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REVIEW ARTICLE

Laser applications in oral surgery and implant dentistry

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Abstract Lasers have been used for many years in oral surgery and implant dentistry. In some indications, laser treatment has become state of the art as compared to conventional techniques. This article is a comprehensive review of new laser applications in oral surgery and implant dentistry. One of the most interesting developments over the last years was the introduction of the 9.6-μm CO_2 laser. It has been shown in the recent literature that the use of this new device can preserve tissue with almost no adverse effects at the light microscopic level. In contrast, modifications of approved CO_2 laser therapies of premalignant lesions resulted in higher recurrence rates than the conventional defocused laser technique. However, several studies indicate that other wavelengths such as Nd–YAG (λ=1,064 nm) or diode lasers (λ=810 nm) may be also of value in this field. In many other indications, the use of lasers is still experimental. Intraoperatively used photodynamic therapy or periimplant care of ailing implants with the CO_2 laser seems to be more of value than conventional methods. However, further studies are required to assess standard protocols. Over the past years, research identified some new indications for laser treatment in oral surgery and implant dentistry. Moreover, well-known laser applications were defined as state of the art. Nevertheless, further studies are required for laser treatment in oral surgery and implant dentistry.

Keywords Laser · Oral surgery · Implant dentistry

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Introduction

This article is a comprehensive review of recent laser applications in oral surgery and implant dentistry, providing information for dentists and oral and maxillofacial surgeons. Therefore, the authors focus on new laser techniques in osteotomy, treatment of premalignant lesions, fluorescence spectroscopy and photodynamic therapy (PDT), periimplant care of ailing implants, and local hemostasis.

To understand the use of laser surgery, it is necessary to know the fundamental principles of laser light. Unlike other light sources, lasers emit coherent, monochromatic, and collimated electromagnetic radiation. These characteristics endow lasers with unique applications. The most common surgical lasers emit wavelengths in the infrared part of the spectrum: the neodymium:yttrium–aluminium–garnet laser (Nd–YAG, λ=1,064 nm), the erbium–yttrium–aluminum–garnet laser (Er–YAG, λ=2.94 μm), and the CO_2 laser (λ= 10.6 and 9.6 μm). Within the visible portion of the electromagnetic spectrum, argon lasers emit a light between 458 and 515 nm, and excimer lasers are located in the ultraviolet part of the spectrum (100 to 400 nm). Diode lasers emit wavelengths of λ=810 and 906 nm. In surgical indications, within the last years, the latter seem to be of increasing interest.

Whether a laser system is suitable for incisions, vaporization, or coagulation is determined by the wavelength, the energy fluence, the optical characteristics of the tissues, and how the laser is operated. In continuous mode, the laser provides a constant and stable delivery of energy. Pulsed laser systems, in contrast, provide bursts of energy. Lasers within the ultraviolet region (100 to 380 nm) are able to ionize tissues, a process known as photochemical desorption. Lasers of longer wavelengths, especially those within the infrared part of the spectrum (700 to 10,000 nm), cause significant tissue heating. Most of the surgical lasers are embedded in this group and comprised as thermal lasers. The light of these lasers is rapidly converted to thermal energy, causing denaturation of proteins, decomposition of tissue, microexplosion of cell water, and charring. However, recent studies showed that the CO_2 laser at 9.6 μm made an important step toward replacing conventional osteotomy techniques [1, 2].

New laser applications in oral surgery and implant dentistry

Laser osteotomy

For most patients, drills and hand pieces are the most inconvenient components in oral surgery. Therefore, laser osteotomy could be an elegant alternative [1–3]. Research was focused on most of the medically used laser systems. The major components of bone and dental hard tissues are inorganic structures such as water and hydroxyapatite as well as organic structures (collagen). Several authors described the critical temperature for bone and noted that temperature elevation between 44 and 47°C may lead to osteonecrosis [3]. The laser light emitted by the CO_2 and the Er–YAG laser are well absorbed by water. The wavelength of the Er–YAG laser, moreover, is well absorbed by water and hydroxyapatite. In addition to a high absorption coefficient for water and for hydroxyapatite with phosphate, carbonate, and hydroxyl groups, the energy emitted by the CO_2 laser at 9.6 μm is also highly absorbed by collagen. Therefore, this wavelength seems to play an increasingly important role in oral and maxillofacial surgery.

