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Review Article

Application of lasers in oral and maxillofacial surgery: A literature review

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ABSTRACT

Laser technology is an important addition to both therapeutic and diagnostic modalities. It is a rapidly growing field and the surgeon must have thorough knowledge of the current literature and also of the advancements so as to perform the laser surgical procedures efficiently and effectively. The surgeon must also be aware of the benefits, safety and hazards of the lasers and must follow the safety guidelines. Advances in the laser systems make the procedures easier to perform. Incorporating the lasers in the oral and maxillofacial surgery practice has led to improvement in the patient care. In this article, we have summarized the application of lasers in the field of oral and maxillofacial surgery by review of literatures.

1. Introduction

The term laser is an abbreviation for —Light Amplification by Stimulated Emission of Radiation. Lasers are regarded as a crucial part of most of the medical and surgical practices which are currently employed. Hence, it is necessary to understand the rationale behind their use so that they can be used efficiently.[1] Lasers have become the standard of care for most of the procedures in the field of oral and maxillofacial surgery and they are considered to be efficient instruments for a various new applications within this speciality. Since mid -1960s, lasers have been included in the practice of oral and maxillofacial surgery. Lasers are commonly used in oral and maxillofacial surgery for the treatment of coagulopathic patients, preprosthetic surgeries, benign, malignant and vascular lesions excision. The emergence of lasers in the field of medicine has led to the development of other techniques like skin resurfacing which would not have been possible with the use of electrocautery or scalpel. With the development of laser surgery, the management of patients with dental implants, derangements of temporomandibular joint, premalignant lesions, sleep apnea, and facial scarring after trauma has changed considerably.[2] They can be used in addition to conventional surgical techniques and also as a sole modality for treatment of various pathologies of the oral cavity and as well as other regions of the body. More sophisticated laser systems have been purchased by some hospitals for use in various specialities such as oral and maxillofacial surgery, general surgery, ophthalmology, dermatology, plastic surgery, obstetrics and gynaecology.[3]

2. History o f Laser Development

In 1917, the development of lasers began when Albert Einstein proposed a theory of stimulated emission. The concept of this theory was based on the quantum theory, developed in the year 1900 based on concept of light given by Max Planck which composed of small energy packets called quanta. Maiman implemented the use of Ruby laser,

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using the experience which he gained while working with the army corps. A pulsed flashlamp was used to pump a ruby optically and the first LASER working model was developed. On May 16, 1960, the first laser was successfully tested.[1]

The actual use of lasers was limited due to cost, complexity and unreliability of the surgical lasers, except in the fields of ophthalmology and dermatology, till the past 15-18 years. Improved knowledge of interactions of light and tissue and new technologies developed for delivering the laser light to the tissue, have transformed lasers into valuable and versatile surgical instruments.[4]

3. Initial use of Lasers in Oral and Maxillofacial Surgeries

The development of CO2 laser and its properties of tissue ablation enhanced the interest in the laser application in the field of surgery. It was noticed that the use of lasers minimised the haemorrhage and provided a bloodless surgical field, the dLase 300 Nd: YAG laser which was designed for use in dentistry specifically, was introduced on May 3, 1990 in the United States by Dr. Terry D. Myers and Dr. William D. Myers. Strong et al. used CO2 lasers for excision of premalignant lesions and malignant lesions surgically and it was the first reported laser use specific to Oral and Maxillofacial surgery among other surgeries. For the treatment of various vascular lesions in the maxillofacial region, Apfelberg used Argon laser in 1987.Since then, the lasers were generally accepted for performing routine procedures in oral and maxillofacial surgery.[1]

4. Laser Physics

To understand the use of the laser, it is necessary to have proper knowledge of the laser principles and how this lasers light is produced and how it interacts with the tissues. The term laser is an abbreviation for —Light Amplification by Stimulated Emission of Radiation. Chain reaction of atoms produces laser light and a laser medium is used consisting of argon, ruby, CO2, and various other elements. Within the laser medium, there is a source of energy (electrical, another light source or chemical) which excites atoms. A laser tube or resonant cavity contains the energy source and medium. When the energy source excites or charges the medium, the atoms in their ground state are put into an excited state. Energized atoms return to the ground state after interacting with each other and photons are emitted which are of identical wavelength. Photon emission is stimulated when photons interact with other atoms in excited states. The laser light delivery to the tissues is by a contact or non-contact mechanism, after the laser light is delivered through fibre optic cable, waveguide and articulating arm system.[3] Four reactions can happen when there is interaction of laser light with tissues: 1. Reflection off the tissue 2. Scattering to the surrounding tissues 3. Transmission through tissues 4. Absorption by the tissue chromophores.

