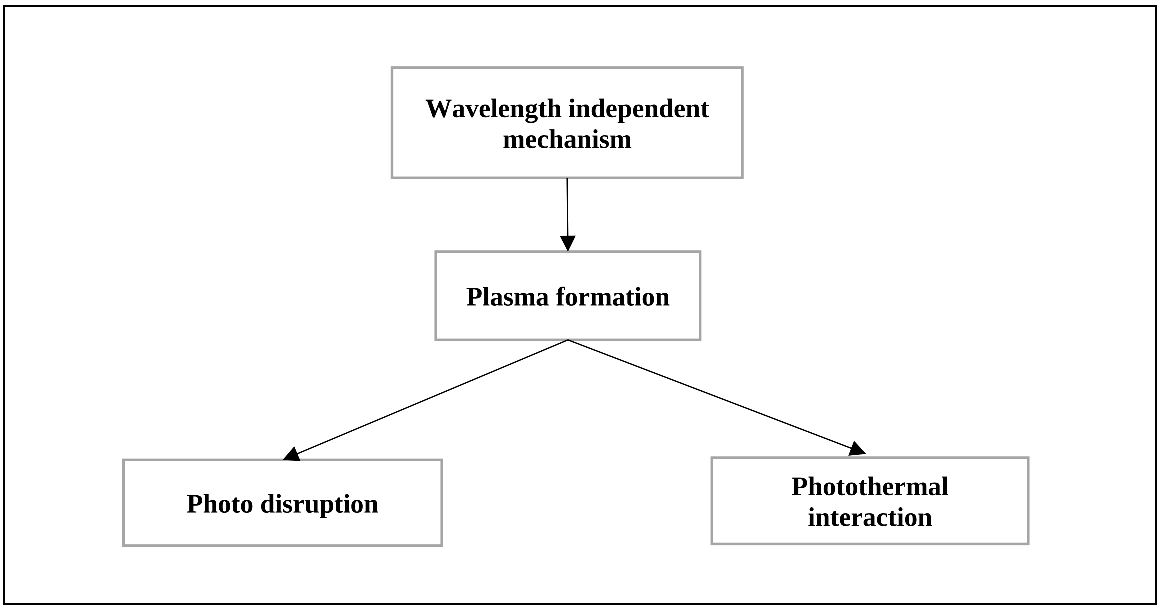


Figure (1-12) Wavelength independent mechanisms (**Aboud,2005**).

Optical breakdown can occur when employing power densities more than 10^{11} W/cm^2 in solids and fluids, or $10^{14} W/cm^2$ in air, and pulse durations in the picosecond or femtosecond range. Plasma formation and shock wave generation are two physical processes related with optical breakdown. Cavitation and jet formation can happen when breakdown happens inside soft tissues or fluids. Whenever the proper laser parameter is employed, plasma induced ablation occurs, extremely clean and well-defined tissue removal can be achieved without thermal or mechanical destruction (**Gordon, 1966**).

A free electron is accelerated by the intensified electric field seen in the vicinity of a closely focused beam of laser in plasma induced ablation. Plasma is an ionized gas, a chain reaction of collisions results in plasma. One example is posterior capsulotomy, which is used to treat secondary cataracts (**Cox, 2007**). plasma induced ablation have Pulse durations: 500 ps – 100 fs and Power densities: 10^{11} – 10^{13} W/cm^2 (**Niemz, 2007**).

In photo-disruption, the physical effects associated with optical breakdown are plasma formation and shock wave generation. If breakdown occurs inside soft tissues or fluids, cavitation and jet formation may additionally take place, photodisruption have Pulse durations: 100 ns – 100 fs and Power densities: 10^{11} – 10^{16} W/cm², Special applications: lens fragmentation, lithotripsy (stone fragmentation) (**Niemz, 2007; Cox, 2007**).

1.12.7 Laser hazards and safety precautions

1.12.7.1 Laser hazards effects

The dangers of laser radiation must be discovered and assessed.

Types of laser hazards

1- Eye: Acute laser irradiation of a specified wavelength and power to the eye can result in burns of retina or cornea (or both). Long term exposure to high levels can result in opacities of cornea or lens (cataract), as well as damage of the retina.

2- Skin: Acute exposure to elevated concentrations of optical radiation can cause skin burns, while ultraviolet and near-ultraviolet wavelengths can induce cancer.

3- Chemical: Certain lasers necessitate the use of a hazardous or toxic material to work (i.e. chemical dye).

4- Electric shock: The majority of lasers generate high voltage, which can be fatal.

5- Fire hazards: Dye laser solvents are highly flammable. Ignition can be caused by high-voltage pulse or flash bulbs. Direct beams or specular reflections from high power continuous wave (CW) infrared lasers can ignite flammable materials **(ANSI, 1993)**.

6- Inhalation of airborne biohazardous compounds that may be emitted into the air as a result of laser surgery is another risk.

Laser and laser systems are divided into groups based on their ability to cause injury, with specific controls given for each group. The manufacturer classifies and labels lasers built after August 1976. The class, maximum power output, duration of pulse (if pulsed), and active medium of laser or emitted wavelength must all be listed on the label.

Maximum Permissible Exposure (MPE): the maximum value of laser radiation to which a person can be exposed without harming their eyes or causing biological alterations in their skin **(ANSI, 1993)**.

1.12.7.2 Laser hazards Classification:

An immediate and generalized method for determining the danger level of a particular laser is to be alert to the hazard class of the laser (**Laser Safety Manual, 2007**).

- The following criteria are used to classify and regulate lasers in general:

1- Class 1: Low-power lasers and laser systems that are not permitted to generate radiation of laser at levels higher than the Maximum Permissible Exposure (MPE). Because class one lasers and systems of laser are incapable of inflicting eye harm, they are not subject to any restrictions. (<0.4mW)

2- Class 2: Low-power visible lasers or laser systems that cannot cause eye damage unless they are viewed directly for an extended period of time (greater than 1000 second). (<1mW)

3- Class 3: Exposures to the direct or specularly reflected beam for a short time (0.25 sec) can cause eye injury with medium-power lasers and laser systems. Lasers of classes 3a and 3b are included.

- Class 3a*:* If exposure to laser beam for a brief period of time with the unaided eye, lasers or laser systems are not harmful to the eyes. When exposure is done with collecting optics, there is a potential eye hazard. (1-5mW)

- Class 3b*:* If viewed directly, a laser or laser system can cause eye injury as in an intra-beam viewing and specular reflections. (5-500mW)

4- Class 4: Short-duration (less than 0.25 seconds) high-power lasers and laser systems can cause significant eye injury. Class 4 lasers and laser systems can also burn flammable and combustible items and cause significant skin injury. (>500mW) **(ANSI, 1993)**.

1.12.8 Laser Safety Measures

The danger of eye harm is the key worry in laser safety. Skin damage is a secondary issue. The wavelength of the light, it's power, whether it is a continuous or pulsed wave, and whether it is the consequence of a direct exposure of laser light rather than a diffuse reflection may all influence the biological effects of laser light. This was avoided by wearing safety goggles with special filters that block light at certain laser wavelengths. In addition, the standard laser warning signs were employed **(Laser Safety Manual, 2007)**.

Eye protection: The requirement for laser eye protection for certain lasers is determined by principle investigations for workers who operate or manage the functioning of a laser. The supervisor will offer eye protection to personnel and visitors to the area if necessary. Always the usage of the minimal laser radiant energy or laser power level required for this purpose.

Beam control: Follow these precautions will decrease direct eye exposure:

1. Never look directly into laser beam or specular reflection, regardless laser beam intensity.
2. Terminate beam path at the end of treatment session.
3. Project the path of laser beam to a point other than eye level when standing or sitting at a desk.
4. Direct the laser beam in a way that it is not pointed toward door entrance or aisles.
5. Reduce the specular reflections.

6. Attach the laser system on a flat, solid surface, in order to preserve the laser beam in a steady spot through surgery and to restrict beam travel through adjustments.
7. Restrict primary beams and harmful reflections to the optical table.
8. Clearly mark the path of the beams and make sure they do not even cross any populated areas of the traffic path.