Eyrich [1] compared the super-pulsed CO_2 laser at 9.6 μm to the Er–YAG laser and the conventional drill with regard to their respective thermal effects on human bone. Therefore, temperature rise during ablation of human bone was measured. The results of the study suggested that a maximum rise of mean temperature to 1.88°C (well below the critical range of 7°C) demonstrated the safety and tissue-preserving capability of the super-pulsed 9.6-μm CO_2 laser. The laser caused an even lower temperature rise than conventional drilling when using this device for osteotomies on larger bone segments compared to small bone slices. Moreover, the laser showed acceptable efficacy with drilling times comparable to a conventional drill.

In another study [1], bony osteotomies were produced in six patients with 60-μs pulses of a pulsed 9.6-μm CO_2 laser and a scanning system. Histologic sections revealed no charring, but a very thin basophilic zone was seen next to the cut surface. Cutting trabecular structures resulted in a coagulation zone of 20–150 μm. The author concluded that clinical use of a 9.6-μm CO_2 laser as a cutting tool can be considered to preserve tissue with almost no adverse effects at the light microscopic level.

Lasers in premalignant lesions of the oral mucosa

According to the literature, malignant transformation of premalignancies such as oral leukoplakia and oral lichen planus occurs in up to 28% of these lesions [4]. Consequently, due to the high rates of malignant transformation and basically unchanged prognosis of head and neck cancer, early treatment of premalignant lesions is mandated. Even though there are some reports in the literature on laser-assisted tumor treatment, surgery is mostly performed conventionally. As an alternative to the scalpel, the CO_2 laser (λ=10.6 μm, continuous wave, defocused) is an established device which has been in use for more than 20 years. It has been demonstrated histologically that thermal laser energy carbonizes superficial parts of epithelium. Consequently, reepithelization is delayed for more than 2 weeks. This technique has been proven very effective being associated with recurrence rates of less than 20% [5].

However, a delay in healing caused by the thermal laser energy is an encumbrance for the patient. Therefore, new methods of applying laser energy, such as scanners or the use of very short laser pulses (the so-called super pulses, sp), could be of value. Scanners allow the focused CO_2 laser beam to sweep quickly over an area, thereby reducing the dwell time on each individual point to less than 1 ms which is shorter than the thermal relaxation of soft tissue (3.6 ms) [6]. Through the use of the sp-mode as well as the scanners, thermal laser effects such as delays in healing can be reduced but, on the other hand, a lesser degree of destruction of dysplastic cells could lead to an increased recurrence rate.

Accordingly, the aim of a recent study was to evaluate the recurrence rates resulting from different methods of CO_2 laser surgery in a prospective clinical study. Therefore, a total of 56 patients with a total of 68 premalignant lesions of the oral mucosa were treated with three different modes of CO_2 laser surgery [5]. In the group with defocused resection of oral leukoplakias, a recurrence rate of 23.1%

was seen, which is very similar to that found in the literature [4, 7]. In contrast, neither the application of scanner plus cw-irradiation nor the scanner plus sp-mode yielded results superior to those of the classic defocused technique. These results were explained by the pulsed mode of laser beam delivery and, furthermore, the geometry of the laser beam on the scanned area.

Oral lichen lesions were associated with very high recurrence rates. According to the literature, oral lichen is an autoimmune disease which is not amenable to healing by means of resection. Consequently, only erosive lesions should be treated to achieve pain relief for the patient.

