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Thermal effects on zirconia substrate after Er,Cr:YSGG irradiation

Alteração de temperatura em substrato de zircônia após irradiação com laser Er,Cr:YSGG

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Resumo

Objetivo: O objetivo do presente estudo foi investigar os efeitos térmicos do laser de Er,Cr:YSGG (1,5W/20Hz) em zircônia tetragonal policristalina estabilizada com ítrio (Y-TZP). **Material e método**: Quinze discos de Y-TZP (AS Technology Titanium FIX, São José dos Campos, Brasil) com 5 mm de diâmetro e 3 mm de altura padronizados com CAD-CAM (computer-aided design e computer-aided manufacturing) foram usados. Os discos de Y-TZP foram randomicamente distribuídos em três grupos (n=5): Y-TZP-G1 = controle (sem irradiação); Y-TZP-G2 = Y-TZP + Er,Cr:YSGG (proporção resfriamento ar-água 80%/25%); Y-TZP-G3 = Y-TZP + Er,Cr:YSGG (proporção resfriamento ar-água 80%/0%). Um termopar (SmartMether, Novus, Porto Alegre, RS, Brasil) acoplado a um termômetro digital (SmartMether, Novus, Porto Alegre, RS, Brasil) foi fixado na face oposta à superfície irradiada. Os gradientes de temperatura ΔT foram calculados (ΔT = Temperatura final – Temperatura inicial) para cada grupo. Os valores foram analisados estatisticamente por o*ne-way* ANOVA com 95% de confiança e comparados pelo teste Tukey (α=0,05). Uma amostra de cada grupo foi analisada por microscopia confocal de luz branca. **Resultado**: O teste ANOVA mostrou diferenças significativas para o fator “laser” (p< 0,001). Os gradientes de temperatura (valores de ΔT) apresentaram os seguintes resultados: Y-TZP-G1 = 0 °C; Y-TZP-G2 = –1,4 °C e Y-TZP-G3= 21,4 °C. O valor de ΔT (°C) do grupo sem refrigeração foi maior do que o grupo refrigerado. Os valores de rugosidade (Ra) variaram de 4,50 até –33,65 µm. **Conclusão:** A refrigeração com água para a irradiação do laser de Er,Cr:YSGG é essencial para evitar o aumento de temperatura de Y-TZP.

Descritores: Cerâmicas; temperatura ambiente; microscopia confocal; implantação dentária, lasers.

Abstract

Objective: The objective of the present study was to investigate the thermal effects of Er,Cr:YSGG laser irradiation (1.5W/20Hz) on yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP). **Material and method**: Fifteen disks of Y-TZP (AS Technology TitaniumFIX, São José dos Campos, Brazil) with 5 mm diameter and 3 mm high standardized with CAD-CAM were used. The Y-TZP disks were randomized in three groups (n=5): Y-TZP-G1 = control (no laser treatment); Y-TZP-G2 = Y-TZP + Er,Cr:YSGG laser (air-water cooling proportion 80%/25%); Y-TZP-G3 = Y-TZP + Er,Cr:YSGG laser (air-water cooling proportion 80%/0%). A thermopar (SmartMether, Novus, Porto Alegre, RS, Brazil) was attached to a digital thermometer (SmartMether, Novus, Porto Alegre, RS, Brazil) fixed to the opposite irradiated surface. The temperature gradients (ΔT) were calculated (ΔT = Final Temperature – Initial Temperature) for each group. Values were statistically analyzed by one-way ANOVA at the 95% confidence level and compared by Tukey post-hoc test (α=0.05) for each material. One sample of each group was analyzed by confocal white light microscopy. **Result**: The ANOVA test showed significant differences for the factor “laser” (*p*<.001). The temperature gradients (ΔT value) showed the following results: Y-TZP-G1 = 0 °C; Y-TZP-G2 = –1.4 °C and Y-TZP-G3 = 21.4 °C. The ΔT values (°C) of the non-refrigerated group were higher than the refrigerated group. The roughness value (Ra) ranged from 4.50 to –33.65 µm. **Conclusion:** The water refrigeration for Er,Cr:YSGG irradiation is essential to avoid thermal increase in the Y-TZP.

Descriptors: Ceramics; temperature; confocal microscopy; dental implantation, lasers.

INTRODUCTION

Titanium implants reach high values of success to rehabilitation of partially or totally edentulous patients[1,2]. It has been demonstrated that osseointegration is influenced by the implants surface[3].

Actually, both zirconia ceramic abutments and zirconia dental implants are commercially available as alternative materials to titanium[4]. Zirconium dioxide (ZrO_2) is known as zirconia[4] and stabilizing oxides such as Y_2O_3 are responsible for maintaining the tetragonal structure of dental zirconia at room temperature[5]. The zirconia ceramics are yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) and presents biocompatibility, tooth-like color and high strength[6-8]. Y-TZP abutments have the esthetic as an advantage compared to titanium and also as dental implant material[9-11]. Zirconia surface has lower bacteria adhesion[12].

Peri-implantitis is a disease that has as an undesirable result such as crestal bone reabsorption with bleeding on probing[13,14]. The treatment consists of decontamination of the implant surfaces using scaling with curettes or alternative methods such as ultrasonic system, air powder system, and laser treatment[12,15-17].

Several laser wavelengths have been reported for this purpose[18] such as Gallium-Aluminum-Arsenide (GaAlAs, diode laser, 980 nm)[19,20]; Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG, 1064 nm)[21]; Erbium-doped yttrium aluminum garnet (Er:YAG; 2940 nm)[22,23]; carbon dioxide laser (CO_2, 10600 nm)[20,22]; erbium chromium-doped yttrium, scandium, gallium, and garnet (Er,Cr:YSGG, 2780 nm)[24,25].