Whenever the beam path is not totally contained, position the laser system in a way that the beam is outside the standard eye-level range, which is 1.2 to 2 m from the floor. Where the beam irradiant exceeds the MPE, a beam path that departs from a regulated area must be enclosed**. (ANSI,1993)**.

1.12.9 Laser applications in oral and maxillofacial surgery

In spite the fact that lasers are extremely useful in all types of minor surgeries, their expense and the difficulty of minimizing unwanted effects are major limitations. Lasers have a variety of benefits over scalpels and electrosurgery in soft tissue cutting. These advantages are **(Caroth & Mckenzie, 1985; Nobor, 1989; Catone & Alling, 1997)**:

1- The non-contact technique which is used during the procedure, will reduce tissue distortion while cutting.

2- The incision will be sterilized by the laser.

3- The laser is always precise in cutting mode.

4-. Scarring after laser procedure is quite minimal.

As a result, it is critical to underline that lasers are a viable alternative to traditional surgical procedures. In oral and maxillofacial surgery, CO2 and diode lasers have become the standard cutting lasers. For homeostasis, several surgeons employed the Nd-YAG laser (**Nobor, 1989**).

Several investigators have discovered that the diode laser can be utilized to treat oral soft tissue lesions which are benign, premalignant, or malignant. (**Caroth & Mckenzie, 1985**). However, it does not have any superior ability to treat these lesions than the scalpel; rather, it is a preferable means of cutting with minimal patient discomfort. Many authors' clinical findings state a high degree of recovery **(Caroth & Mckenzie, 1985; Nobor, 1989; Catone & Alling, 1997)**.

many laser properties applied for soft tissue surgery are beneficial in the surgical treatment of oral cancers and related tissues. The laser's capacity to do hemostatic operation by sealing blood vessels with a smaller diameter; The beam of laser is beneficial since it allows precise surgery in a bloodless field, and it may minimize malignant cell seeding during operation **(Charstpher et al., 1995)**.

Identically, the laser capacity to close the lymphatics during surgery is beneficial in reducing problems associated with surgery such as swelling and edema. This may reduce the need for tracheostomy in the treatment of laryngeal edema, as well as the demand for postoperative steroids. Lymphatics sealing may also reduce the risk of seeding of malignant cells into the lymphatics during surgery. Furthermore, the capability to block endings of nerves aids in reducing discomfort after operation **(Fitzpatrick,1992; Charstpher et al.,1995)**.

The laser's capacity to sterilize wound, make it dry, and sealed is apparent reason of the low rate of infection observed after laser surgical procedure. This is a beneficial in the treatment of malignant lesions because of reducing the need for therapeutic and prophylactic antibiotics. This suggests that wounds that were treated by laser recover with little discomfort and scarring, and that formal reconstruction with primary closure, skin grafting, or local flap procedures is unnecessary since wounds can be left to recover by secondary intention, resulting in a good functional outcome with less scarring and lack of movement. In addition, employing the laser, some treatments that were formerly conducted in the hospital can now be done as outpatient procedures **(Conn, 1981) (Alster & Amy, 1996)**.

In dentistry, laser technology is commonly used. They have become a popular treatment choice for a variety of soft tissue lesions due to their capacity to perform deep and precise incisions, better hemostasis, and less invasive treatments with reduced patient discomfort **(Chaya & Pankaj, 2015)**. Periodontics, endodontics, pedodontics, prosthetics, cosmetic dentistry, oral implant, conservative dentistry, oral pathology, oral surgery, and maxillofacial surgery all these branches make use from the technology of laser (**Afrah et al., 2017**).

Lasers are increasingly being used as the therapy of choice by the specialist and the patients, and are even becoming the standard of care in many cases. In spite of all lasers emit in the same way, semiconductor lasers differ from other types of lasers in terms of both operational performance and pumping mechanism **(Tahrir & Afrah, 2015)**.

1.13 The Aim of the study

Evaluation the therapeutic advantages of diode laser (810-980 nm) in an intraoral pyogenic granuloma treatment compared with conventional surgical technique.

Chapter two

Materials

&

Methods

2.1 Introduction

In this chapter, the equipment, materials and methods will be presented. The laser treatment & dental procedure are illustrated. Also, the evaluation criteria are described. The laser safety measurement that were used in this work also will be mentioned. So, this chapter includes detailed description of materials, patients and methods were used.

2.2 Equipment & Materials

2.2.1 Equipment and materials used during lesion excision with conventional scalpel technique as shown in Fig (2-1) include:

1. Diagnostic instruments (a: mirror, b: probe, c: tweezer).(MDS, Italy)
2. Cheek retractor. (Flamingo dental, U.S.A)
3. Dental syringe. (Germany)
4. Local anesthesia cartilage. (Septodont, France)
5. Disposable dental needle. (CK, Korea)
6. Topical anesthesia. (Egypt)
7. Needle holder. (M.D.S, Italy)
8. Scissor. (M.D.S, Italy)
9. Surgical blade no.12. (Turkey)
10. Blade handle. (Germany)
11. Periosteal elevator. (MDS, Italy)
12. Silk 3/0 suture. (Sinali Dent, China)
13. 10% Formaldehyde solution container. (China)
14. Listerine mouth wash. (Johnson & Johnson, U.S.A)
15. Normal saline for irrigation. (Turkey)
16. Saliva ejector. (Goldenwell, China)
17. Disposable syringe. (MEDICO, U.A.E)

18. Cotton. (S.D.I, Iraq)
19. Gauze. (Sinali Dent, China)

Figure (2-1): surgical equipment used during scalpel procedure

2.2.2 Equipment and materials used during lesion excision with laser technique as shown in Fig (2-2) include:

1. Diode laser (810-980) nm (QuickLase dentalase, United Kingdom).
2. Laser protective goggles supplied with laser system.
3. Disposable laser tips 300µm. (United Kingdom)
4. Diagnostic instruments (a:mirror, b:probe,c:tweezer).(M.D.S, Italy)
5. Dental syringe. (Germany)
6. Local anesthesia cartilage. (Septo Dent, France)
7. Disposable dental needle. (CK, Korea)
8. Topical anesthesia. (china)
9. Cheek retractor. (Flamingo dental, U.S.A)
10. Listerine mouth wash. (Johnson & Johnson, U.S.A)
11. 10% Formaldehyde solution container. (China)
12. Cotton role. (VMED, U.S.A)
13. Gauze. (Sinali Dent, China)

14. Saliva ejector. (Goldenwell, China)
15. Articulating paper. (China)

Figure (2-2): Equipment used during lesion excision by laser technique

2.3 Laser System

2.3.1 Laser System Specifications

Active medium of the dentaLase device: The major component of the dentaLase is the diode laser, which consists of semiconductor "chips" made from Gallium Aluminum Arsenide referred to as AlGaAs. An electrical current is passed through the diode to activate it, resulting in an elliptical shaped display of monochromatic light that may be focussed into a very small point and connected to a delivery fiber. The soft tissue diode laser is a non-ionizing infrared light that does not cause alterations in cellular DNA. The dentaLase unit is an air-fan-cooled device.

- Weight: <1.8 kg
- Laser Classification: diode laser, class IV

- Wavelength: 810 ± 10nm and Dual models D; 810 ± 10nm +980 ± 10 nm
- Fiber Tips Diameter: 200µm_400 um bendable tip.
- Operation Modes: Continuous wave mode and Pulse wave mode
- Dimensions: depth<19cm, width<18.5, height<14.5

2.3.2 Laser System and Parameters

Diode laser 810-980 nm (QuickLase dentalase, United Kingdom) system was used in this study. In the front of the Console is a Display Panel (Touch Screen and Control Button). An external power supply can be used to operate it.Once the desired setting selected (power& mode of radiation) turn on the ready mode and the laser energy emits by pressing down a foot switch. Power setting which applied was 0.8W, Continuous Wave mode (CW) and tip diameter was 300 µm with tips length of 4 mm. The dentaLase is used for a broad variety of procedures of oral soft tissue, temporary relieving of minor pain, and dental whitening. It is generally indicated for incision, excision, homeostasis, coagulation and vaporisation of soft tissue. Laser device unit & parameters are shown in Fig**(2-3)**

Figure (2-3) Quicklase laser device unit & parameters setting

2.3.3 Components of diode laser device (QuickLase dentalase)

1. Quicklase laser unit.
2. Protective glasses+black out for patient.
3. Fibre optic.
4. Handpiece.
5. Disposible fibre tips.
6. Foot switch_ wired.
7. Power adapter and plug.