Tissue effects resulting from different scanning systems were also assessed in an experimental study [8]. Therefore, healing of skin wounds after CO_2 laser resection was evaluated with the use of two different scanners (Swiftlase® and Silktouch®). Histologically and clinically, both scanners yielded better results with regard to progress of wound healing than those seen with the use of a defocused laser beam. Nevertheless, these differences could no longer be detected at 2 weeks after surgery. Due to the digitally generated mode of the laser beam on the irradiated area, smoother skin surfaces were yielded with the Silktouch® scanner.

In recent studies, very low recurrence rates were observed with the Nd–YAG laser (λ=1064 nm) [9] and a diode laser (λ=810 nm) [10]. At these wavelengths, laser energy is not absorbed to any significant extent in water. As a result, deleterious effects on sensitive structures such as the mental nerve might occur. Nevertheless, the use of these wavelengths for resection of premalignant lesions should be evaluated in subsequent studies.

Lasers in fluorescence spectroscopy and PDT

Laser-induced fluorescence (LIF) spectroscopy is a noninvasive technique that has been used in various fields to differentiate tissues and, therefore, might be an important tool for cancer diagnostics. In a recent pilot study, the ability of LIF spectroscopy to detect dysplasia or cancerous tissue was validated [11]. Therefore, a 337.1-nm nitrogen laser with a 600-μm fiber optic was used to induce fluorescence in human normal and pathological tissues. Fluorescence spectra were obtained by means of a spectrograph and analyzed by a computer program. The results of this study indicated that differentiation of benign and malignant tissues was possible with a sensitivity above 80%. The authors concluded that this method might be applicable for discrimination of benign and malignant tissues. It was stated that LIF spectroscopy may provide the clinician with a reliable technique for detecting malignancies. Nevertheless, the authors recommended further studies to verify the in vivo applicability of the method.

It has been shown in the past that PDT can optimize conventional surgery in squamous cell carcinoma [12–14]. In a recent animal study, PDT has also been performed intraoperatively next to vital structures like the carotid artery using a new photosensitizer meta-tetrahydroxyphenylchlorin (m-THPC) [14, 15]. As a result of the irradiation, complete necroses of muscles and connective tissue were found. Nerve tissues demonstrated demyelination (above 75%), however, without clinical symptoms.

Intraoperative PDT using m-THPC has also been performed in 22 patients with malignancies of the brain [16]. The authors concluded that m-THPC-mediated, intraoperative fluorescence-guided resection followed by PDT is a highly promising concept in improving the radicality of tumor resection combined with a therapeutic approach.

Nevertheless, more studies are necessary before these methods can be recommended as standard therapies in the treatment of oral carcinoma.

Periimplant care of ailing implants

A new indication of laser treatment might be the sterilization of exposed implant surfaces to rehabilitate ailing implants. However, apparently not all laser systems available in dentistry are of value in this regard. Park et al. [17] reported that the potential exists for Nd–YAG laser irradiation (λ=1064 nm) to melt the surface and even to remove the surface layer from plasma-coated titanium implants. From this study, it was concluded that the use

