Various Tip Applications and Temperature Changes of Er,Cr:YSGG-Laser Irradiated Implants In Vitro

The impact of the laser tip on implant temperature when irradiating implants with lasers to treat peri-implantitis has received little attention. The present study was designed to assess the influence of two laser tips (sapphire chisel [MC3] and radial firing perio [RFP]) on temperature change of an implant irradiated with an Er,Cr:YSGG laser in vitro under various operational conditions. The results suggest that Er,Cr:YSGG irradiation using either tip with supplemental cooling can be a thermally safe approach to implant decontamination. However, use of the RFP tip consistently resulted in a greater temperature rise. The MC3 tip thus may be preferable to the RFP tip for open-flap implant debridement. Int J Periodontics Restorative Dent 2017;37:387–392. doi: 10.11607/prd.3258

As dental implants and their associated prostheses have become an increasingly common treatment option for replacing lost dentition, proper treatment of peri-implantitis has become more critical. This disease is characterized by bacterial-induced inflammation and subsequent degradation of the alveolar bone and soft tissue at implant sites. Most dental implant systems are susceptible to peri-implant biologic complications that may have local and/or systemic effects, and progression of peri-implantitis has been strongly associated with implant failure.1,2

Debridement and disinfection of the implant surface, designed to restrict further tissue loss and promote the regeneration of new hard and soft tissues, can be accomplished via surgical or nonsurgical means,3–7 including traditional and ultrasonic mechanical debridement, acid application, air-powder abrasion, lethal photosensitization, and laser therapy.3,6,7 These procedures may or may not require the raising of a flap to ensure complete access to the defect. Despite the numerous options, no single protocol for treating peri-implantitis has yet been accepted as the standard.5–8

Several studies have suggested that laser therapy for periodontal or peri-implant ailments can provide results that are similar or superior to more traditional mechanical...
nonsurgical treatments. While the erbium-doped yttrium-aluminum-garnet (Er:YAG) and neodymium-doped yttrium-aluminum-garnet (Nd:YAG) lasers may melt, crack, or alter implant surfaces, the use of carbon dioxide (CO₂) and diode lasers on implant surfaces has been seen as more promising. In particular, CO₂ laser decontamination of peri-implantitis–derived defects has been shown to result in nearly complete hard tissue regeneration over a 2-year span. Reosseointegration has been demonstrated after use of a CO₂ laser to decontaminate failing implants in beagle dogs, and 810-nm-diode laser treatment for peri-implantitis that was assessed over a 5-year period was demonstrated to be more effective than other nonsurgical techniques alone over similar intervals. The literature does not currently provide evidence that any particular laser type or power setting treats peri-implantitis most reliably or effectively. A single tapered dental implant (3.5 × 11 mm Ankylos, Dentsply-Sirona) was inserted into a cylindrical portion of artificially cemented bovine bone block (BoneSim) of a quality that resembled Type II. This was placed on a level surface, and a 3-mm-deep, 2-mm-wide cavity was created circumferentially around the apical-most portion of the implant to simulate a common clinical crestal bone defect. The defect also provided access for the temperature-reading instrument. The same implant was used for all laser irradiations to ensure comparative consistency of the same crestal peri-implant defect.

In an attempt to find a laser wavelength capable of safe, prolonged tissue exposure while adequately decontaminating implant surfaces, the present in vitro study was designed. The goal was to evaluate temperature changes generated by different manufacturer-recommended glass contact tips (Fig 1) for an Er,Cr:YSGG laser used to irradiate a fixed dental implant, focusing on the thermal safety protocol and thermal efficiency.

**Materials and Methods**

A thermocouple (ADInstruments) was used to measure the temperature change of the implant surface during irradiation. For half the trials (described below) the thermocouple was affixed to the apical surface of the implant. For the other half, it was affixed to the coronal surface. The thermocouple was insulated with blue wax so that only the tip of the metallic point (2 mm) was exposed. The thermocouple also was connected to an electronic digital thermometer system (ADInstruments) powered by LabChart software (ADInstruments). This enabled a continuous real-time temperature readout. Temperature increases that exceeded 51°C were considered out of range because of the instrument’s temperature-ceiling limitations. Before any series of experimental trials, implant-surface baseline temperatures were recorded.

**Fig 1 Sapphire chisel tip (top) and radial firing perio tip (bottom).**

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were defined as the temperature readings at the apical and coronal surfaces of the implant at ambient room temperature before any irradiation took place. To ensure a consistent initial temperature prior to every irradiation, the implant surface was cooled back to baseline temperature using a combination of cool water and compressed air. A 5-minute waiting period also was observed between irradiations to ensure that any residual heat transferred to the implant core had dissipated.