Figure (2-4): Components of diode laser device (QuickLase dentalase)

2.4 Patients

Forty-two patients had been enrolled in this study (23 female and 19 male) with age range between (10 to 65years) old and mean age of studied sample was 27.93±14.44 year.

All patients required surgical treatment for pyogenic granuloma, the surgical treatment was decided after clinical oral examination. Some patients treated by conventional surgical method, while the other patients treated by using QuickLase diode laser 810-980 nm. The study was carried out from January 2021 to December 2021. The Patients 'were divided into two groups:

Group A: The control group includes 19 patients treated with conventional surgical method by using scalpel (blade no.12)

Group B: The experimental group included 23 patients treated by using diode laser 810- 980nm (QuickLase dentalase, United Kingdom).

2.4.1 (Inclusion Criteria)

- The patients having oral pyogenic granuloma (0.5-2 cm) in diameter.
- Patients aged between (10-65 years).
- Pregnant women who have oral pyogenic granuloma or females with hormonal (estrogen and progesterone) imbalance under close gynecologist observation.
- Adolescent patients & young patients having oral pyogenic granuloma.
- Patients with recurrent lesions.
- Patients who are in good health or who have a well-controlled systemic illness.

2.4.2 (Exclusion Criteria)

- Patient with uncontrol Systemic diseases.
- patients having oral pyogenic granuloma greater than 2 cm in diameter.
- smoker patients.
- Mentally retarded patients.
- patients who receive chemotherapy.

2.4.3 Patient Case Sheets

Case sheet was recorded for each patient in our study. It used to record the demographical information including patients age, gender, medical history and clinical examination of the lesion, follow up visits &the patient questionnaire. It involves all detailed information about pain, discomfort, bleeding, oedema, function & overall satisfaction depend on clinical observations and patient's outcome.

2.4.4 Patients Preoperative Assessment

All the patients were prepared for lesion excision few days before the procedure time. Preoperatively, a patient consent form was collected, and the operation was thoroughly explained to the patient. Full medical and dental history were taken from the patients. Scaling was already done to the patients three days before the procedure time. oral hygiene instructions & prophylactic treatment also were given to the patients. hormonal examination should be also assessed.

2.4.5 Clinical Evaluation Scores

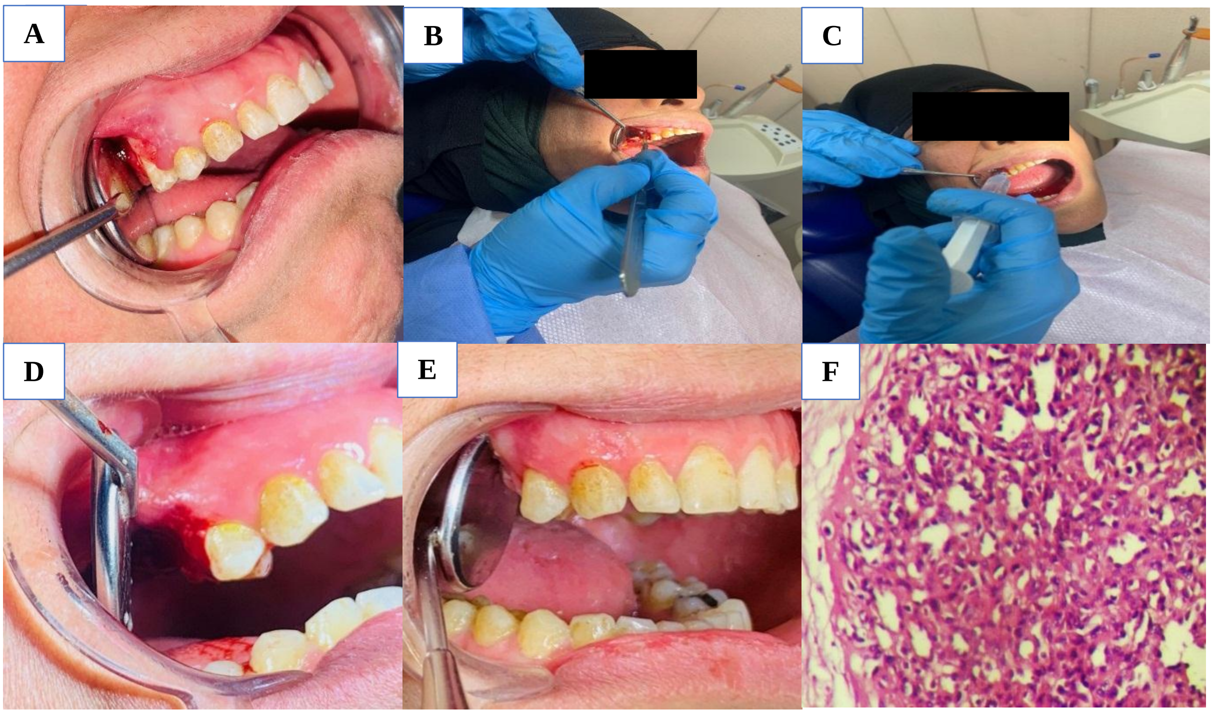
This study designed to assess the therapeutic advantages of diode laser 810-980 nm in an intraoral pyogenic granuloma treatment compared with conventional surgical technique, For the comparison of two techniques, the following clinical parameters were assessed:

- The following score was applied to assess pain: **0.**no pain, **1**. mild pain, **2**. moderate pain, **3**. sever pain.
- Bleeding was assessed according to this score: **0**. no bleeding, **1**. mild bleeding,**2**. moderate bleeding, **3**. sever bleeding.
- The following score was used to assess oedema: **0**. no oedema **1**. mild oedema **2**. moderate oedema, **3**. severe oedema.

- The following score was used to assess function: **0**.no function interference, **1**. mild function interference, **2**. moderate function interference, **3**. sever function interference.
- Overall satisfaction was assessed according to the following score: poor **(%): 0-25`** fair **(%): 26-50`** good **(%): 51-75`** excellent **(%): 76-100.**

2.5 Conventional Surgical procedure

Firstly, the surgical field was exposed & the lesion borders were identified, then the cheek retractor was placed. Prior to surgery; intraoral antisepsis using Listerine mouth wash for roughly 30sec as a part of the treatment strategy. The surgical area was anesthetized by giving deep infiltration to the surrounding oral PG lesion with 2% Xylocaine and adrenaline (2.2 ml cartridge containing 2% lidocaine with epinephrine 1:80.000). The lesions were meticulously cut & excised completely as one piece by using surgical blade no.12 & the surgical operated field was irrigated using normal saline irrigation. The same surgical intervention had been used for all the patients & The wounds layers were sutured to approximate the incision lines &the sutures (silk 3/0) were used to suture the wounds, after that, the specimens were preserved in a 10-percentage formaldehyde solution for histological examination as shown in fig (2-8).



Figure(2-5): Surgical excision technique of 1.5cm pyogenic lesion for 54 years female patient. **A:** Preoperative lateral view. **B:** Lesion excision using surgical scalpel no.12. **C:** Irrigation using normal saline of the wound. **D:** Immediately after suture the wound (postoperative view). **E:** Follow up of the wound after complete healing. **F:** 10X showed histopathological confirmation of pyogenic granuloma.

2.6 Laser Surgical procedure

2.6.1 Fiber Initiation/Carbonizing articulating paper

The laser fiber tip will not cut until the fiber end has been initialized. When the laser is activated while the fiber is in contact with a dark chromophore or articulating paper, the fiber tip is initiated. the handpiece at about 60-degree angle. Once the tip burns the articulating paper; the tip is now ready. The purpose is of fiber initiation to concentrate heat energy at the tip of fiber, increasing the tissue thermal interaction & accelerating lesion excision. Heat can accumulate rapidly inside the tissues because an initiated fiber concentrates the laser energy at the point of tissue contact. Initiation is utilized with lower fluence lasers, notably diode lasers. To avoid collateral tissue damage, the application time should be kept to a minimum. Low settings are used in continuous-wave mode for a short duration to complete the procedure as quick as possible. Fiber initiation & carbonizing articulating paper shown in fig (2-6).

