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Research Paper

Applications of Lasers in Oral and Maxillofacial Surgery – A Review Article

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ABSTRACT
LASER technology has become a cornerstone in oral and maxillofacial surgery (OMFS), transforming the field with its precision, versatility, and minimally invasive nature. This article provides practitioners with an update on the use of new dental instruments in daily practice to improve efficiency and reduce issues from traditional approaches.

KEYWORDS: *Laser, Application, Oral and maxillofacial surgery*

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I. INTRODUCTION

Maiman's successful laser demonstration in 1960 predicted its future medical applications. Today, lasers are essential tools for Oral and Maxillofacial Surgeons (OMS), evolving from adjunctive to integral. While the CO2 laser has been the traditional choice, advancements and new laser types have broadened their utility. This growth has strengthened the evidence for their efficacy and safety, enhancing conventional OMS procedures and enabling new techniques not possible with traditional tools [1].

This article's goal is to give a general review of lasers' key features, their clinical use in dentistry, particularly oral surgery, and its benefits, drawbacks, and safety.

INITIAL USE OF LASER IN ORAL SURGERY

Strong et al. were the first oral surgeons to use CO2 lasers for various treatments, including removing premalignant and malignant lesions. In 1974, Kaplan et al. applied lasers for oral tumor treatment. Ackermann highlighted the use of Nd:YAG lasers for oral surgery in hemophiliacs in 1984, while in 1987, Apfelberg utilized Argon lasers to address vascular lesions in the maxillofacial region. [3].

DEFINITION

A laser (Light Amplification by Stimulated Emission of Radiation) generates a powerful, coherent, monochromatic beam of light through optical amplification [1]. This highly directional and in-phase light makes lasers valuable for applications in science, medicine, industry, and communications.

ELECTROPHYSIOLOGY OF LASER

Lasers emit monochromatic, coherent, and collimated beams that produce various effects upon interacting with targets. The energy can be absorbed, reflected, transmitted, or scattered, but tissue absorption is preferred in surgery for predictable coagulation and vaporization. The "laser cavity," where the beam is generated through stimulated emission, includes an active medium, a pumping source, and an optical resonator[1] (Fig.1).

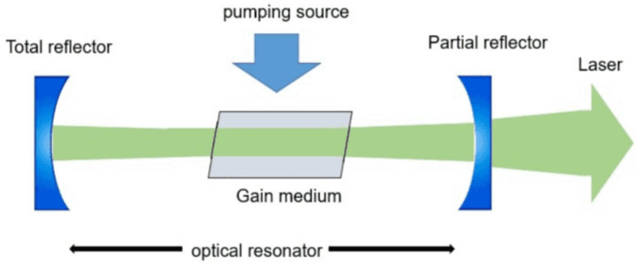

Figure 1 *Components of laser tube*

The main mechanism converts light energy into heat through photothermal effects. Energy is generated by stimulating photons, while an optical resonator with two parallel mirrors around the active medium supports a continuous avalanche process, producing laser light [11]. The active medium—gas, liquid, or solid—defines the laser type and enables stimulated emission. The resulting laser beam, collimated and amplified, is delivered to target tissues via fiber optics, hollow waveguides, or mirrored arms [1] (Fig.2a-c).

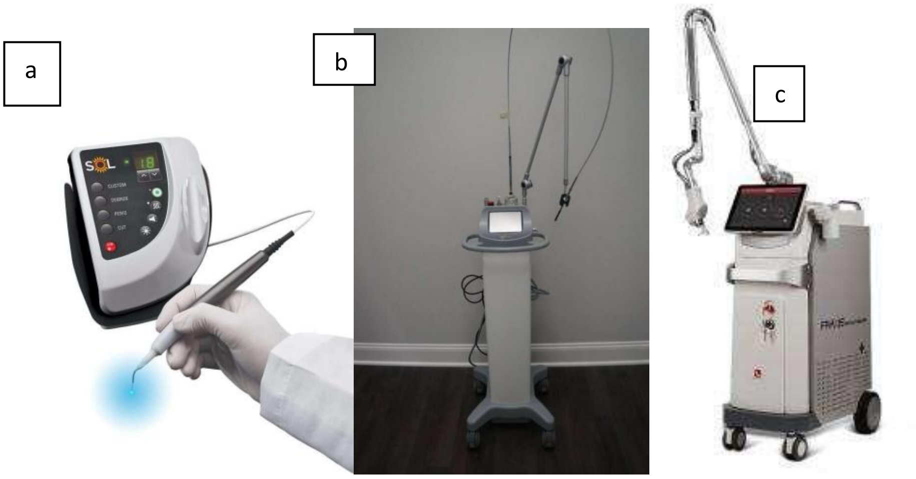

Figure 2 *(a) Fiber-optic laser (b) Hollow wave-guide laser (c) Articulated arm laser*

