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New aspects of lasers in oral and craniomaxillofacial surgery

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Abstract

Background: Lasers have been used for many years in oral and craniomaxillofacial surgery. 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 and craniomaxillofacial surgery.

New techniques of laser application in oral and craniomaxillofacial surgery: 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 microscope 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 ($\lambda = 1064$ nm) or diode lasers ($\lambda = 810$ nm) may be also of value in this field. In many other indications, use of lasers is still experimental. Intraoperatively used photodynamic therapy or peri-implant 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.

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

Keywords: Laser; Oral and craniomaxillofacial surgery

Introduction

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, $\lambda = 1064$ nm), the erbium-yttrium-aluminium-garnet laser (Er-YAG, $\lambda = 2.94$ μm) and the CO_2 laser ($\lambda = 10.6$ 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 (100–400 nm). Diode-lasers emit wavelengths of $\lambda = 810$ and 906 nm. In surgical indications, within the last years, the latter seem to be of increasing interest.

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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 (100–380 nm) are able to ionize tissues, known as photochemical desorption. Lasers of longer wavelengths, especially those within the infrared part of the sprectrum (700–10.000 nm), cause significant tissue heating. Most of the surgical lasers are embedded in this group and comprised as thermal lasers. 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 [9].

This paper is a comprehensive review of recent laser applications in oral and craniomaxillofacial surgery, providing information for dentists, oral and craniomaxillofacial surgeons and general surgeons. Therefore, the authors focus on new laser techniques in local hemostasis, osteotomy, fluorescence spectroscopy and photodynamic therapy, treatment of premalignant lesions and peri-implant care of ailing implants.

New techniques of laser application in oral and craniomaxillofacial surgery

Local hemostasis

In modern societies, there is an increasing number of older and often polymormide 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 ($\lambda = 1064$ nm) has been shown to be very effective in this field.

However, if bleeding occurs massively from the apical region of the socket, 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 could 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.

Laser osteotomy

For most patients, drills and handpieces are the most inconvenient components in oral surgery. Therefore, laser osteotomy could be an elegant alternative [11]. 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 osseonecrosis [8,9]. 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 hydroxyle 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 [9] 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 [9], 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 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 fluorescence spectroscopy and photodynamic therapy

Laser-induced fluorescence spectroscopy (LIF) is a non-invasive 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 to detect dysplasia or cancerous tissue was validated [1]. Therefore, a 337.1 nm nitrogen