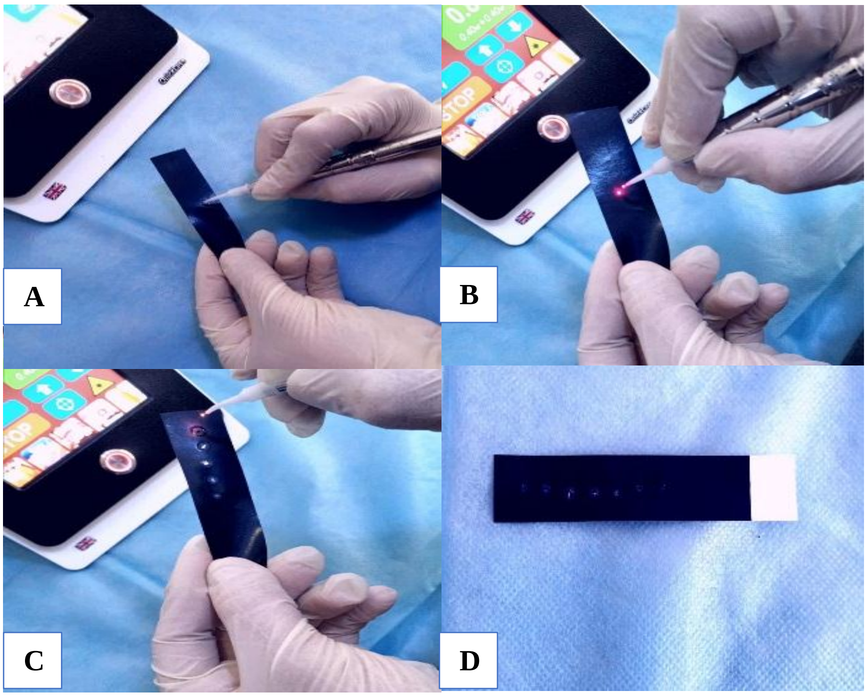


Figure (2-6): Fiber Initiation/Carbonizing articulating paper.

All the surgical teammates worn protective googles & all unnecessary reflective items such as shiny medical instruments, jewelry, watches, etc., were removed from the operating field in which the beam may be located to avoid unwanted beam reflections. Airborne contamination control systems were operated. The beam was carefully controlled in the oral cavity at all times during the operation due to most dangerous lasers are the invisible beam lasers, particularly near infrared lasers. So, a high degree of caution was carefully used when operating with the laser system. Under local anesthesia, the laser surgical procedure was performed. The lesions were removed in one piece using a diode laser (810-980 nm and 0.8W) in continuous wave mode using a fiber-optic delivery system. To achieve coagulation and prevent bleeding, the lesions were meticulously excised by laser fiber tip movement in a sweeping manner on the site of surgery. The wounds were left unstitched for secondary healing purposes, and the specimens were preserved in a 10% formaldehyde solution before being sent for histopathological examination. Then the eyewear's were returned into their protective cases and the scene was kept clean & dry.

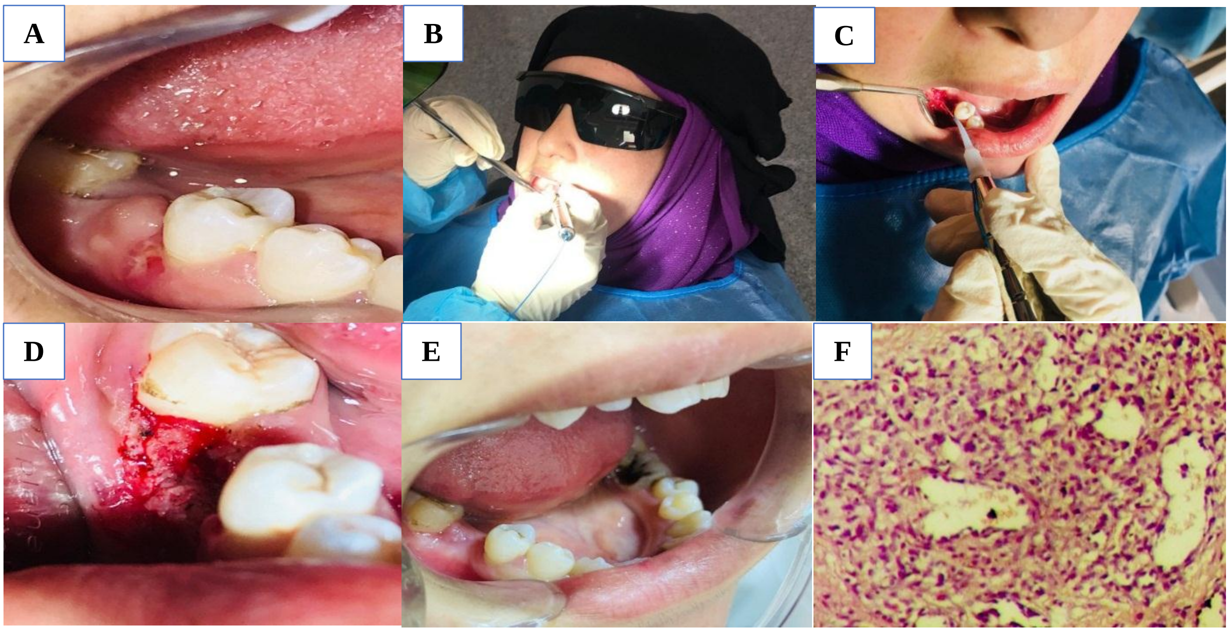


Figure (2-7): Laser excision technique of 1 cm Pyogenic granuloma for 21 years old female patient. **A:** preoperative lateral view, **B**, **C:** lesion excision by diode laser application, **D:** immediately after lesion removal (postoperative view). **E:** Follow up of the wound after complete healing. **F:** 10X showed histopathological confirmation of pyogenic granuloma.

2.7 Postsurgical Instruction

All the patients were given Ciprofloxacin (ciprodar) tablets 250mg (50mg/kg/day), Metronidazole (Flagyl) tablets 500mg (8mg/kg/day) & Mefenamic acid (Ponstan) capsules 250mg (50mg pediatric dose) as analgesic. For the first 24 hours immediately after the operation, the patients were advised to apply cold packs on the operated areas in order to reduce the swelling. Listerine mouth wash were given & utilized as treatment regimen to the patients postoperatively; each patient was motivated to enhance his oral hygiene practice by listerine mouth wash, softly brushing, soft diet for the first week duration after the lesion excision procedure, in order to prevent further mechanical damage to the treated field. all patients were monitored for 3 days, then 1-2&4 weeks to check the healing progress, with a six-month follow-up to rule out the possibility of relapse. All patients were asked to share their thoughts and fill out a questionnaire chart as well as digital images for documentation in order to participate in the study.

2.8 Postoperative Clinical Assessments

Clinical Assessments were done using (Verbal Rating Scale). It was used to assess the study parameters by using descriptive words to describe the severity of pain, bleeding, oedema, function interference & overall satisfaction.

2.8.1 Assessment of Pain was graded as:

- 0= No pain
- 1= mild pain
- 2= Moderate pain
- 3= Severe pain

2.8.2 Assessment of bleeding was graded as:

- 0= No bleeding
- 1= mild bleeding
- 2= Moderate bleeding
- 3= Severe bleeding

2.8.3 Assessment of oedema was graded as:

- 0= No oedema
- 1= mild oedema
- 2= Moderate oedema
- 3= Severe oedema

2.8.4 Assessment of function interference was graded as:

- 0= No function interference
- 1= Mild function interference
- 2= Moderate function interference
- 3= Severe function interference

2.8.5 Assessment of overall satisfication was graded as:

- Poor (%): 0-25`
- Fair (%): 26-50`
- Good (%): 51-75 `
- Excellent (%): 76-100`

2.9 Safety Measures

Biological effects of laser light may depend on a number of factors such as the wavelength of the light& its power, so whenever the laser is operating, the medical team members and patient must wear proper protective eyeglasses to safeguard their eyes and skin from any reflected, diffused, or accidental direct laser beam exposure. The access to the operating room must be limited & suction with high-volume must be applied to empty the plume formed by ablation of tissue. The laser must be in good operating order in order for the manufacturer to take precautions against inadvertent laser exposure. To minimize inhalation of the laser plume, masks must have sufficient filtering ability. A 0.1µm filtration mask should be worn by the surgeon during most laser treatments. Because the laser plume may contain particle organic and inorganic debris (e.g., viruses, chemicals, and toxic gases) and may be infectious or carcinogenic, regular dental masks are ineffective at filtering laser plumes and must not be worn throughout laser surgery.