Lenses focus the laser beam into a focal point for optimal effects. Some fiberoptic systems use quartz or sapphire crystals for better absorption and direct contact, while others operate non-contact. Nd:YAG, CO_2, and erbium lasers emit across the spectrum and often include a visible aiming beam to help surgeons locate the impact point, powered by standard light or a lower-power laser [1].

Surgeons control laser settings such as exposure, power, and spot size, with the smallest size at the focal point for precision. Greater distance enlarges the spot and decreases penetration. Laser type and surgeon speed influence thermal effects. Lasers can be used in contact mode (tip touches tissue) or non-contact mode (beam focused from a distance)[1] (Fig 3a-b).

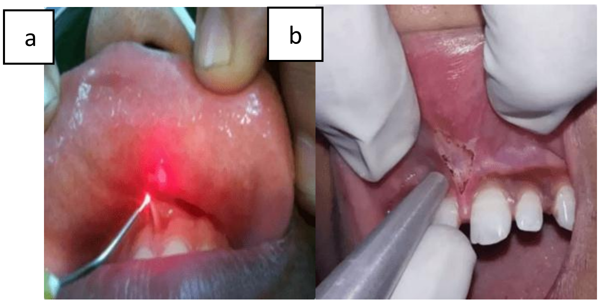

Figure 3 *(a) Contact mode (b) Non-contact mode*

Tissue temperature varies with laser mode and surgeon speed. Lasers are either "continuous-wave" or "pulsed," with pulsed lasers allowing cooling intervals. Proper timing between pulses is crucial to reduce thermal effects. Pulsed lasers can be "gated pulsed" (using an external shutter) or "true pulsed" (internally generated) [1].

INTERACTION WITH ORALTISSUES

Laser light exhibits four distinct interactions with target tissue, contingent upon the optical characteristics of the tissue [16].

1. **ABSORPTION -** Laser energy is absorbed by tissue based on its wavelength, affecting the absorption of components like water and pigments. This wavelength determines both penetration depth and absorption extent in the tissue (Fig.4a).

2. **TRANSMISSION OF LASER ENERGY-** Laser energy can penetrate tissue selectively. Erbium and CO2 lasers are rapidly absorbed at the surface, minimizing damage to surrounding areas, while Nd:YAG, Argon, and diode lasers penetrate deeper, with effects varying by wavelength (Fig.4b).

3. **REFLECTION-** This property causes laser light to reflect off surfaces, reducing its effectiveness on target tissue and posing a risk if redirected to unintended targets like the eyes (Fig.4c).

4. **SCATTERING-** Laser light scattering results in energy loss and reduced biological effects, potentially causing unintentional harm by transferring heat to surrounding tissues (Fig.4d).

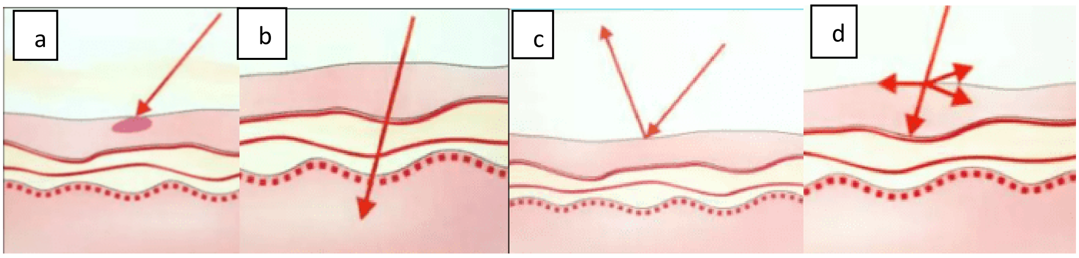

Figure 4*Interaction with oral tissues (a) Absorption, (b) Transmission (c) Reflection (d) Scattering*

CLASSIFICATION OF LASERS [4]

1. **SOFT LASERS** (low energy wavelength)
- Helium-neon lasers (He-N)
- Gallium- arsenide lasers (Ga-As)