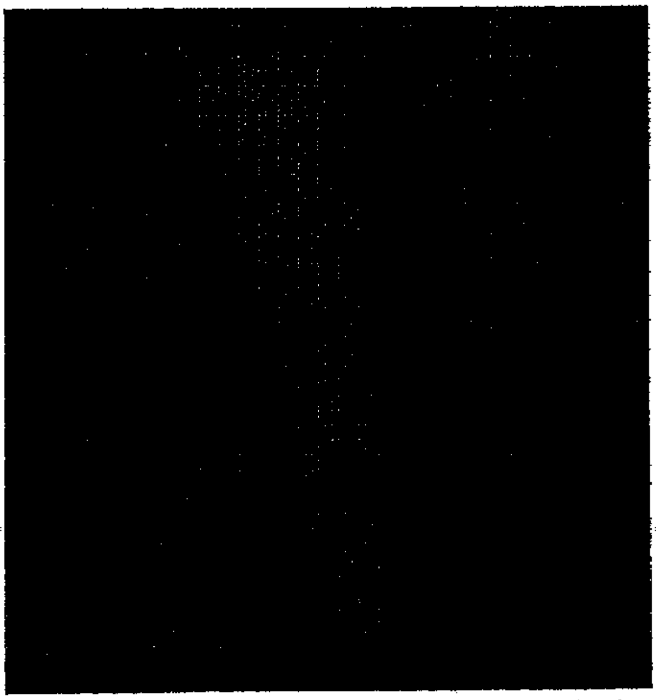

Fig. 1 Radiograph indicating chronically progressive periimplant bone resorption

Fig. 2 Surgical intervention: full thickness flaps and granulation tissue removal

of Nd–YAG lasers in implant-uncovering procedures or periimplant gingival surgery should be considered inherently unsafe for such procedures.

Better results were seen with the use of a CO_2 laser (λ= 10.6 μm). The purpose of a study in a total of 16 patients with 41 ailing implants was to assess the reliability of the CO_2 laser-assisted implant decontamination vs a conventional decontamination procedure [18]. The results of the clinical study showed, 4 months after therapy, that implants treated with laser decontamination and soft-tissue resection exhibited statistically significant better clinical parameters than conventionally decontaminated implants followed by soft-tissue resection. From these results, it was concluded that treatment of periimplantitis can be optimized using a CO_2 laser-assisted decontamination (Figs. 1, 2, 3, 4, and 5).

There are several positive reports in the literature in which laser decontamination has been recommended

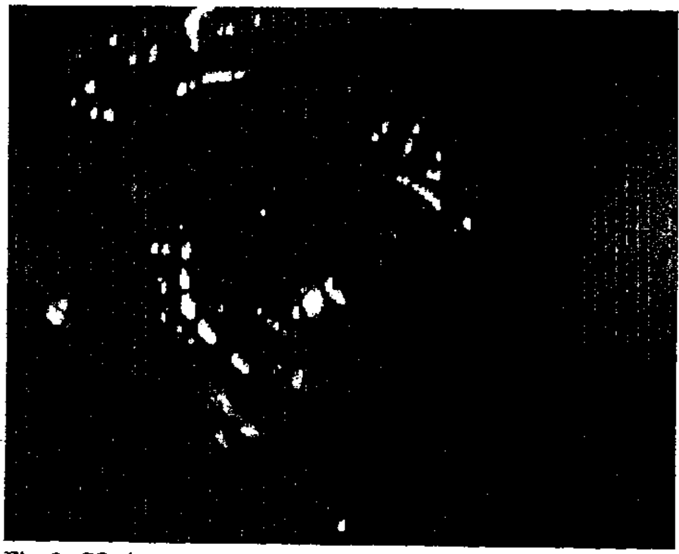

Fig. 3 CO_2 laser-assisted implant decontamination and augmentation with beta-TCP