2.10 Histopathological study

All samples of tissue were fixed in 10 percent neutral formalin and handled using standard paraffin blocks and sectioning techniques: each formalin- fixed paraffin-embedded specimen into 5µm thickness sections were mounted on clean glass slides for staining with Haematoxylin and Eosin (H&E), from each block of the studied sample and the control group for Histopathological evaluation and confirmation of the diagnosis. Specimen collecting container with 10% formaldehyde solution for histopathological study shown in fig (2-8).

Figure (2-8): Specimen collecting container with 10% formaldehyde solution for histopathological study.

2.11 Statistical Analysis

The collected data were loaded into SPSS V24 statistical software program. Descriptive statistics were displayed using tables and graphs. Independent two samples t test was applied to find out the significance of differences between means of related numerical variables. Chi square test was used to find out the significance of associations between related categorical variables. P value less than 0.05 was considered as discernment point of significance.

2.12 Ethical considerations

The research proposal was discussed and approved by ethical scientific committee in the Institute of laser for postgraduate studies. A written consent was taken from each patient after full explanation to the aims of study and insuring him/ her about the confidentiality of the collected data which would be anonymous and would not be used for any purpose other than current study.

Chapter Three

Results,

Discussions

&

Conclusions

3.1. Introduction

This chapter includes the results of this research work, discussion of these results, conclusions and the future work also will be mentioned. For this investigation, a total of 42 patients were joined For treatment of pyogenic granuloma, they all had surgical lesion excision procedures.

3.1.1. Study groups

They were allocated into two groups to treat ,either experimental (laser Group) or control (surgical group) where 55% of the patients were treated by laser and 45% of the patients were treated by surgery as shown in (Figure 3.1).

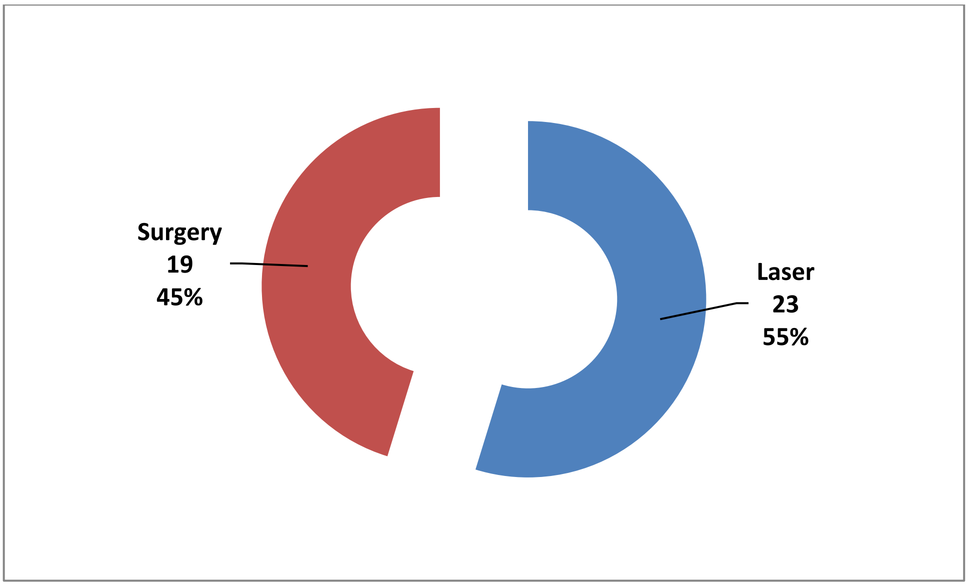


Figure 3.1: study groups

3.1.2. Age and gender

The mean age of studied sample was 27.93±14.44 year (10-65 year).The mean age of laser group was 25.17±11.73year (69.6% of them aged 25 years or less and 30.4% aged more than 25 years), while the mean age of surgical group was 31.26±16.88 (47.4% of them aged 25 years or less and 52.6% aged more than 25 years). (Figure 3.2).

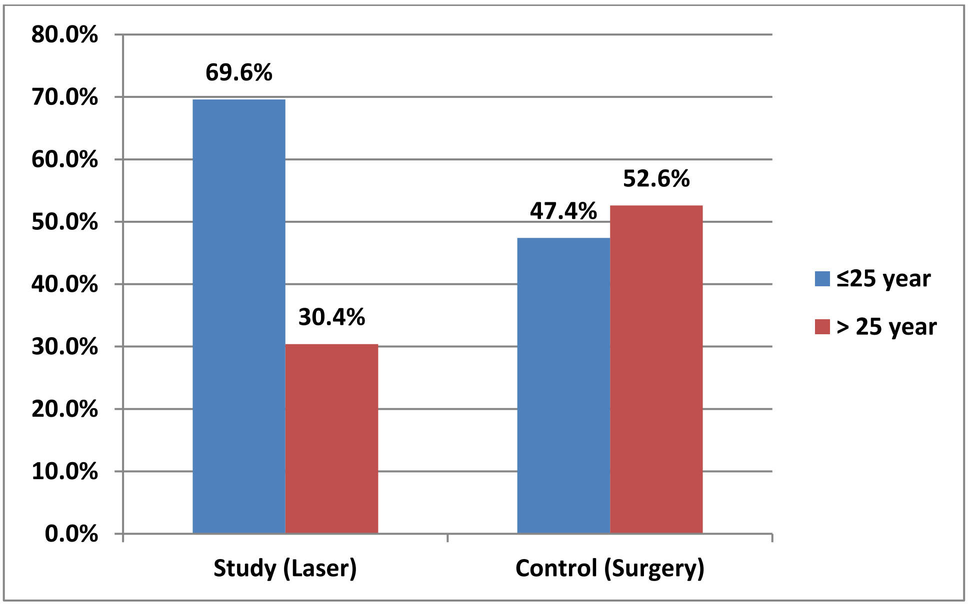


Figure 3.2: Distribution of study patients by age

Regarding gender distribution 10 (43.5%) patients in laser group were males and 13 (56.5%) were females, while 9 (47.4%) patients in surgical group were males and 10 (52.6%) were females (Figure 3.3, table 3.1).

There were no statistically significant differences between the study groups in terms of age (P= 0.177) and gender (P= 0.810).

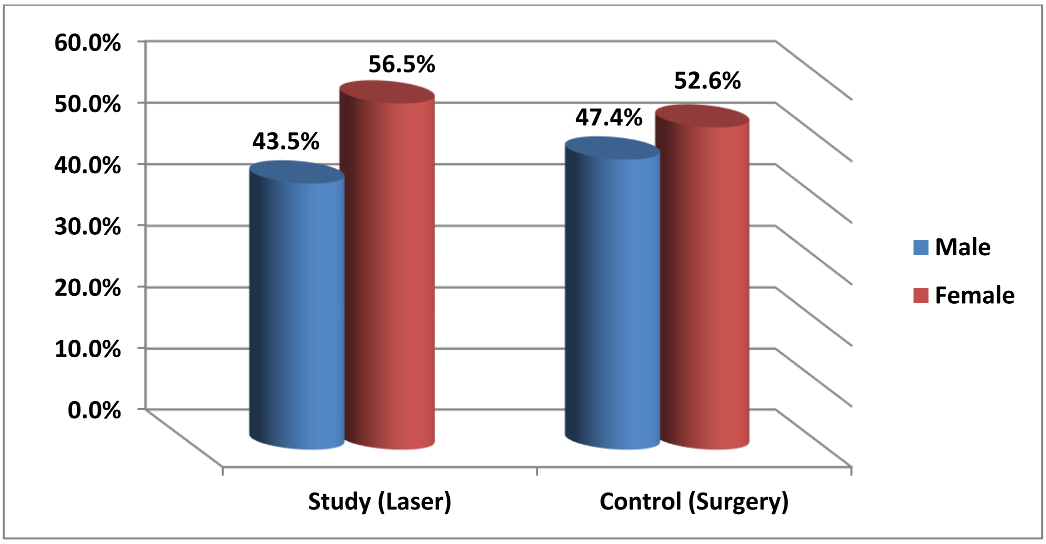


Figure 3.3: Distribution of study patients by gender

Table 3.1: Comparison between the study groups by age and gender Laser Mean ± SD, Scalped Mean ± SD

Demographic data	Study group				P value
	Laser 23 Mean ±SD		Surgical 19 Mean ±SD		
Age	25.17±11.73		31.26±16.88		0.177
Gender	No 23	%	No 19	%	
Male 19	10	43.5%	9	47.4%	0.810
Female 23	13	56.5%	10	52.6%	

3.1.3 Comparison between the study groups by postoperative pain, bleeding, edema, function& patient Satisfaction Score

3.1.3.1. Pain

In the current study, the postoperative pain score showed a statistically significant difference between both techniques. The pain score was significantly lower in laser group than in surgical group at POD3 (1.52 vs 3, P= 0.001), POW1 (0.52 vs 2, P= 0.001), and at POW2. Both laser and surgical groups had no pain at POW4 as shown in (Table 3.2).