To irradiate the implant surface and surrounding bone, an Er,Cr:YSGG laser (Waterlase iPlus, Biolase) (Fig 2) was used with either a sapphire chisel (MC3) or a radial firing perio (RFP) contact tip since they are used in those applications (Fig 1). Each irradiation was conducted for 60 seconds by a single experienced clinician (G.R.) (on the same day) who used a continuous vertically oscillating, circumferential clockwise motion of the laser handpiece (Gold, Biolase), with contact to the implant surface along its long axis held constant for the entire irradiation period (Fig 3).

For each tip, a total of 40 irradiation trials were conducted. The trials were subdivided as follows. Half of the trials (n = 20) were conducted using a pulsed mode with a frequency of 30 Hz while half were conducted using 50 Hz (pulse duration for both: 60 microseconds). For each pulse mode, five trials were conducted using one of four different cooling procedures: ratios of water-to-air of 30:70, 50:50, or 70:30 plus a noncooling condition (no water or air). In all trials, laser power output settings were confined to 2 W throughout the time of irradiation. Maximal thermal peaks and temperature variations (ΔT) were recorded in degrees Celsius. The findings were statistically analyzed using SPSS software (IBM). Mean values were compared using one-way analysis of variance, and Tukey-Kramer post-hoc test was used for comparison of differences between groups. Statistical significance was accepted as P < .05.

Results

Application of the Er,Cr:YSGG laser increased the temperature along the implant surface in all experimental groups. However, the mean implant surface temperature increase was greater when the implant was irradiated with the RFP tip under nearly every condition (P = .041). When comparing the two tips, the difference was most apparent in the coronal recordings (Tables 1 and 2). Mean coronal temperature changes while using the MC3 tip ranged from 0.5°C to 4.2°C, while for the RFP tip they ranged from 2.8°C to an undetermined temperature because the maximum recorded temperature exceeded recordable values by the thermocouple device (> 51°C) (Table 2).
The largest temperature increases were observed at the coronal region for both tips when no cooling was done (Tables 1 and 2). ∆T values were significantly greater for all the experimental groups at the coronal portion of the implant while using the RFP tip compared with the MC3 tip ($P = .036$). For the coronal region, the 30% water/70% air-cooling ratio resulted in lower thermal variations (Tables 1 and 2). Temperature variations were similar when 30-Hz and 50-Hz power settings were used. Comparison between groups showed no statistical significance ($P = .065$). Thermal changes at the apical portion were recorded (1°C to 5°C); however, these data were not significant between groups ($P = .071$).

### Discussion

This study examined the thermal consequences of irradiating a roughened implant surface with an Er,Cr:YSGG laser equipped with one of two different tips. Previous in vitro and in vivo studies have established that when compared to traditional turbine drills, Er,Cr:YSGG laser irradiation can be a safe and effective alternative for preparation of caries.$^{21,22}$ The first study on treatment of a contaminated implant surface by ablation using an Er,Cr:YSGG laser showed this wavelength to be highly efficient at removing potential contaminants on the roughened implant surface without causing morphologic effects on the titanium substrate.$^{23}$ However, a primary concern when using lasers to treat peri-implantitis continues to be the possibility of heat-induced damage to the implant or neighboring tissues.$^{17,18}$ Heat-induced injury to osseous tissue has been reported to occur after 60 seconds at a temperature above 47°C.$^{17,18,20}$ The authors of the present study hypothesized that as long as some form of cooling was applied during laser exposure, Er,Cr:YSGG laser irradiation would not cause the peri-implant temperature to exceed that critical 47°C threshold. The results suggest that this form and duration of radiation is thermally safe in the treatment of peri-implantitis as long as a combination of water and air is used.

### Table 1 Mean Thermal Change Observed Along Implant Surfaces Under Various Water/Air Cooling Conditions While Using an Er,Cr:YSGG Laser Equipped with the Sapphire Chisel Tip (MC3)