5. Various Laser Systems

Various laser systems available are Carbon dioxide, Argon, Nd:YAG, Hol:YAG, KTP, Er:YAG, Q-switched, ruby, FLPPD, Copper vapour, Excimer and Alexandrite.

Carbon dioxide laser is the most commonly used laser in the surgeries. Zhiquan Huang et al reviewed 73 cases for evaluation of advantages and safety of the CO2 laser and the study showed that CO2 laser used in continuous mode for treating superficial lesions on the mucosa of oral cavity, and also for the precancerous lesions and vascular malformations. Compared to the conventional scalpel surgery assisted with electric knife, the operative time was found to be shorter and there was less bleeding intraoperatively.[5] Excellent haemostasis is provided by the argon laser, as the haemoglobin absorbs the argon beam.[3] White et al compared conventional surgery using scalpel with surgery using Nd:YAG laser and they concluded that laser can be successfully used for soft tissue intraoral applications without using anaesthesia and with reduced bleeding. HO:YAG laser is an excellent tool for arthroscopic procedures of TMJ such as synovectomy, diskectomy and diskoplasty.[2] Er:YAG laser is useful in implant surgery. 2 KTP laser is useful in Vascular and pigmented lesions, Tattoo removal and Blepharoplasty. Q-switched ruby laser is used in removal of pigmented lesions and blue-black tattoo with very low scarring. Flashlamp pumped pulsed dye (flppd) laser is used in Scar revision and haemostasis. Copper vapour laser is used for hemangiomas. Excimer laser is useful in keratotomy for reshaping corneal tissues and correct poor vision. Alexandrite laser can be used for pigmented lesions extending into deep dermal layers.[3] According to Romanos and Nentwig, the incision margin made with diode laser is more accurate compared to other systems. In the management of peri-implantitis, this laser is useful as it offers bactericidal effect and does not alter the implant surface.[2] Studies suggested the use of 980-nm diode laser as an adjunct to the non surgical conventional treatment of peri implant mucositis and initial peri implatitis.[6] These lasers are useful and safe if properly selected and used for oral soft tissue surgery like frenectomy, fibroma, facial pigmentation, epulis fissuratum and vascular lesions.[7]

6. Laser Safety

Safety in operation theatre is highly important during any procedure, special considerations have to be kept in mind while using lasers. Clear written descriptions of precautions of safety must be available in the working environment where a laser is used, as each laser has its own safety issues. This section discusses the necessity of executing safety

precautions for surgical laser procedures.[3] International standards are accessible by means of the International Electrotechnical Commission (IEC), documents 60601, 60825 and 60825-Part 8. These standards are the global criteria for safety of lasers and include informative and normative guidance for the manufacturers, professional clinicians and administrators of laser use facilities. For national standards of the country, they are used as the basis.[8]

6.1. ***Indications of Laser Use***

6.2. *Laser osteotomy*

Using various wavelengths of CO2, excimer lasers, Ho:YAG and Er:YAG laser in vivo and in vitro experimental osteotomies were performed earlier. Histologic sections, light microscopy and SEM did not reveal charring, but a coagulation zone was seen which was due to very narrow basophilic zone close to the cut surface, during cutting of the trabeculae.[9]

6.3. *Benign lesions of oral cavity*

Lasers like CO2, Er:YAG, diode and Nd:YAG lasers have been used for benign lesions‘ excision papilloma, fibroma, mucocele, gingival lesions ,sailoliths, benign lesions of salivary glands, epulis fissuratum, lesions of tongue and excision of hyperplastic tissue. It is minimally invasive and the surgery becomes less extensive, and also decreases the requirement of hospital care or general anaesthesia which in turn lowers the overall costs.[9]

6.4. *Premalignant lesions of oral cavity*

Lasers can effectively excise the premalignant lesions and the recurrence rates of < 20% are noted. The generated heat reaches the cells lying deeper and thus very low rates of recurrence. Recent studies have shown lower recurrence rates with the diode and Nd:YAG lasers while treating the premalignant lesions which may be due to their deeper penetration of light through the tissues.[9]