Table 3.2: Comparison between the study groups by means of pain score at three days, one week, two weeks, and four weeks after operation.

Post-operative pain	Study group		P value
	Laser	Surgery	
	Mean±SD	Mean±SD	
Day3	1.52±0.51	3±0.	0.001
Week1	0.52±0.51	2±0	0.001
Week2	0	1.1±0.22	0.001
Week4	0	0	-

3.1.3.2 Bleeding

At POD3, the bleeding score was significantly lower in the laser group compared to the scalpel group (0.54 vs 2, P= 0.001), the bleeding score was significantly lower in the laser group compared to the surgical group in POW1(0 vs 1.1, P= 0.001). Patients in the study groups didn't develop bleeding at POW2 and POW4 as shown in (Table 3.3)

Table 3.3: Comparison between the study groups by means of bleeding at three days, one week, two weeks, and four weeks after operation.

Post-operative bleeding	Study group		P value
	Laser	Surgery	
	Mean±SD	Mean±SD	
Day 3	0.54±0.5	2±0.	0.001
Week1	0.±0	1.1±0.315	0.001
Week2	0	0	-
Week4	0	0	-

3.1.3.3 Oedema

It was clear that, there was a statistically significant difference in postoperative edema between the study groups. The swelling score was lower significantly in laser group compared to surgical group at POD3

(1.52 vs 3, P= 0.001). The difference in swelling between both techniques was also significant at POW1 (0.52 vs 2, P= 0.001) and at POW2 and POW4 no swelling was seen among the patients in both groups as shown in (Table 3.4).

Table 3.4: Comparison between the study groups by means of swelling at three days, one week, two weeks, and four weeks after operation.

Post-operative edema	Study group		P value
	Laser	Surgery	
	Mean±SD	Mean±SD	
Day 3	1.52±0.51	3±0.	0.001
Week1	0.52±0.51	2±0	0.001
Week2	0	0	-
Week4	0	0	-

3.1.3.4 Oral function

In this study, a statistically significant difference was found between the study groups in regards to postoperative function score. The function score was significantly higher in laser technique as compared to surgical technique at POD3 (0.52 vs 0, P= 0.002), POW1 (1.35vs 0.26, P= 0.001), at POW2 (2.13 vs 1, P= 0.001). and at POW4 (2.91vs 2, P= 0.001. as shown in (Table 3.5).

Table 3.5: Comparison between the study groups by means of oral function score at three days, one week, two weeks, and four weeks after operation.

Post-operative function	Study group		P value
	Laser	Surgery	
	Mean±SD	Mean±SD	
D3	0.52±0.73	0±0.	0.002
Week1	1.35±0.49	0.26±0.45	0.001
Week2	2.13±0.38	1±0	0.001
Week4	2.91±0.28	2±0	0.001

3.1.3.5 Patient Satisfaction Score (PSS)

Regarding PSS about laser and surgical procedures, laser group achieved significant higher score of satisfaction than surgical group in all times of measurements, at POD3 (0.65 vs 0, P= 0.001), POW1 (1.39 vs 0.26, P= 0.001), at POW2 (2.17 vs 1, P= 0.001). and at POW4 (2.91vs 2, P= 0.001. as shown in (Table 3.6).

Table 3.6: Distribution of the study groups by mean of satisfaction at three days, one week, two weeks, and four weeks after operation.

Post-operative satisfaction	Study group		P value
	Laser	Surgery	
	Mean±SD	Mean±SD	
D3	0.65±0.71	0±0.	0.001
Week1	1.39±0.5	0.26±0.45	0.001
Week2	2.17±0.38	1±0	0.001
Week4	2.91±0.29	2±0	0.001

3.2. Discussion

Pyogenic granuloma (PG. is a well-known oral benign growth, that occurs mostly on the gingiva (it can occur on any surface) in response to long standing, mild, local irritants. Regezi et al. hypothesized that PG is produced by a recognized stimulant or damage inside the gingival crevice, such as calculus or foreign particles, resulted in excessive connective tissue growth, A good agreement with **(Regezi et al., 2003**) **(Newadkar et al., 2018**).

While younger PGs have increased vascularity and hyperplastic granulation tissue, older PGs contain greater collagen. Local irritants and other traumatic factors must be diminished, to avoid recurrence local irritant and other stressful factors must be reduced. A good agreement with

(**Al-Mohaya & Al-Malik, 2016)**. Pyogenic granuloma can affect people of any age; however, it is more common in those in their second decade. Pyogenic granuloma lesions are more prevalent on the facial gingiva than on the lingual gingiva; some extend between the teeth and include both the facial and lingual gums. Majority of the pyogenic granulomas are found on the marginal gingiva and only 15% of the tumors noticed on the alveolar part of the gingiva according to Vilmann et al. A good agreement with **(Amit et al., 2018)**.

Females were found to have a distinct predominance in this study. The most cases can be observed in the 2nd and 3rd decades. Pyogenic granuloma occurs often in pregnant women, to the point where the term "pregnancy tumor" is widely used. These lesions can appear as early as the first trimester and progress until the seventh month of pregnancy. The hormones resume normal concentrations after pregnancy, and some of these lesions heal without treatment or undergo fibrous maturation. A good agreement with **(Amit et al., 2018)**.

The levels of estrogen and progesterone are markedly elevated in pregnancy and can affect the endothelium of oral cavity. A good agreement with **(Newadkar et al., 2018)**. It is generally believed that the vascular effects of female sex hormones play significant role in its pathogenesis**.** A good agreement with **(Namazi et al., 2005; Adusumilli et al., 2014; Asnaashari et al., 2014)**.

The improvement in aesthetic aspect and soft tissue function with minimum invasion should be considered while choosing a treatment approach. Because of the risk of bleeding at the surgery site, the patient's oral hygiene may be compromised. A good agreement with **(Samieifar et al., 2018)**.

Most of collected cases presented with the same features as painless erythromatous nodule where the surface of the lesion becomes ulcerated which can bleed easily on simple probing as a result of less collagen fibers as well as high vascularity and that has a strong tendency to recur after simple excision; in contrast, the older lesion has more collagen and less vasculature. A good agreement with **(Gordon et al., 2010; Debadutta, 2020)**.

In this study, post-operative pain, bleeding and oedema for the experimental (laser) group completely disappeared in most cases at second visit due to the laser's capability to block nerves endings aids in reducing discomfort after operation as well as the laser's capacity to do hemostatic operation by sealing blood vessels with a smaller diameter and close the lymphatics during surgery which aid in reducing problems associated with surgery such as swelling and edema, regarding to patients satisfaction and function also improved at second visit, A good agreement with Roy et al who made it clear that the Patients were recalled after 2 weeks, the lesion had completely healed and patients were not complaining any kind of discomfort **(Roy et al., 2020)**, while the surgical cases were treated surgically by scalpel technique, pain, bleeding and oedema completely disappeared in most cases as well as patients satisfaction and function were improved after four weeks of surgical operation. The difference in surgery time between Group A and Group B was discovered to be greater in scalpel (Group A) patients than in laser (Group B) patients (Group B). When comparing bleeding scores between two groups, we found that Group A had normal bleeding in the majority of cases and Group B had minimal bleeding in all cases, making the difference between Group A and Group B statistically significant. We found similar results when comparing pain and oedema scores between two groups. Accordingly, the laser can be considered a first choice for treating this type of lesion due to fast reaction, a little bleeding, and better repair**.** A good agreement with **(Akbulut et al., 2013; Asnaashari & Zadsirjan, 2014; Darmiani, 2020)**.