2. **HARD LASERS** (High energy wavelength)
- Argon lasers (Ar)
- Carbon dioxide lasers (CO2)
- Neodymium-doped yttrium aluminum garnet lasers (Nd: YAG)
- Holmium-yttrium-aluminum-garnet lasers (HO: YAG)
- Erbium (Er)

3. **BASED ON STATE OF GAIN MEDIUM**

(i) LIQUID
- Dye

(ii) MOLECULAR
- Excimers (Argon-F, Xenon-F)

(iii) GAS
- CO2
- HeN
- Ar

(iv) SOLID
- Nd:YAG
- Er: YAG
- Ruby

(v) SEMI SOLID
- Silicone

4. **OTHER TYPES**
- Chemical
- Dye
- Diode
- Semiconductor

SCOPE OF LASER IN OMFS

Key applications include:

1. **Soft Tissue Surgery**

- Lasers used for Incisions and Biopsies, Frenectomy (Fig.5), Gingivectomy and Gingivoplasty.

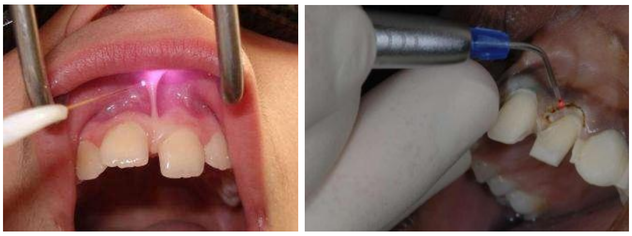

Figure 5*Frenectomy using laser*

2. **Hard Tissue Surgery**

- Lasers are used in Bone Surgery for cutting and contouring bone, Dental Implants.

3. **Aesthetic and Cosmetic Procedures**

- Scar Revision: Reducing the appearance of scars, Skin Resurfacing can be done.

4. Pain Management

- Low-Level Laser Therapy (LLLT) to reduce pain and inflammation in TMJ disorders, Nerve Regeneration: Promoting healing in damaged nerves.

5. Oncology

- Tumor Removal: Eliminating benign and malignant lesions, Palliative Care is effective.

6. Healing and Regeneration

-Photobiomodulation: Enhancing tissue healing and regeneration post-surgery or injury.

7. **Hemostasis**

- Achieves immediate bleeding control during and after surgery.

APPLICATION OF LASERS IN ORAL SURGERY

Laser use in oral and maxillofacial surgery includes [1]:

1. Incisional/Excisional: Precise tissue cutting or removal.
2. Vaporization: Tissue ablation through vaporization.
3. Hemostasis: Achieving coagulation for bleeding control.

1. ORAL LEUKOPLAKIA- Lasers can effectively remove these lesions and promote the regeneration of healthy epithelium. Small lesions are excised with a focused CO2 laser, maintaining a 3–4 mm margin. The choice between excision and vaporization depends on the lesion's texture and thickness. Thick hyperkeratotic lesions, with low water content, cannot be vaporized, while diffuse lesions are unsuitable for excision; for these, CO2 lasers can be used in a defocused mode to create a cross-hatched pattern [4] (Fig.6).
Ishii et al. found that healing of the lesion following laser surgery is effective, with a reduced likelihood of recurrence [10].

Figure 6*Treatment of leukoplakia using laser*

2. ORAL LICHEN PLANUS- Erosive oral lichen planus can be managed with laser treatment, typically using a carbon dioxide laser in continuous, defocused mode with a cross-hatched pattern, along with local and systemic medications. A contact Nd:YAG laser may also be effective. While not a cure, laser therapy provides palliative care, often reducing burning sensations and improving histological appearance [4] (Fig.7).

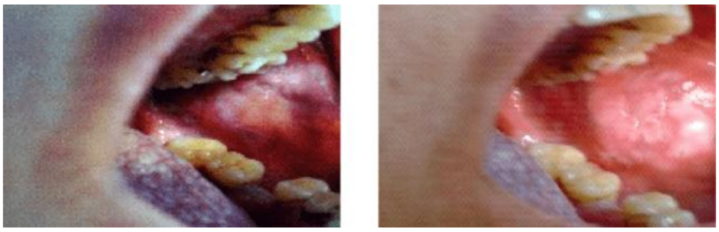

Figure 7 *Treatment of OLP using laser*

3. ERYTHROPLKIA- Erythroplakia is treated by excising the lesion with a pulsed carbon diode laser, followed by focused continuous wave mode to create a moat. To account for potential deeper dysplastic changes, the upper lamina propria should be included, and multiple deep biopsies are advised to prevent infiltration [4].
4. KERATOACANTHOMA- The lesion can be excised with a carbon dioxide laser, minimizing scarring. In pulsed mode, the laser outlines the lesion, then removes a full-thickness wedge by directing the beam perpendicularly. The tissues can then be sutured together [4].

