

FROM SCIENCE FICTION TO SURGICAL REALITY: THE REMARKABLE JOURNEY OF LASERS IN MAXILLOFACIAL PROCEDURES

Abstract

The advent of lasers has left an indelible mark across various scientific domains, solidifying their crucial role in contemporary surgical and medical practices. Consequently, a profound comprehension of the foundational principles guiding laser application becomes imperative, facilitating their seamless and optimal integration. Oral surgery has witnessed an unprecedented surge in laser adoption, encompassing a diverse spectrum of procedural paradigms. Concurrently, a growing community of surgical practitioners has embraced lasers as an indispensable element within their routine clinical toolkit. This article endeavors to provide practitioners with a comprehensive update, shedding light on the dynamic landscape and current intricacies underpinning the deployment of cutting-edge laser technology within established dental protocols. The aim is not only to elevate the proficiency of dental interventions but also to mitigate the inherent sequelae associated with conventional modalities.

Keywords: Lasers, surgery, oral surgery, oral and maxillofacial surgery, ablation

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I. INTRODUCTION

A laser, operating on the principle of stimulated emission of electromagnetic radiation, emits light through a process of optical amplification.[1] The integration of lasers into dentistry during the 1960s, spearheaded by Maiman, instigated a continuum of research into the multifarious applications of lasers within dental practice.[2] The domain of oral and maxillofacial surgery adopted laser technology in the mid-1960s, with the current trajectory witnessing an upsurge in popularity due to the advent of compact, office-based lasers amenable to facile manipulation within the oral cavity. This surge has enriched the surgical armamentarium and expanded the purview of oral and maxillofacial procedures. In this context, lasers have traditionally found utility in pre-prosthetic surgery, excision of benign and malignant lesions, treatment of vascular lesions, and addressing coagulopathic patients.

II. HISTORY OF LASERS

Albert Einstein's seminal work in 1917 laid the foundational groundwork for the inception of the laser and its antecedent, the 'Maser,' postulating that photoelectric amplification could yield a singular frequency in the form of stimulated emission.[1]

By 1957, Charles Hard Townes and Arthur Leonard Schawlow, then affiliated with Bell Labs, embarked upon a rigorous exploration of the infrared laser. Their conceptual evolution transitioned from infrared radiation to visible light, culminating in the coinage of the term "optical maser." In 1958, Bell Labs filed a patent application for their envisaged optical maser, corroborated by Schawlow and Townes' comprehensive theoretical elucidations.[3]

The acronym LASER, denoting 'Light Amplification by the Stimulated Emission of Radiation,' entered public discourse in 1959 through an article authored by Columbia University graduate student Gordon Gould. Theodore Maiman etched a significant milestone by constructing the inaugural operational laser at the Hughes Research Laboratories in Malibu, CA. Utilizing a blend of helium and neon gases, this pioneering creation generated red laser light at a wavelength of 694 nanometers. Meanwhile, another breakthrough transpired in 1961 with the development of a laser originating from yttrium-aluminum-garnet crystals infused with neodymium (Nd: YAG). It's noteworthy that Maiman's prototype operated in a pulsed mode owing to its three-level pumping design.[3] Coincidentally, the same year bore witness to the construction of the first continuous-operation gas laser, employing helium and neon in the infrared spectrum, by Iranian physicist Ali Javan, along with William R. Bennett and Donald Herriott, a feat recognized through the bestowal of the Albert Einstein Award to Javan in 1993. A pivotal stride materialized when Basov and Javan introduced the concept of the semiconductor laser diode.[4]

III. LASERS IN ORAL SURGERY

The effectiveness of lasers as agents for incising soft tissue was initially investigated by Yamamoto et al. in 1972, utilizing ruby lasers.[5] Subsequent advancements, particularly the development of the CO₂ laser with its tissue ablation capabilities, fueled heightened interest in laser applications for surgery. Notably, their utilization was found to curtail local hemorrhage and furnish a pristine surgical field conducive for operation.[6] The dLase 300

Nd: YAG laser, custom-engineered for dental use, was introduced in the United States on May 3, 1990, by Dr. Terry D. Myers and Dr. William D. Myers.[7] Furthermore, credit for the inception of lasers in dentistry is owed to the extensive investigations conducted by Goldman L., who scrutinized the impact of lasers on both soft and hard tissues, emerging as a steadfast proponent of their integration into routine dental practice.

IV. CLASSIFICATION OF LASERS

Lasers are most aptly delineated by their gain medium, thus they are broadly categorized as follows:

1. Gas Lasers:

Helium neon lasers
Nitrogen laser
Argon laser
Carbon dioxide laser
Krypton laser
Carbon monoxide laser
Xenon ion laser
Excimer laser.

2. Solid State Lasers

Ruby laser
Nd: YAG laser
Er: YAG laser
Ho: YAG laser.