The study found that the diode laser had advantages over traditional surgery. The use of a surgical laser to treat soft tissues has a number of potential benefits. Procedures using the diode laser, for example, did not require suturing. The results of this study were compared to those of Vescovi et al, who found that the laser appeared to be a better option than the scalpel procedure. A good agreement with **(Vescovi et al., 2010; Ize-Iyamu et al., 2013)**. Other research by Stubinger et al. showed that the laser can be used for a variety of surgical procedures in the oral cavity, with excellent results on the oral soft tissues. A good agreement with (**Stubinger et al., 2006; Ize-Iyamu et al., 2013)**. As a consequence of the laser's strong cutting and coagulation abilities, there was less intraoperative and postoperative hemorrhage and pain.

The laser is seen to be a much less invasive instrument than that of the scalpel, and the patient acceptance is better. The esthetic use and a need to suture at the end of the procedure permitted the time of operation to be cut in half. In the case of resection of lesion (sessile or pedunculated) which really are benign either children or adults, the laser can be regarded a useful technique. A good agreement with **(Massimo et al., 2021)**.

When compared to traditional treatment methods, laser surgery has additional advantages, such as minimized hemorrhage, rapid sterilization, decreased bacteremia, less use of sutures and/or post-surgical dressing, pain control and less edematous swelling during and after the process, less contraction of wound and minimal formation of scar tissue compared with Surgical therapy which may result in scarring in addition to lasers ability for rapid process of healing and increased acceptance of patients. A good agreement with **(Preeti et al., 2021)**.

The diode laser has been approved by the food and drug administration **(FDA)** for all soft tissue procedures, A good agreement with **(Pai et al., 2014; Sotoode et al., 2015)**, with 810-980 nm wavelengths has been used for surgical cutting procedure of soft tissue. Soft tissue procedures can be done carefully adjacent to tooth structures because wavelengths of diode laser are significantly absorbed by pigmented tissue but minimal absorption by teeth and bones. Additionally, since it eliminates 'beam escape' in an open field and makes this laser safe, diode lasers can cut or evaporate soft tissues in continuous or gated pulse mode via contact or at an exceptionally close distance to the tissue, which prevents injury. A good agreement with **(Coleton, 2004; Coluzzi, 2004; Akbulut et al., 2013; Erbasar et al., 2016)**.

The advantages of lasers in removal of soft tissue lesions include less hemorrhage, less stress, a better field of view for the surgeon and no need for suture with minimal postoperative discomfort. It has also been documented that laser creates locally sterile conditions due to reduction of bacteremia at the site of operation. The patient did not complain from any discomfort during and post-surgical procedure so laser excision is well tolerated by patients with no adverse effect, A good agreement with **(Asnaashari et al., 2015)**.

The application of diode laser can stimulate fibroblast proliferation, collagen synthesis, vessels proliferation accompanied by enhanced epithelial cell division resulting in faster wound healing**,** A good agreement with **(Fekrazad et al., 2012; Ghadimi et al., 2015)**.

The benefits of diode laser surgery include virtually bloodless surgery that aids in greater field visualization since the heat created closes the blood vessels and nerve bundles during cutting, preventing hemorrhage and oedema. This is in contrast to a study by **(D'Arcangelo et al., 2007; Ize-Iyamu et al., 2013)**. that found that scalpel recovery was better than laser repair due to thermal damage to the tissues, but also advised the clinical usage low intensity diode laser as a substitute for knife incision. Furthermore, the laser disinfects of the surgical wound, resulting in less postoperative infection and swelling, as well as faster recovery. When compared to the knife procedure, the laser is a less invasive technique in regions where aesthetics is crucial. A good agreement with **(Rai et al., 2011; Al-Mohaya & Al-Malik, 2016)**.

Dental professionals and oral surgeons are attracted to the usage of diode laser equipment because of its compact size, portability, and decreased costs. For surgical procedures, diode lasers with wavelengths of 810, 940, and 980nm have been employed. All of them are safe and practical. A good agreement with **(Azma & Safavi, 2013; Al-Mohaya & Al-Malik, 2016)**. Lasers have been found to less the need for sutures and lower the amount of bleeding in lesion excisions while also improving working comfort. When compared to other conventional procedures, Powell & colleagues found that using a laser for Pyogenic granuloma excisions has a lower bleeding risk and a higher coagulation rate. According to Rai et al., a diode laser could be a promising therapy choice for intraoral pyogenic granuloma because of its benefits such ease of use and low recurrence rate. When compared to the usual approach, Mavrogiannis et al. found that laser therapy had a lower recurrence rate. Diode laser therapy is connected with quick recovery and minimal postsurgical pain because it is a less invasive and sutureless process.With diode laser therpy, a need for post-surgical dressing is minimized, haemostasis and coagulation are enhanced. It also plays a key function in the elimination of a variety of pathogenic microorganisms. When used to treat such lesions, it has been linked to reduced post-operative discomfort, oedema, scarring, and shrinking. Preserving oral hygiene should be prioritized. The most common reason of lesion recurrence is incomplete resection. Failure to remove causal factors leads to reinjury of the area, which causes it to recur.Gingival lesions have a substantially greater recurrence rate than other oral cavity lesions, according to studies. A good agreement with **(Preeti et al., 2019)**.

Despite surgical resection is the standard treatment for pyogenic granuloma, many researchers had found that up to 16 percent of tumors return following simple resection. A good agreement with **(Kamal et al., 2012; Erbasar et al., 2016)**. It's worth noting that gingival lesions have a considerably greater recurrence rate than other oral mucosal sites. Inadequate excision, failure to eradicate causative causes, and/or repetitive trauma can all lead to recurrence. No recurrence following laser surgery in the treatment of PGs, according to various publications **(Lindenmuller et al., 2010; Rai et al., 2011; Fekrazad et al., 2014; Asnaashari et al., 2015; Erbasar et al., 2016)**. To reduce the likelihood of PG recurrence, certain surgeons still recommend 'surgical excision.' A good agreement with **(Asnaashari et al., 2014; Erbasar et al., 2016)**.

To exploit the major benefits afforded by laser surgery, laser was applied during the excision of a PG located in the oral cavity in the current investigation. We employed a diode laser with a wavelength of 810-980nm, which is a compact equipment that is less expensive than other kinds of dental lasers and has a strong affinity for hemoglobin and dark pigments. The effect of cutting and hemostatic were ideal for analyzing the lesion's histological and vascular characteristics, as well as the area of anatomy in which it had developed. The findings of the follow-up visits revealed that the patients' healing was excellent, with no problems or discomfort. A good agreement with **(Massimo et al., 2021)**.

Diode laser application was compared to traditional surgery by Medeiros Junior et al using a cold blade for the management of soft tissue surgery and found that the laser was related with a shorter surgery time, encompassing presurgical, intraoperative, and postsurgical clinical parameters. A good agreement with **(Medeiros et al., 2015; Massimo et al., 2021)**.

Isola et al investigated the benefits of surgery of a diode laser with a cold blade for pyogenic granuloma resection and found that the diode laser minimized intra-surgical hemorrhage and improved gingival healing when compared to cold blade surgical treatment. A good agreement with **(Isola et al., 2018;Massimo et al., 2021)**.

When studies of diode laser procedures were examined, some researches had found that the pain experienced after the laser surgery was greatly reduced, A good agreement with **(Rai et al., 2011; Esmaeil et al., 2012; Ghadimi et al., 2012),** while it disagree with some studies which had reported that diode lasers caused thermal tissue damage, which resulted in an increase in postoperative pain. A good agreement with **(Asnaashari et al., 2013; Elif et al., 2017)**.

The main goal of surgical treatment is to achieve postoperative satisfactory results with no or minimal intraoperative and postoperative complications with maximum patient’s comfort. Scalpel technique is the gold standard surgical technique but may have some complication postoperatively.

