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REVIEW ARTICLE

Comparison of the Effects of Different Laser Wavelengths on Implants Surfaces

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ABSTRACT

Lasers have been long introduced in dentistry. Today lasers are been used for Endodontics, Periodontics, Oral Surgery as well as restorative procedures. Here, we describe the effect of different wavelengths on the implant surface.

Keywords: Dental laser, Laser uses in dentistry, Oral applications of laser, Implants.

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INTRODUCTION

When an implant becomes infected with bacteria in the oral cavity, the surrounding tissues breakdown causing diminished peri-implant support, leading to implant mobility and failure. The term peri-implant disease is collectively used to describe biological complication in implant dentistry, including peri-implant mucositis and peri-implantitis. While peri-implant mucositis includes reversible inflammatory reactions located solely in the mucosa adjacent to an implant, peri-implantitis was defined as an inflammatory process that affects all the tissues around an osseointegrated implant in function resulting in a loss of the supporting alveolar bone. In addition to the dark-pigmented, Gram-negative anaerobic rods, other bacterial species are associated with peri-implant infections (e.g. *Bacteroides forsythus*, *Fusobacterium nucleatum*, *Campylobacter*, *Peptostreptococcus micros* and *Prevotella intermedia*).[1] Organisms that are less frequently associated with periodontitis, such as *Staphylococcus* sp, enterics and *Candida* species, have also been found in peri-implant infections.[2,3]

Peri-implant tissue differs considerably from periodontal tissue.[4] Peri-implant tissues are easily susceptible to any bacteria or mechanical attack because a supracrestal connective area that is highly acellular and with a great number of collagen fibers and lesser fibroblasts.[5] This has a lesser reparative potential than the normal periodontium. Thus, when the implant–bone interface is disturbed, it tends to scar down rather than reattach on the implant surface. Contemporary practices suggest mechanical debridement of the implant surface with a scaler/air abrasive system followed by disinfection with chemical agents giving unsatisfactory and inconsistent results. Mechanical instrumentation with rubber cups and plastic curettes insufficiently remove the bacteria.[6,7] Although the air powder system was efficient, there was a risk of development of emphysema and it also caused microsurface alterations on the implant surface. Chemical methods with citric acid, chlorhexidine gluconate, hydrogen peroxide, tetracycline chloridrate, stannous fluoride were suggested even if they leave microscopic residues or resulted in a loss of implant surface roughness when viewed on scanning electron microscopy.[8-10]

With the introduction of lasers in dentistry, applications were found in both soft and hard tissue procedures. The advantages of lasers over conventional methods are painless procedures, excellent hemostasis so bloodless field, germ free operation site, no suturing required in many cases, faster wound healing, minimal anesthesia required minimal postoperative swelling lesser recurrence rates, reduced chairside time. In oral implantology, uncovering the implant (second stage surgery),[11] excision of mucosal hyperplasia,[12] treatment of ailing and failing implants, decontamination of implant surfaces[13,14] were a few procedures indicated with lasers. Lasers are absorbed by chromophores in the tissues like water, hemoglobin, melanin (depending on wavelength) resulting in tissue interactions according to the temperatures associated with them. However, the exact action of lasers on the implant surface still remained unknown.

Eriksson et al.[15] demonstrated that a temperature of over 47°C maintained for 1 minute causes irreversible bone damage. Considering a baseline tissue temperature of 37°C, temperature increments of over 10°C during laser application may suffice to cause irreparable damage to bone. Hence, it is important that the laser parameters do not exceed this biologic temperature threshold.

Diode

The diode laser is a soft tissue laser having its target chromophores as the tissue pigments (hemoglobin and melanin). It is the cheapest and most extensively used laser by the dentists. They lie in the near infrared part of the electromagnetic spectrum. The delivery system in this system is the fiber delivery system either in the form of a spool or disposable tips. This is the only laser system that is independent of power density, does not provoke any negative structural changes on implant surfaces.[16] Studies have shown that 810 nm diode at 3 W continuous wave mode 400 µm fiber and no surface alterations are caused on SLA surface.[17] In a study conducted with the 980 nm diode laser on titanium disks, laser irradiation of 5, 10, 15 W were lased on the titanium disk. It was observed that 980 nm diode did not cause any surface alterations on the titanium surface irrespective of the power settings or the pattern.[18] Moritz et al. showed that up to 96.9% bacteria could be eliminated with an 810 diode at 2.5 W, 50 Hz at pulse duration of 10 ms with a 0.4 mm tip.[19] Significant bacterial reduction was seen even at low levels of irradiance with low energy diode lasers.[20] Thus, with the extensive research it can be concluded that diode lasers can be used safely and efficiently on the implant surfaces.