6.5. *Selected malignant lesions*

Oral cancer with cancer of the oropharynx is the 6th cause of cancer death worldwide. In spite of improvements in the treatments, 5-year survival is seen only in 45−50%. Various studies proved that the laser therapy is sufficient for oral premalignant lesions further studies are needed to evaluate the effectiveness of lasers in the treatment of malignant lesions.[10] In the patients having squamous cell carcinoma of oral cavity, lasers have been used for the excision and it was presumed that thermal energy of laser may seal lymphatic vessels , arteries and veins.[9]

6.6. *Fluorescence spectroscopy and photodynamic therapy (PDT)*

It is a non-invasive procedure which has been used widely for differentiating the tissues and thus may be a valuable tool for the diagnosis of cancer. Differentiating benign from malignant tissues with sensitivity > 80% is possible with PDT. It can improve traditional surgery of squamous cell carcinoma cases by using metatetrahydroxy-phenylchlorine (m-THPC) which is a newer photosensitizer. PDT succeeding Fluorescence-guided removal intraoperatively, seems very promising as it improves the tumor resection radicality in combination with a therapeutic conventional approach.[9]

6.7. *Esthetic and plastic indications*

Since > 25 years, lasers have been employed in facial cosmetic surgery. Argon laser is used mostly for the superficial pigmented and vascular lesions. Nd:YAG laser has been used for the management of vascular deep lesions and tumors. CO2 laser can be used to vaporize the exophytic lesions. Commonest procedure performed using laser is the skin resurfacing which involves removal of epidermal surface layer and papillary dermis which contracts the dermal collagen and allows the skin to uniformly re-epithelialize. The advantages are haemostasis, reduced scarring and reduced disability postoperatively.[9]

6.8. *Surgical indications in children*

Argon, dye and Nd:YAG laser is used for congenital vascular malformations like nevi or hemangioma. CO2 laser has been effectively used in cleft surgery of the infants.[9] CO2 laser surgery with orthodontic appliance which is customized with buccal shield which passively contacts the surgical site, is effective in treating the defects of soft tissue when there is large and high frenal attachment, adhered scar tissue and redundant soft tissue after the alveolar bone graft site healing. Molding of the soft tissues during healing occurs and the morphology of the soft tissues is maintained without relapse even when appliance is not worn for a year.[10] Cleft lip scarring post lip revision surgeries have an annoying appearance especially in patients treated for a bilateral cleft lip. This scarring occurs due to the impaired healing or resolution. Some studies found that the facial wounds, which were sutured in layers healed better. Early treatment with ablative fractional CO2 laser for postoperative scars was preferred by most patients, as it is safe, effective and causes increases the patients satisfaction.[11]

6.9. *Temporomandibular joint laser-assisted surgery*

A common disease involving the facial joint is the temporo mandibular disorder. It is characterized by

temporomandibular joint (TMJ) pain on palpation or mastication, trismus, and TMJ sounds. Such discomforts have an effect on the daily lives of the patients.[12] The need for surgery can be minimised by some effective conservative treatments, like diet modification, physical therapies and medications. Modality therapies which include low-level laser therapy (LLLT), electrotherapy and laser acupuncture, are also advocated before beginning the treatment of temporomandibular joint disorders. Arthroscopic surgery for internal derangements of the TMJ is done by using, CO2, Ho:YAG and Er:YAG lasers. Discectomy, synovectomy, discoplasty, eminectomy, contraction of posterior attachment and haemostasis are performed using this technique through 2 incisions of less than 2mm each.[9]

6.10. Dental implantology

CO2 laser showed better results, which doesn‘t alter the surface of the implant and the changes in the temperature are acceptable clinically and there is significant reduction in the number of bacteria. Clinically, diode laser which doesn‘t change the surface of implant, has very good properties for excision, incision and coagulation of the soft tissues. PDT along with toluidine blue + diode laser beam was used for the management of peri-implant diseases. Hastening of implant osseo-integration and healing of the defect of bone following the augmentation procedures is due to the biostimulating effect of lasers on osteoblasts.[9]

6.11. Laser hemostasis

Diode and Nd:YAG laser have been effectively used due to increased depth of penetration of the laser in the soft tissues. Pulsed lasers have been used for the reduction of thermal effect. Blood optical characteristics cause dispersion and scaterring of the laser light, reducing the harmful effects on the bone. They provide bloodless field intra operatively and the need for suturing is minimised. Due to hemostasis, Visualizing the tissue anatomy and identification of layers becomes easy.[9]