5. RECURRENT APHTHOUS ULCERS- Low Level Laser Therapy (LLLT) offers immediate pain relief and accelerates wound healing. De Souza et al. reported that 75% of patients had significant pain relief during the session, with complete lesion regression in four days, while steroids took 5-7 days. Bladowski et al. found that low-level diode laser treatment can halve healing time compared to pharmaceuticals [4] (Fig.8).

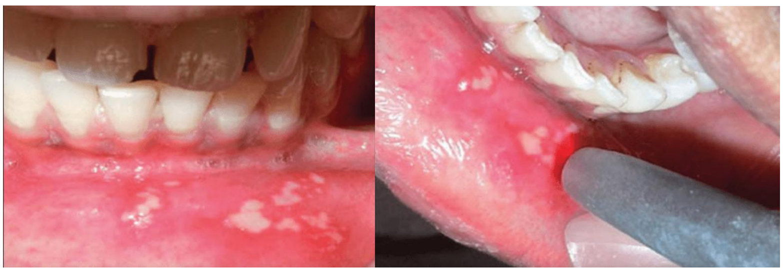

Figure 8*Treatment of RAU using laser*

6. VERRUCOUS CARCINOMA- Exophytic lesions can be excised using a CO2 or Nd:YAG laser. The long-term effectiveness of lasers for leukoplakia control is still unclear. Horsch et al. noted a 78% cure rate with the carbon dioxide laser, and microscopic control improved precision [4] .

7. ORAL SUBMUCOUS FIBROSIS- Shah et al. reported excellent outcomes using the Opal-5 diode laser for excising bands of oral submucous fibrosis. Similarly, Chaudhary et al. identified the Er,Cr:YSGG laser as an innovative and precise technique for treating OSMF [8] (Fig.9).

Figure 9*Treatment of OSF using laser*

8. MUCOCELE- The mucocele can be unroofed and excised with gland tissue using the Laser HF5, which employs high-frequency technology for precise cutting and reduced necrosis risk [4]. A comparison of oral mucocele resection showed that CO_2 laser ablation resulted in more reliable outcomes and fewer complications and recurrences than scalpel resection [2] (Fig.10).

Figure 10*Treatment of mucocele using laser*

9. RANULA- Lai et al. reported a case series on carbon dioxide laser treatment for ranulas, noting that their findings and existing literature indicate it is a safe method with minimal or no recurrence [14] (Fig.11).

Figure 11*Ranula treatment done by laser*

10. PYOGENIC GRANULOMA- Lindenmüller et al. treated a large pyogenic granuloma of the gingiva with a CO_2 laser, noting smooth initial healing and no recurrence after 12 months, with healthy periodontal tissues [2] (Fig.12).

Figure 12*Treatment of pyogenic granuloma using laser*

11. EPULIS FISSURATUM- It is adviced to undergo both surgical excision and prosthetic reconstruction. According to a study, a patient receiving antithrombotic medicine discovered that CO_2 laser removal was succesful and did not result in any major side effects. When it came to removing these lesions, CO_2 is thought to be the best option, especially in individuals who have bleeding disorders [2].

12. GINGIVAL HYPERPLASTIC LESIONS- Asnaashari et al. used an 810 nm diode laser to remove gingival hyperplastic lesions, achieving complete removal in one session with excellent shaping and no recurrence after 6 months [2].

13. LYMPHANGIOMA- A case report on lymphangioma treatment with a CO2 laser found it to be a viable, safe option with potentially lower recurrence rates than traditional excision, though long-term monitoring is necessary [2].

14. HEMANGIOMA- Genovese et al. studied surgical lasers for treating hemangiomas and found that a high-power GaAs diode laser reduced bleeding, shortened surgery time, and enabled faster postoperative hemostasis [2].