CO_2 Laser

The CO_2 laser (10,600 nm) is a soft tissue laser which has its wavelength in the far infrared spectrum and maximum absorption in water than any other laser. This is the reason it is the most aggressive soft tissue cutting laser and its application in hard tissue ablation by plasma generation are researched. It is delivered to the target tissue with an articulated arm delivery system. The CO_2 laser system is not absorbed by the titanium of implants. This prevents excessive energy transformation in the form of heat development.[21] Stubinger et al. based on their studies on plasma sprayed implants stated that CO_2 laser irradiation with a spot size of 0.4 mm at 4 W continuous wave mode for 10 seconds without external cooling did not cause any significant alterations on implant surfaces.[17]

Nd:YAG

The Nd:YAG (Neodymium-doped:Yttrium-Aluminum-Garnet) laser (1,064 nm) like the diode laser lies in the near infrared spectrum. It has similar properties to the diode but not the same. The target chromophores are water and tissue pigments. It has a deeper penetration depth in the tissues as compared to the diode lasers and hence causing more thermal injury to the tissues.[22,23] Kranendonk et al. studied the effects of Nd:YAG laser on six peri-implant pathogens (*Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythia*, *Fusobacterium nucleatum* and *Parvimonas micra*) in an *in vitro* model and concluded that laser settings of power 6 Watt, frequency 50 Hz, 0% air, 0% water, pulse duration 250 µs for 15 seconds effected total killing of these bacteria.[24] In a study conducted by Romanos et al, the titanium disks were irradiated with pulsed Nd:YAG, at 2.0, 4.0, 6.0 W representing energy of 40, 80, 120 mJ and frequency of 50 and 120 Hz have shown that Nd:YAG laser irradiation on titanium disks can lead to extensive melting and damage of the porous surface and coating.[25] Increased absorption of the Nd:YAG laser irradiations by the metallic surfaces cause unnecessary thermal injury to the peri-implant tissues.[18,26] So, it can be advocated that Nd:YAG laser is not suitable for implant therapy since it easily ablates titanium irrespective of pulse energy and frequency.[27]

Er,Cr:YSGG Laser

The Er,Cr:YSGG (2,780 nm) is one of the two hard tissue lasers used currently in dentistry, the other being Er:YAG. These lasers cannot be obtained in a continuous mode as they are free running pulsed lasers. They work on the concept which states that the water embedded in the dental hard tissues absorbs the laser energy and undergoes volumetric expansion causing increase in intrinsic pressure within the dental hard tissues resulting in microexplosions effecting ablation. The Er,Cr:YSGG laser allows precise bone sectioning and ablation, with minimal thermal effects upon the adjacent tissues.[28-31] Erbium-based lasers (YAG, YSGG) are considered cool lasers, therefore they prevent burning, charring, and coagulation at the site of interaction and are safe to use directly on titanium surfaces. It is for this reason that they are preferred for oral implantology procedures. Experiments were conducted on different types of implant surfaces like hydroxyapatite (threaded, impacted), sandblasted acid etched, titanium plasma sprayed and machined titanium to measure the temperature rise at different parameters of laser radiation with and without refrigeration.[32]

The power settings chosen were 1.5 W, 20 Hz; Z-6 (Zirconium) 600 µm tip, 12% air, 6% water. The focal distance of 1.5 mm and an angle of 90° were maintained over a period of 60 seconds of laser irradiation. They observed that apical temperature increase was recorded in all cases of Er,Cr:YSGG without refrigeration. However, when the Er,Cr:YSGG was used with a water spray, a decrease in temperature was observed in all implants. The threaded hydroxyapatite and sandblasted acid-etched surfaces were those most affected by the thermal changes (7.50°C and 6.70°C respectively). The Ti machined was the coolest one of all implants after laser irradiation without refrigeration (2.7°C). At the end of the experiment the mean thermal increment after 60 seconds of irradiation was 5.02°C (range 2.7°C-7.5°C) without refrigeration. A drop in temperature was observed when the Er,Cr:YSGG laser with a water spray applied to the sealing cap or coronal zone of the implants. The mean drop in temperature was 0.6°C (–0.20°C to –1.30°C). Again the SBAE surface was affected the most showing a temperature drop of –1.30°C and Ti machined the least with a drop of –0.20°C. Miller found no significant changes on the implant surface even after irradiation at 6 W.[33] Hence, it was concluded that Er,Cr:YSGG does not generate thermal increments in the apical surface capable of adversely affecting osseointegration and the integrity of the peri-implant bone tissue.