Neuralgic pain is usually the most difficult condition to treat but some studies have shown low level laser therapy can be effective in the management of trigeminal neuralgia and a very good alternative to traditional treatment modalities which have been used in the management of trigeminal neuralgia.[13]

6.12. Sinus lift procedure

Lasers can be effectively used in the sinus lift technique. The procedure is carried out by performing lateral osteotomy using laser with which there is lower incidence of perforation of sinus membrane.[13]

6.13. Fordyces granules excision

Baeder FM, Pelino JE, de Almeida ER, Duarte DA, Santos MT reported a case of excision of fordyce granule present on the lip in a 19 year old male and a high power diode laser was used. Use of laser offered excellent aesthetics. High and low-intensity lasers both effectively excise fordyces granules.[14]

6.14. Oral submucous fibrosis

Laser can be used as an alternative and better tool for surgical fibrotomy in moderate cases of Oral Submucous Fibrosis. Lasers are minimally invasive and are advantageous because of shorter operating time, bleeding control, healing is faster, minimal morbidity, less postoperative scarring and relapse. Laser fibrotomy in moderate cases has been performed under general anaesthesia. ErCr:YSGG laser can be used for fibrotomy and the surgery can be performed under local anaesthesia which is not possible in Group IV cases due to limited access to surgical site but is a good option for Group II and III cases of OSMF. ErCr:YSGG laser offers cost effective, minimally invasive procedure which can be performed under local anaesthesia on a dental chair.[15]

6.15. Endodontic surgery

Laser surgery increases the therapeutic approaches in the endodontic treatment. Mohammad A, Saeede Z, conducted a study and results showed that the erbium laser used for performing apicoectomy had high success rates and is beneficial in terms of therapeutic success and clinical outcome.[16]

6.16. Bisphosphonate-associated osteonecrosis of the JAWS

The ideal treatment remains controversial. Main objectives are to control the infection, to slow down the disease progression, and to facilitate tissue healing. Treatments available are surgical and non-surgical. The non-surgical methods include antibiotic therapy (systemic) and oral antiseptic rinses, along with hyperbaric oxygen, LLLT (low-level laser therapy), and application of medical ozone. Surgical treatments include conservative approaches like debridement of bone, sequestrectomy, more aggressive therapies like removal of affected bone and reconstruction of jawbone, if it is indicated.[17]

6.17. Myofascial pain dysfunction syndrome

Management of MPDS patients with low level laser therapy using diode laser of wavelength 810 nm (Ga-AlAs) showed improved mouth opening and intensity of pain. It is considered to be a non-invasive and a suitable alternative for myogenous pain.[18]

6.18. Fibromyalgia

According to American College of Rheumatology – ACR, it is a musculoskeletal chronic condition which is characterized by pain which is generalized and the body is sensitive when 11-18 points at specific areas also called tender points, are palpated during 3 months.[19] Various treatment options are available for relieving the fibromyalgia symptoms like instructions to the patient, exercises, psychotherapy, alternative medicine, pharmacologic treatment and Low Level Laser Therapy. Recent studies have shown that the low level laser therapy efficiently relieves pain in patients having fibromyalgia.[19]

6.19. Orthognathic surgeries

Low Power Laser phototherapy positively affects the sensitivity recovery following orthognathic surgeries and oral surgeries like third molar extractions, lateralization of inferior alveolar nerve and implant placement. Some studies have described the therapeutic effects of this method following orthognathic surgery. Studies have reported improved neurosensory recovery following mandibular orthognathic surgery using laser therapy. It also reduced postoperative pain and edema.[20] Studies evaluated the efficacy of diode laser in lefort I osteotomy and it proved to be safe and effective for making circumvestibular incisions in Le Fort I osteotomy compared to conventional tools.[21]

6.20. Low level laser therapy

Low level laser therapy is also called low-intensity level laser, soft laser, low-reactive laser and low energy laser and the therapy used is called biomodulation / biostimulation.[22] And has many therapeutic effects which have been described in literature, like hastened wound healing, pain reduction, relief from trismus, reduction in edema, stimulated release of endorphin, immune system modulation and nerve repair, which allows for recovery in sensory perception (objective and subjective) in a short and long-term postsurgical period.[23]