15. CANCER OF ORAL CAVITY- A retrospective study assessed the Nd:YAG laser's effectiveness for Stage I squamous cell carcinoma of the lip, showing it aligns with minimally invasive surgical principles. Another study indicated that enoral laser microsurgery for oral cavity cancer yields comparable oncological and functional outcomes with reduced morbidity and few complications [14].
An experimental study compared piezoelectric, laser, and tungsten carbide bur osteotomies. Despite high costs and training requirements limiting their use, lasers and piezosurgery are advantageous for high-risk procedures near vital structures. Equipment choice depends on the patient's condition, the procedure, and the operator's experience [14].
In a clinical instance, the healing process following lesion excision was assessed using a laser diode. The use of laser diodes significantly improved the surgical management of oral cavity cancers [2] (Fig.13).

Figure 13*Treatment of tongue carcinoma using laser*

16. BISPHOSPHANATE ASSOCIATED OSTEONECROSIS OF THE JAWS- A retrospective study on laser surgery with biostimulation versus traditional surgery for bisphosphonate-induced bone necrosis showed no significant differences in outcomes, though stage II patients fared better than stage I. The study highlighted the need for dental health evaluations before medication to prevent BRONJ, noting laser surgery as a viable alternative treatment [2]. Five cases of bisphosphonate-associated osteonecrosis of the jaws treated with an Er,Cr:YSGG laser achieved stable mucosal covering, suggesting that laser surgery is an effective option for treating BRONJ [2].

17. FRENECTOMY- A study compared Nd:YAG laser frenectomies to traditional surgery, finding that the laser method significantly reduced surgical times and transoperative hemorrhage, eliminating the need for sutures [2] (Fig.14). A comparison of upper lip frenectomies using CO2 and Er,Cr:YSGG lasers showed that the CO2 laser provided a bloodless field and shorter surgical times, while the Er,Cr:YSGG laser promoted quicker wound healing [2].

Figure 14*Treatment of Frenectomy using laser*

18. ORAL MELANOMA- A retrospective study found that CO2 laser treatment for oral mucosal melanomas, combined with dental extraction and alveolar curettage, achieved complete surgical resection without compromising quality of life [2].

19. TRIGEMINAL NEURALGIA- The authors found that low-level laser therapy (LLLT) is an effective treatment for trigeminal neuralgia and a valuable addition to standard therapies [7].

20. FORDYCES GRANULES- Excision of Fordyce granules with low- and high-intensity lasers results in better aesthetics, faster healing, and reduced postoperative pain and inflammation [13].

SAFETY PROTOCOL - LASER

1. Provide laser safety goggles for all personnel and patients, ensuring multiple pairs are available [12].
2. Plume hazard: It is Composed of vaporized water, carbon particles, and cellular debris, which emits an unpleasant odor. This smoke can irritate and be toxic [5].
3. Each office should have a Laser Safety Officer to ensure proper laser use, coordinate staff training, oversee protective eyewear, and understand relevant regulations [12].
4. To prevent fire hazards, limit supplemental oxygen or use room air, keeping endotracheal tubes below 30% oxygen. All personnel must understand laser operation, and a "danger" sign should restrict access during use [1].
5. Laser use enhances tissue healing and reduces scarring by minimizing lateral damage, lessening surgical trauma, and improving control over tissue depth [6].

ADVANTAGES OF LASERS USED IN OMFS

1. Laser procedures enhance precision and control, minimizing bleeding for a clear operating field [7].
2. Reduced Pain and Discomfort for the patient [9].
3. Faster Healing and Recovery compared to conventional method of treatment [9].
4. Reduced Risk of Infection providing enhanced aseptic condition [9]
5. Laser procedures result in less postoperative swelling and pain, eliminate the need for sutures, and cause less mechanical trauma due to contact-free incisions [7].

DISADVANTAGES

Laser procedures require a specially trained operator and can be costly. The laser plume generated during treatment may pose risks to personnel, and healing may take longer, potentially leading to increased pain 4 to 7 days after the procedure [7].

LIMITATIONS

The interplay of lasers effects on hard and soft tissues is underexplored. Future research should focus on the thermal effects of lasers, wavelength accuracy, and consider the limited databases used for selecting relevant studies [15].

II. CONCLUSION

In conclusion, laser technology in oral and maxillofacial surgery offers significant benefits, such as increased precision, reduced bleeding, and enhanced patient comfort. This minimally invasive approach promotes faster recovery and less postoperative pain while effectively treating various conditions. Ongoing research is expected to further improve surgical outcomes and patient satisfaction, reinforcing the importance of lasers in modern surgical practice.

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