Er:YAG Laser

The Er:YAG laser (2,940 nm) is a laser used extensively in dentistry on account of its ability to ablate dental hard tissues with the target chromophore being water. It is absorbed approximately 300% more than the YSGG laser in water. Seong-Won Kim et al. on the basis of their research on effect of Er:YAG irradiation on microstructure of hydroxyapatite coated (HA) implants suggested that when Er:YAG at 100 mJ/pulse, 10 Hz for 1 minute with air and water is safe to use on the implant surface without thermal damage to the adjacent tissues. However, crazing was seen if the time was increased to 1.5 and 2 minutes. When 140 and 180 mJ/pulse were applied, the surface alterations were seen which increased with an increase in exposure time though these changes were not very statistically significant.[34] Stubinger et al. stated that pulsed Er:YAG irradiation caused distinct surface alterations with power settings beyond 300 mJ/pulse at 10 Hz on sand blasted, large grit, acid etched (SLA) surface and 500 mJ/pulse at 10 Hz on polished surfaces. These results suggested that the SLA surfaces were more affected by the laser irradiation than the polished ones. Also that the temperature rises in SLA surfaces would be more than the polished surfaces at the same laser settings. A mean bacterial load reduction and detoxification up to 98% could be achieved with these parameters. The surface alterations caused by these settings are minimal. Settings beyond this will cause surface melting, crack formation and peeling of the hydroxyapatite on the implant surface.

DISCUSSION

The conventional means of treating peri-implant infections was mechanical debridement adjunct with chemotherapeutic agents for implant site disinfection.[35] Since, there is a resective nature in these, the tissues get traumatized and inflamed immediately after the procedure.[36] This is followed by the period of healing in which tissue remodeling takes place with the formation of metalloproteinases (elastase, collagenase, gelatinase). These tissues are responsible for remodeling of the bone in the crestal area.[37] Thus, with the loss of crestal bone the interdental papilla collapses forming an unesthetic zone deprived of gingival display.[38] Studies indicate lasers act on a cellular action zone of only 8 to 15 microns, leaving adjacent tissue undisturbed. This results in pure tissue ablation rather than coagulation. The absence of tissue damage eliminates the precursors of the inflammatory cascade that may affect tissue as far as 10 mm from the surgical site. Tissues can then go directly to regrowth and regeneration. When compared to traditional techniques, tissue stability appears to be enhanced when lasers are employed with preservation of interdental papillae was found to be more predictable and crestal bone remodeling was significantly reduced or eliminated.[39]

The use of various laser systems in implantology as compared to the conventional methods or the other newer methods has many advantages. Not only does the laser have bactericidal and anti-inflammatory action but also they can be used for managing soft tissues and hard tissues (erbium lasers only). The advantages are bloodless field, acceleration of wound healing, precise tissue cutting, lesser collateral damage, minimal requirement of anesthesia, etc. However, the effects of the lasers on the implant topography and temperature rise during the procedure are important factors which have to be taken under consideration. The diode and carbon dioxide lasers do not cause any irreversible damage to the implant surface within therapeutic dosage parameters. The Nd:YAG laser energy is absorbed by metallic surfaces to a large extent causing a rise in temperature and alteration in the surface morphology of the implants. Thus, they cannot be used on the implant surfaces even with the lowest of energy settings. The Er,Cr:YSGG lasers can be used safely on the implant surfaces with adequate water spray without any increase in temperature. The Er:YAG lasers can be used safely below 300 mJ/10 Hz. Beyond this temperature there will be alteration in the implant texture. Another important factor affected by lasers is the surface texture of the implant. It is observed that the polished surface shows lesser rise in temperature after laser irradiation than the SLA. Using pulsed mode instead of continuous mode is a more effective way of achieving bacterial morbidity without increasing the temperature greatly.

CONCLUSION

In most of the studies conducted, a porcine femur was used as it would have similar density, heat absorbing properties, and thickness to that of a human mandible. It also contained soft marrow on the inside just as a human jaw would. Further studies could be made such that they could exactly mimic the human nature of peri-implant tissues in the presence of saliva and blood, as the porcine bone on which these studies were carried out were dehydrated. Attempts can be made to observe the clinical effects of objective findings like temperature rise and changes in roughness of implant surface after laser irradiation. Apart from the Nd:YAG laser all other lasers mentioned above can be safely used in implant therapy within appropriate clinical parameters. Thus, lasers can be safely used in implantology for implant site sterilization, uncovering implants in second-stage implant surgery, treatment of peri-implant infections, obtaining bone graft from host, etc.

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