3. Other Types of Lasers

Diode lasers
Dye lasers
Semiconductor lasers
Chemical lasers
Lasers can also be classified based on their application

4. Hard Tissue Lasers

Operate at longer wavelengths
Achieve tissue incision through ablation
Employed for tooth and bone procedures

5. Soft Tissue Lasers

Employ low-energy wavelengths
Induce tissue incision through coagulation, vaporization, and carbonization

V. PRECAUTIONS BEFORE AND DURING IRRADIATION

- Employ protective eyewear for all individuals involved (patient, operator, and assistants).

- Ensure noncontact mode to prevent inadvertent irradiation.
- Safeguard the patient's eyes, throat, and surrounding oral tissues outside the target area.
- Utilize wet gauze packs to minimize reflections from shiny metal surfaces.
- Maintain adequate high-speed evacuation to manage generated debris effectively.

VI. APPLICATIONS OF LASERS IN ORAL SURGERY

The realm of maxillofacial surgery is marked by an extensive spectrum of laser applications, each contributing to refined surgical outcomes and enhanced patient experiences.

- 1. Soft Tissue Excision:** Laser utilization in tissue excision within OMFS offers distinct advantages. Comparative assessments reveal that laser-assisted excisions exhibit diminished bleeding in contrast to traditional scalpel techniques. The concomitant hemostatic effects of lasers further cultivate a virtually bloodless surgical milieu, while thermal interactions engender coagulation in adjacent regions. This dual effect extends to the postoperative phase, where notable reduction in swelling has been observed.[9]
- 2. Frictional Keratosis:** Laser therapy finds utility in addressing frictional keratosis lesions. Employing carbon dioxide lasers equipped with a 0.2mm spot size, proficient excision of small, questionable lesions becomes attainable. The procedural approach involves meticulous creation of an elliptical lesion outline, elevation of tissue edges utilizing forceps, and subsequent precise dissection of underlying tissues via laser application at a deliberate angle.[10]
- 3. Smokeless Tobacco-Induced White Lesions:** Laser-assisted intervention holds promise for lesions induced by smokeless tobacco usage. Focused laser application is adept at the excision of such lesions, particularly those ensconced within the mucolabial or mucobuccal folds of the mandible. Notably, persistent lesions post-habit cessation warrant meticulous evaluation and may necessitate targeted laser ablation for optimal resolution.[11]
- 4. Leukoplakia:** Laser therapy emerges as a viable modality for treating an array of oral white patches, encompassing benign, leukoplakic, and malignant lesions. The CO₂ laser's distinct attributes render it instrumental in achieving favorable outcomes. While resection of benign lesions culminates in robust healing, managing premalignant and malignant lesions demands judicious follow-up to gauge post-laser treatment recurrence rates and epithelial stability.[12]
- 5. Solar Cheilitis:** Addressing solar cheilitis lesions along the vermilion border of the lips, especially the lower lip, mandates precision and comprehensive management. Carbon dioxide lasers, wielded with focused accuracy, enable precise outlining of lesions, curtailing the propensity for transformation into squamous cell carcinoma and ensuring meticulous therapeutic navigation.[13]

- 6. Laser Vaporization and Ablation:** Laser technology proves invaluable for the targeted vaporization of large, epithelium-confined surface lesions, circumventing excessive tissue removal synonymous with conventional scalpel techniques. Furthermore, laser ablation strategies facilitate selective removal of cell layers from superficial surfaces, accentuating precision and tailored treatment outcomes.[14]
- 7. Coagulation and Hemostasis:** Laser-induced hemostasis, achieved through precise collagen contraction in vessels with diameters up to 500 μm , redefines bleeding control within the surgical milieu. This property engenders a meticulously bloodless surgical field, amplifying surgical precision. Employing the defocused laser mode over dry, saliva-free surgical sites further ensures effective bleeding arrest, fostering optimal visibility and procedural clarity.[14]
- 8. Recurrent Aphthous Ulcers and Apicoectomy:** Beyond the purview of conventional surgical interventions, lasers extend their transformative influence to recurrent aphthous ulcers and apicoectomy procedures. Low Level Laser Therapy (LLLT) emerges as a potent tool for alleviating palpable pain and expediting healing in recurrent aphthous ulcers. Notably, the immediate pain relief and expedited regression of lesions witnessed post-laser treatment surpass the outcomes associated with traditional steroid-based interventions. Additionally, laser technology augments apicoectomy procedures by not only effecting root structure removal but also by concurrently sterilizing infected root areas, fostering optimal surgical outcomes.[15][16]
- 9. Frenectomy and Sialolithotomy:** Laser-guided excision extends to frenectomies, where their precision and swift execution facilitate the excision of high frenal attachments. Minimized bleeding and enhanced precision remain hallmarks of laser-assisted frenectomy. Moreover, sialolithotomy procedures are enhanced by laser-guided incisions, characterized by a distinct flash of light upon reaching the sialolith. This feature serves to expedite localization within the duct, augmenting procedural efficiency and accuracy.
- 10. Trigeminal Neuralgia and Mucocoele:** Laser therapy's expanding frontiers encompass the management of conditions like trigeminal neuralgia, wherein its efficacy as a standalone or adjunct treatment mode demonstrates notable success. Low reactive level laser therapy (LLLT) emerges as an effective strategy for alleviating neuralgic pain, affording patients a life with reduced discomfort. Similarly, laser technology transforms the management of lower lip mucocoeles, with carbon dioxide laser vaporization yielding commendable outcomes marked by minimal complications and recurrence rates.[17][18]
- 11. Temporomandibular Joint Arthroplasty and Prevention of Surrounding Anatomic Structures:** In the intricate domain of temporomandibular joint arthroplasty, Holmium Laser emerges as a compelling tool, expediting tissue ablation, and enhancing procedural precision with minimal energy consumption. Furthermore, laser bone cutting systems, underpinned by integrated tissue differentiation sensors, emerge as invaluable assets in osteotomies. By mitigating risks to critical structures such as blood vessels and nerves, these systems redefine surgical precision while preserving anatomical integrity.[19][20]