In 1978 it was first reported that when the nerve tissue was exposed to laser radiation, there was a direct effect on the nerve and it was preventive and therapeutic. In 1992, Rochkind demonstrated that Low Level Laser Therapy influenced the morphology and electric activity in traumatised and intact peripheral nerves of rats and action potential of intact nerves raised by 33% following single transcutaneous laser light treatment along with corresponding treatment of traumatised nerves also resulted in raised amplitude of action potential proportional to untreated traumatised nerves. Various other studies, have shown that there was subjective improvement with LLLT in many lesions, musculoskeletal recovery postoperatively and osteogenic differentiation.[24]

6.21. Juvenile hyaline fibromatosis

The management is based on aesthetics and is planned for limiting the orthopaedic disability. The early removal of skin lesions surgically could help, but lesions may recur. Lasers can be used for the removal of lesions and they provide excellent haemostasis and clear field and offer maximum comfort to the patient post-surgery; hence the laser therapy is the treatment of choice for such lesions.[25]

6.22. Advantages of laser surgery

Lasers offer following advantages

1. Increased precision.[26]
2. Better infection control and bacteremia is eliminated.[26]
3. Microsurgical ability.[26]
4. Provides sterile field of operation due to contact free ablation and tumour seeding prevention.[26]
5. Contact- free incision reduces chances of mechanical trauma.[1]
6. Provides bloodless operating field as there if effective coagulation of blood vessel which is useful during removal of hemangioma, epulis fissuratum which is inflamed, incision of soft palate, tongue or tonsillar pillars.[26]
7. As mentioned earlier, due to fewer myofibroblasts at the wound edges, the scarring and contraction are minimised.[1]
8. When compared to scalpel wounds, better healing is seen in laser wounds.[1]
9. Reduced postoperative pain and swelling.[1]
10. Suturing is mostly not needed.[1]

6.23. Disadvantages of laser surgery

Following are the disadvantages of the laser surgery

1. 4-7 days postoperatively, there may be increased incidence of pain.[1]
2. There may be delayed/ slower wound healing.[1]
3. Plume generated during laser surgery in the operating room, may be harmful.[1]
4. Health hazard to all the people present in the operating room due to reflected and scattered laser beam during surgery.[1]
5. Increased cost.[1]
6. Operator training required.[1]

6.24. Future trends in laser surgery

As the understanding of tissue laser interaction and the technology are advancing, there is a constant change in the laser surgery and medicine. Knowledge of the current literature and advances in this field is necessary. There are several techniques which are currently being evaluated.[3]

6.24.1. Photodynamic therapy (PTD)

It is being evaluated for cancers of head and neck region, intra-abdominal region and also for the other types. In this procedure, a photosensitising agent which is absorbed by the cells undergoing ablation is given to the patient prior to the surgery and through a dispersive medium or directly the laser beam is delivered to the area. For intra-abdominal cancers, a lipid medium and a sensitising agent are poured into the abdominal cavity. The laser beam is delivered to the medium which disperses it to multiple areas in the abdominal cavity where the tissue contacts the lipids. Disadvantages: less selectivity for tumour cells and severe burns of the tissues.[3] The noninvasive nature PDT preserves organ function in carcinoma patients. But, it is delayed by the hypoxia in the microenvironment of tumor which is caused by high oxygen consumption in the cells and distortion in blood vessels of the tumor. Hence, raising the oxygen generation in the microenvironment of tumor can be a promising technique for improving the PDT. A study conducted showed that ferroptosis facilitated PDT approach enhanced the anticancer action as it relieved the hypoxia and promoted reactive oxygen species production.[27]

In the microanastomosis of the vascular tissue and nerve, CO2 and some other lasers have been used with good results but in humans, the results have not yet been applied clinically.[3]

In future, microlaser surgery will become more useful with the advances in the delivery systems but for a good anastomosis and reduced scarring, best delivery systems and wavelengths have to be provided.[3]

7. Conclusion

Laser technology is an important addition to both therapeutic and diagnostic modalities. It is a rapidly growing field and the surgeon must have thorough knowledge of the current literature and also of the advancements so as to perform the laser surgical procedures efficiently and effectively. The surgeon must also be aware of the benefits, safety and hazards of the lasers and must follow the safety guidelines. Laser is a powerful tool and is used in the treating various conditions of the head and neck region and also other areas of the body. Advances in the laser systems make the procedures easier to perform. Incorporating the lasers in the oral and maxillofacial surgery practice has led to improvement in the patient care.

8. Conflict of Interest

None.

9. Source of Funding

None.

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