In this study, postoperative pain level was less in laser group than surgical group because Patients undergoing diode laser surgery for oral lesions appear to feel less pain due to the thermal necrosis which frequently caused by tissue vaporization covers the sensory nerve endings. This was also true for our cases and most patients required or minimally required postoperative analgesia. A good agreement with **(Gholizadeh et al., 2020)**. the previous studies had suggested that these differences change according to the wavelength and application time of the diode laser. Another study found that patients treated with laser had considerably less post-operative pain and discomfort, as well as a greater degree of satisfaction. This may be because protein coagulum forms on the wound surface, acting as a biologic dressing and sealing the sensitive nerve terminals A good agreement with **(Parker, 2007)**. When compared to knife surgery, the laser surgical group achieved better results because the patients in the laser group reported less scarring and functional difficulties, A good agreement with **(Kumar et al., 2015)**.

The surgical removal of the lesions with a diode laser can be performed with minimal use of local anesthesia and leads to excellent postoperative healing. Nevertheless, the need for local anesthesia injection depends on the extent of the patient's pain threshold as well as the size and location of the lesion. A good agreement with **(Azma & Safavi, 2013) (Gholizadeh et al., 2020)**.

The use of a diode laser was recommended in the study mentioned previously. Laser surgery takes less time to be performed than traditional surgical approaches.

There was no pain throughout the treatment, and no stitches were required. The hemostasis was optimum immediately after the lesions were surgically removed. Laser surgery was preferred by the patients since it was a painless technique both intraoperatively and postoperatively. As a result, diode laser offers benefits to patients who require treatment using a technique that minimizes blood loss and discomfort, as well as specialists in the field of dentistry.

3.3. Conclusions

According to the obtained results, diode laser (810-980 nm) can be used effectively at the selected parameters settings in the surgical excision of intraoral pyogenic granuloma.

1. The use of a diode laser for the removal of pyogenic granuloma with low invasion technique and many therapeutic benefits can be considered an appropriate and acceptable treatment option.it has a number of benefits, including being less invasive, minimal pain and discomfort during and after surgery, providing better hemostasis and hemorrhage control, and increasing patient satisfaction because the procedure is quick and, in most cases, does not require wound suturing.
2. Another advantage of diode laser in pyogenic granuloma excision involve reduced rates of recurrence, while traditional surgical technique with scalpel increased rates of recurrence**.**
3. The outcomes of this study showed that the diode laser was an effective surgical technique with a many clinical advantages compared with conventional surgery in the soft tissue lesions management.

3.4 suggestions for future work

1. Diode laser 810-980 nm can be compared with another type of lasers such as Nd-YAG soft tissue laser in an intraoral pyogenic granuloma management.

2.Selection larger lesions size more than 2cm.

3.comparism between continuous & pulsed mode diode laser 810-980 nm in soft tissue management.

4-Study the proportion of patients who suffer from lesion recurrence after laser therapy.

5-Selection another diode laser wavelength such as diode laser 940 nm and compare with diode laser 810-980 nm results in pyogenic granuloma management.

6- Diode laser 810-980 nm can be compared with cryosurgery results in pyogenic granuloma management.

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Appendix

Patients case sheet

Ministry of Higher Education and Scientific Research

University of Baghdad

Laser institution for Postgraduate Studies

Patient Case Sheet

Case No. (   )

Name ……………………………. **Age** ……………………………. **Gender** ………………………………….

Address ………………………………………………………… **Phone** ……………………………………..

C/C.………

PDH.………

MH.………

No. of Admissions ……………………………………………………………………………………………

Others ……

Follow up	**Pain**	**Bleeding**	**Oedema**	**Function**	**Overall Satisfaction**
Three days					
One week					
Two weeks					
Four weeks					

Scale	**Pain**	**Bleeding**	**Oedema**
No	**0**	**0**	**0**
Mild	**1**	**1**	**1**
Moderate	**2**	**2**	**2**
Severe	**3**	**3**	**3**

Scale of Pain	**Score**	**Criteria**
No	**0**	**No Pain perception and Sensation**
Mild	**1**	**Mild Pain perception and Sensation**
Moderate	**2**	**Moderate Pain perception and Sensation**
Severe	**3**	**Severe Pain perception and Sensation**

Scale	*Poor (%)*	*Fair (%)*	*Good (%)*	*Excellent (%)*
Function	**0-25**	**26-50**	**51-75**	**76-100**
Overall Satisfaction	**0-25**	**26-50**	**51-75**	**76-100**

الخلاصة

المقدمة: الورم الحبيبي القيحي هو تكاثرالتهابي وعائي حميد ، يتطور استجابة لمجموعة متنوعة من المحفزات ، ويميل إلى النزف بسهولة بسبب التجهيز الدموي العالي للورم.تم تحديد مجموعة متنوعة من الخيارات العلاجية. ينصح بشدة أزالة مصدرالتهيج. أصبح الليزر أداة جراحية فعالة للغاية في مجال جراحة الفم والوجه والفكين.حيث يقدم العديد من الفوائد لعلاج آفات الأنسجة الرخوة ومن ضمنها الورم الحبيبي القيحي؛ التي لا يمكن رؤيتها بالجراحة التقليدية.

الهدف: كان الهدف من دراستنا هو تقييم المزايا العلاجية لليزر الصمام الثنائي (٨١٠-٩٨٠ نانومتر) في علاج الورم الحبيبي القيحي داخل الفم مقارنة بالتقنية الجراحية التقليدية التي تعتمد على الملاحظات السريرية ونتائج المريض.

الطريقه: اثنان وأربعون مريضًا تتراوح أعمارهم بين ١٠ إلى ٦٥ عامًا ومتوسط عمر العينة المدروسة ٢٧,٩٣ ± ١٤,٤٤ عامًا ، ويحتاجون إلى علاج جراحي للورم الحبيبي القيحي داخل الفم ؛ تم تقسيم المرضى عشوائياً إلى مجموعتين: المجموعة التجريبية التي عولجت بليزر الصمام الثنائي (٨١٠-٩٨٠ نانومتر) والمجموعة الثانيه التي عولجت بالطريقه الجراحيه التقليدية بأستخدام المشرط الجراحي. تم الحصول على موافقة خطية من كل مريض بعد شرح كامل لأهداف الدراسة.

النتائج: تم تسجيل تسعة عشر ذكرًا وثلاث وعشرين أنثى في هذه الدراسة وتتراوح أعمارهم بين ١٠ إلى ٦٥ عامًا. في الدراسة الحالية، أظهرت درجات الألم والنزيف والتورم بعد العملية الجراحية فروق ذات دلالة إحصائية بين مجموعات الدراسة. وقد وجدت فروق ذات دلالة إحصائية بين مجموعات الدراسة فيما يتعلق بالوظيفة ما بعد الجراحة ودرجات رضا المرضى. كانت درجات رضا المرضى والوظيفة أعلى بشكل ملحوظ في تقنية الليزر مقارنة بالتقنية الجراحيه التقليديه.

الاستنتاجات:يمكن اعتبار تطبيق ليزر الصمام الثنائي (٨١٠-٩٨٠ نانومتر) خيارًا علاجيًا فعالًا وناجحًا مع العديد من الفوائد السريرية مقارنة بالجراحة التقليدية لاستئصال الورم الحبيبي القيحي وكذلك علاج آفات الأنسجة الرخوة.

وزارة التعليم العالي والبحث العلمي
جامعة بغداد
معهد الليزر للدراسات العليا

الإزالة العاجلة للورم الحبيبي القيحي باستخدام ليزر الصمام الثنائي ٩٨٠ نانومتر

رسالة مقدمة الى
معهد الليزر للدراسات العليا /جامعة بغداد /لاستكمال متطلبات نيل
شهادة ماجستيرعلوم في الليزر/ طب الأسنان

مقدّم الرسالة
آية عبد الكريم مجيد
بكالوريوس طب وجراحة الفم والأسنان

بإشراف
الأستاذ الدكتور تحرير نزّال الدليمي
بورد جراحة الوجه والفكين/دبلوم عالي تطبيقات الليزرفي الطب
ماجستير جراحة الفم والوجه والفكين

٢٠٢٢ ميلادي **١٤٤٣ هجري**