12. Ankyloglossia and Excision of Birthmarks: Laser applications extend their transformative touch to ankyloglossia correction, offering infants and mothers a non-invasive avenue for improved, pain-free breastfeeding. Er:YAG and 1064 diode lasers stand as alternatives, obviating the need for operating rooms or general anesthesia. In a parallel trajectory, the eradication of Café-au-Lait birthmarks gains prominence through the deployment of pulsed dye laser therapy at 510 nm. Prolonged follow-up studies validate the complete clearance of lesions, fortifying the safety and efficacy of laser interventions within this context.[22][23]

13. In Summation: The expansive landscape of laser applications within oral and maxillofacial surgery attests to their paramount significance in reshaping procedural paradigms. With each application, lasers underscore their prowess in augmenting surgical precision, minimizing complications, and optimizing patient outcomes. As the field continues to evolve, the harmonious integration of diagnostic and therapeutic laser techniques holds the promise of further redefining the boundaries of contemporary oral and maxillofacial surgical practice.

VII. LASERS IN ORAL IMPLANTOLOGY

An advantage of laser use lies in the immediate availability of impressions after second-stage surgery due to the hemostatic effects of lasers, resulting in a minimally bloody surgical field. Laser surgery also minimizes tissue shrinkage post-operation, ensuring consistent tissue margins throughout healing.[24]

- 1. Implant Site Preparation:** Lasers find utility in mini implant placement, particularly in patients prone to bleeding issues, ensuring virtually bloodless bone surgery.
- 2. Diseased Tissue Removal around Implants:** Lasers aid in ailing implant rehabilitation by decontaminating surfaces through laser energy. Diode, CO₂, and Er:YAG lasers are suitable for this purpose. They also facilitate the removal of granulation tissue in cases of inflammation around osseointegrated implants.
- 3. Socket Sterilization:** In immediate implant dentistry post-tooth extraction, lasers swiftly and painlessly sterilize infection-free sockets.
- 4. Peri-Implantitis:** Laser therapy proves effective in vaporizing granulation tissue and cleaning implant surfaces in peri-implantitis, positively impacting guided tissue regeneration and extending implant utility.
- 5. Sinus Lift Procedure:** Lasers assist in the sinus lift procedure by minimizing the incidence of sinus membrane perforation during lateral osteotomy.

6. Advantages of Laser Surgery

Laser adoption persists due to the following benefits:

- Reduced morbidity and anesthetic requirements post-surgery
- Sterilization of the surgical area, reduced mechanical trauma, decreased swelling, pain, and scarring
- Effective coagulation of blood vessels, maintaining a bloodless field
- Enhanced precision and accuracy due to ablative properties and controlled depth penetration
- Reduced wound contracture and scarring histologically
- Improved healing compared to scalpel incisions
- Decreased need for sutures.

7. Drawbacks of Laser Surgery**Despite its advantages, laser surgery has drawbacks, including:**

- Potentially delayed healing speed
- Increased pain incidence 4-7 days post-surgery
- Generation of harmful laser plume during the procedure
- Risks posed by scattered and reflected laser beams to personnel
- Elevated cost and operator training requirements.

VIII. CONCLUSION

The future of oral and maxillofacial surgery will inevitably involve specific laser technologies. Surgeons should strive to acquire adequate knowledge of laser applications, encompassing both soft and hard tissue use. Ensuring a systematic approach and safety guidelines during laser-assisted surgeries is paramount. Anticipated growth lies in the integration of diagnostic and therapeutic laser techniques, shaping the evolving landscape of oral and maxillofacial surgical practices.

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