<table>
<thead>
<tr>
<th>Water/Air Cooling</th>
<th>Apical Max (°C)</th>
<th>∆T (°C)</th>
<th>Coronal Max (°C)</th>
<th>∆T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Hz 0 W/0 A</td>
<td>29.5</td>
<td>2.7</td>
<td>28.2</td>
<td>1.8</td>
</tr>
<tr>
<td>30 Hz 30 W/70 A</td>
<td>28.0</td>
<td>0.6</td>
<td>23.1</td>
<td>0.5</td>
</tr>
<tr>
<td>30 Hz 50 W/50 A</td>
<td>26.4</td>
<td>0.9</td>
<td>25.7</td>
<td>0.5</td>
</tr>
<tr>
<td>30 Hz 70 W/30 A</td>
<td>25.9</td>
<td>0.7</td>
<td>24.2</td>
<td>0.7</td>
</tr>
<tr>
<td>50 Hz 0 W/0 A</td>
<td>31.1</td>
<td>3.1</td>
<td>28.9</td>
<td>4.2</td>
</tr>
<tr>
<td>50 Hz 30 W/70 A</td>
<td>25.8</td>
<td>0.6</td>
<td>24.8</td>
<td>0.6</td>
</tr>
<tr>
<td>50 Hz 50 W/50 A</td>
<td>27.4</td>
<td>1.1</td>
<td>26.8</td>
<td>0.9</td>
</tr>
<tr>
<td>50 Hz 70 W/30 A</td>
<td>26.3</td>
<td>0.5</td>
<td>25.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Pulse duration: 60 microseconds.

### Table 2 Mean Thermal Change Observed Along Implant Surfaces Under Various Water/Air Cooling Conditions While Using an Er,Cr:YSGG Laser Equipped with the Radial Firing Perio Tip (RFP)

<table>
<thead>
<tr>
<th>Water/Air Cooling</th>
<th>Apical Max (°C)</th>
<th>∆T (°C)</th>
<th>Coronal Max (°C)</th>
<th>∆T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Hz 0 W/0 A</td>
<td>28.2</td>
<td>5.3</td>
<td>≥ 51</td>
<td>NM</td>
</tr>
<tr>
<td>30 Hz 30 W/70 A</td>
<td>25.4</td>
<td>2.4</td>
<td>29.1</td>
<td>5.1</td>
</tr>
<tr>
<td>30 Hz 50 W/50 A</td>
<td>27.6</td>
<td>4.0</td>
<td>31.1</td>
<td>7.2</td>
</tr>
<tr>
<td>30 Hz 70 W/30 A</td>
<td>25.8</td>
<td>1.7</td>
<td>29.2</td>
<td>4.8</td>
</tr>
<tr>
<td>50 Hz 0 W/0 A</td>
<td>28.3</td>
<td>1.7</td>
<td>48.7</td>
<td>28.2</td>
</tr>
<tr>
<td>50 Hz 30 W/70 A</td>
<td>26.3</td>
<td>0.7</td>
<td>21.2</td>
<td>3.2</td>
</tr>
<tr>
<td>50 Hz 50 W/50 A</td>
<td>26.2</td>
<td>1.0</td>
<td>22.8</td>
<td>2.8</td>
</tr>
<tr>
<td>50 Hz 70 W/30 A</td>
<td>26.0</td>
<td>1.0</td>
<td>24.1</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Pulse duration: 60 microseconds. NM = not measured.
used to control temperature climb. One observation was that temperatures tended to equilibrate toward the end of the irradiation period, suggesting that Er,Cr:YSGG laser irradiation could be applied safely to peri-implant tissues and implant surfaces for periods longer than 1 minute. Further study with extended trials are required to confirm this.

When no air or water were used for cooling, implant temperatures remained within safe and acceptable ranges during several irradiation trials, but other trials resulted in dangerous overheating. The choice was made to evaluate laser irradiation with no cooling because in clinical environments, some deep peri-implant intrabony defects may be reached and decontaminated using laser energy only. Alternatively, the three-dimensional structure of the clinical defect may restrict appropriate access of water and/or air to certain areas of the defect, resulting in unequal surface thermal absorption during irradiation. This may be associated with postoperative complications.

Similar to previous findings, the apical thermal increases recorded after irradiation in the present study were minimal.19 These small changes in energy transfer suggest the irradiation poses little to no risk of compromising implant osseointegration or altering the alloy structure. However, the results demonstrate that the choice of laser tip (MC3 or RFP) used with the Er,Cr:YSGG laser on implant surfaces does directly influence thermal absorption. Previous studies also have shown that osteoblast attachment and proliferation may be the same after laser irradiation of different titanium surfaces.18 It would be of significant interest to evaluate the temperature changes during irradiation of implants with machined versus rough surfaces.

Conclusions

Within the limits of the present study, the MC3 tip consistently outperformed the RFP tip, keeping temperature change minimal throughout all the irradiation trials. To decrease the risk of overheating and potential for tissue damage, the MC3 tip appears to be a better choice than the RFP tip for laser-assisted implant debridement procedures with an Er,Cr:YSGG laser. Additional studies on the quality of the bacteria reduction based on tip type would enable better assessment of the clinical efficiency of Er,Cr:YSGG laser irradiation, its predictability in peri-implant therapy, and the influence of tip form on bacterial decontamination on implant surfaces.

Acknowledgments

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References

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