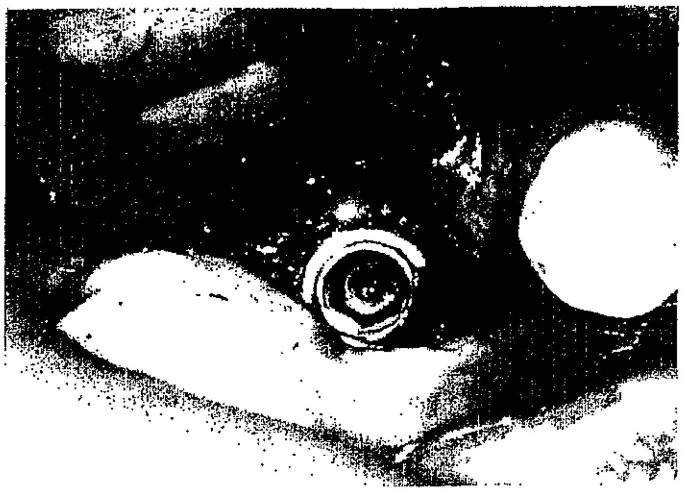

Fig. 4 Reentry 4 months after therapy. Complete closure of the defect

including the use of diode lasers (λ=810 and 906 nm) [19–21] and Er–YAG laser (λ=2.94 μm) [22]. Application of a diode laser (λ=810 nm) resulted in recurrence rates of less than 7% [19]. In further studies, PDT with toluidine blue plus diode laser light (λ=906 nm) was used [20, 23]. Haas and coworkers [20] reported on a mean bony reapposition of 2 mm (±1.90 mm) after a 9.5-month observation period. However, reosseointegrations were demonstrated for the first time for the CO_2 laser [6]. Most

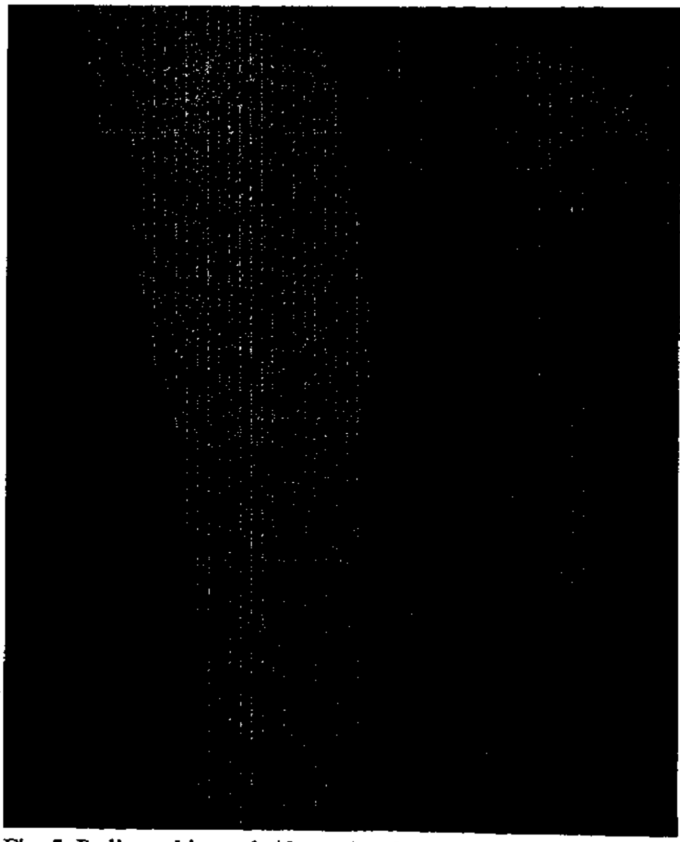

Fig. 5 Radiographic result 10 months after surgery

recent results from a study performed in beagle dogs have indicated that reosseointegration also occurred after irradiation with an Er–YAG laser [24]. Nevertheless, further studies are required in this field.

Bare fiber technique in local hemostasis

In modern societies, there is an increasing number of older patients, especially those treated with anticoagulation because of cardiologic indications. Over the past years, laser hemostasis has been established as an alternative to conventional techniques. Due to a penetration depth of more than 4 mm in soft tissue, cw Nd–YAG laser light (λ=1064 nm) applied with a hand piece has been very effective in this field [25].

However, if bleeding occurs massively from the apical region of the socket, the use of the bare fiber can be of interest. Therefore, in a clinical study in 44 patients, the bare fiber technique was studied in this indication [4]. Moreover, to reduce the thermal effects, a pulsed laser was used. It was concluded that intraalveolar application of pulsed Nd–YAG laser energy can be considered safe. It was demonstrated that optical characteristics of blood result in scattering and dispersion of laser light, thereby reducing the adverse effects on bony tissue.

Conclusion

Over the past years, research identified some new indications and techniques for laser treatment in oral surgery and implant dentistry. Moreover, well-known laser applications were defined state of the art. Nevertheless, further studies are required for laser treatment in oral surgery and implant dentistry.

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