The Er,Cr:YSGG laser irradiation has been proposed for decontamination of titanium implants surface[24]. The temperature increase of 10 °C is considered the critical threshold on bone regeneration[22,26]. It is important to control heat generation during laser treatment and thus, the use of water spray minimizes heat conduction by cooling to avoid thermal effects such as cracks and melted areas[22,26].

The objective of this study was to investigate the thermal effects of erbium chromium-doped yttrium, scandium, gallium, and garnet (Er,Cr:YSGG) laser on yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP).

MATERIAL AND METHOD

1. *Experimental Design*

The experimental units consisted of fifteen disks of yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) (AS Technology Titanium FIX, São José dos Campos, Brazil) with 5 mm diameter and 3 mm high and standardized from CAD-CAM blocks.

2. *Specimen Treatment and Laser System*

The Y-TZP zirconia disks were randomized in three groups (n=5 per group): Y-TZP-G1 = control (no laser treatment); Y-TZP-G2 = Y-TZP + Er,Cr:YSGG laser irradiation (1.5 W/ 20Hz; air-water cooling proportion 80%/25%); Y-TZP-G3 = Y-TZP + Er,Cr:YSGG laser irradiation (1.5 W/ 20 Hz; air-water cooling proportion 80%/0%).

Er,Cr:YSGG laser (λ = 2780 nm; Waterlase, Biolase Technologies Inc., Irvine, CA, USA) was used on each Y-TZP zirconia disk of groups 2 and 3 with a 600 µm quartz core tip (G4, Biolase Technologies Inc., Irvine, CA, USA) positioned at 1 mm (90°) from the disk surface (focused mode). Repetition rate was fixed on 20 Hz. An endodontic K-file fixed to the laser handpiece ensured the distance standardization. One single trained operator uniformly irradiated each disk surface for 30 s. The handpiece was positioned perpendicularly to the disk surface. Each sample was irradiated once in each direction, moving the handpiece slowly horizontally and vertically, to promote homogeneous irradiation and cover the entire sample area. The energy density used for the laser irradiation of each group was 67 J/cm^2.

3. *Temperature Evaluation*

A thermopar (SmartMether, Novus, Porto Alegre, RS, Brazil) was attached to a digital thermometer (SmartMether, Novus, Porto Alegre, RS, Brazil) and fixed to the opposite side of the irradiated surface. The temperature gradient (ΔT) was calculated (ΔT = Final Temperature − Initial Temperature) for each specimen. The mean temperature gradient ΔT (°C) and standard deviations were calculated for each group.

4. *Statistical Analysis*

ΔT values (°C) and standard deviation were calculated from every sample. The factors under study for Y-TZP zirconia material were laser (at three levels): no laser treatment; laser treatment I (air/water - 80%/25%) and laser treatment II (air/water - 80%/0%). Values were statistically analyzed by one-way ANOVA at the 95% confidence level and compared by a Tukey Hoc post-test (α =0.05) using a software package (SANEST, EPAMIG, MG, Brazil).

5. *Confocal White Light Microscope*

The front and back surface topography of one disk of each group was investigated using confocal microscope (Leica Scan DCM 3D - Leica Microsystems Ltd, Switzerland) with objective magnification of 50x. Leica DCM 3D Dual Core profiler software (Leica Microsystems Ltd, Switzerland) calculated the maximum and minimum roughness value (Ra) with 254.64 µm length (768 × 576 pixels) for each surface.

RESULT

ANOVA test showed significant differences for the factor "laser" ($p<.001$) and the results of Tukey test for Y-TZP zirconia material were presented in Table 1.

The ΔT values (°C) of the non-refrigerated group were higher than the refrigerated group. Er,Cr:YSGG achieved ΔT values of 21.4 °C (air/water - 80%/0%) in contrast with the ΔT values of −1.4 °C when the refrigeration air/water – of 80%/25% was selected.

Figure 1 shows representative 2D images obtained for Y-TZP zirconia disks at a control surface and at an irradiated surface and its back.

The roughness value (Ra) maximum and minimum was: Y-TZP-G1, control (superficial)= 3.22 µm and −33.65 µm; Y-TZP-G1, control (behind the disk)= 4.50 µm and −33.0 µm; Y-TZP-G2 (irradiated surface)= 3.01 µm and −3.32 µm; Y-TZP-G2 (behind the disk)= 2.30 µm and −3.15 µm; Y-TZP-G3 (irradiated surface)= 3.90 µm and −3.89 µm; Y-TZP-G3 (behind the disk)= 3.09 µm and −3.58 µm (Figure 1).

DISCUSSION

Peri-implant infection is a concern because its progression can lead to implant loss[14]. The plaque biofilm must be removed and implant surface decontamination can be performed using chemical and/or mechanical agents and techniques[27].

Bacterial biofilm present at peri-implantitis is associated with the progression of the disease[13]. The laser decontamination of the surface caused by CO_2 laser irradiation has been reported to pose a risk because of the temperature increase of the implant surface[28]. Er:YAG did not promote excessive heating[29] and is considered efficient for implant surface decontamination[28]. However, the

Table 1. Er,Cr:YSGG irradiation effects on temperature (°C) for Y-TPZ material

Treatment Y-TPZ	n	ΔT (°C) Gradient temperature [standard deviation]
Control (Y-TZP-G1)	5	0 °C
1.5W/ 20 Hz/ 30s - (air/water) 80%/25% (Y-TZP-G2)	5	−1.4 °C
1.5W/20 Hz/ 30s - (air/water) 80%/0% (Y-TZP-G3)	5	21.4 °C [2.1] A

n= sample number. Means followed by different upper case letter at column indicate statistical differences (p< 0.05).

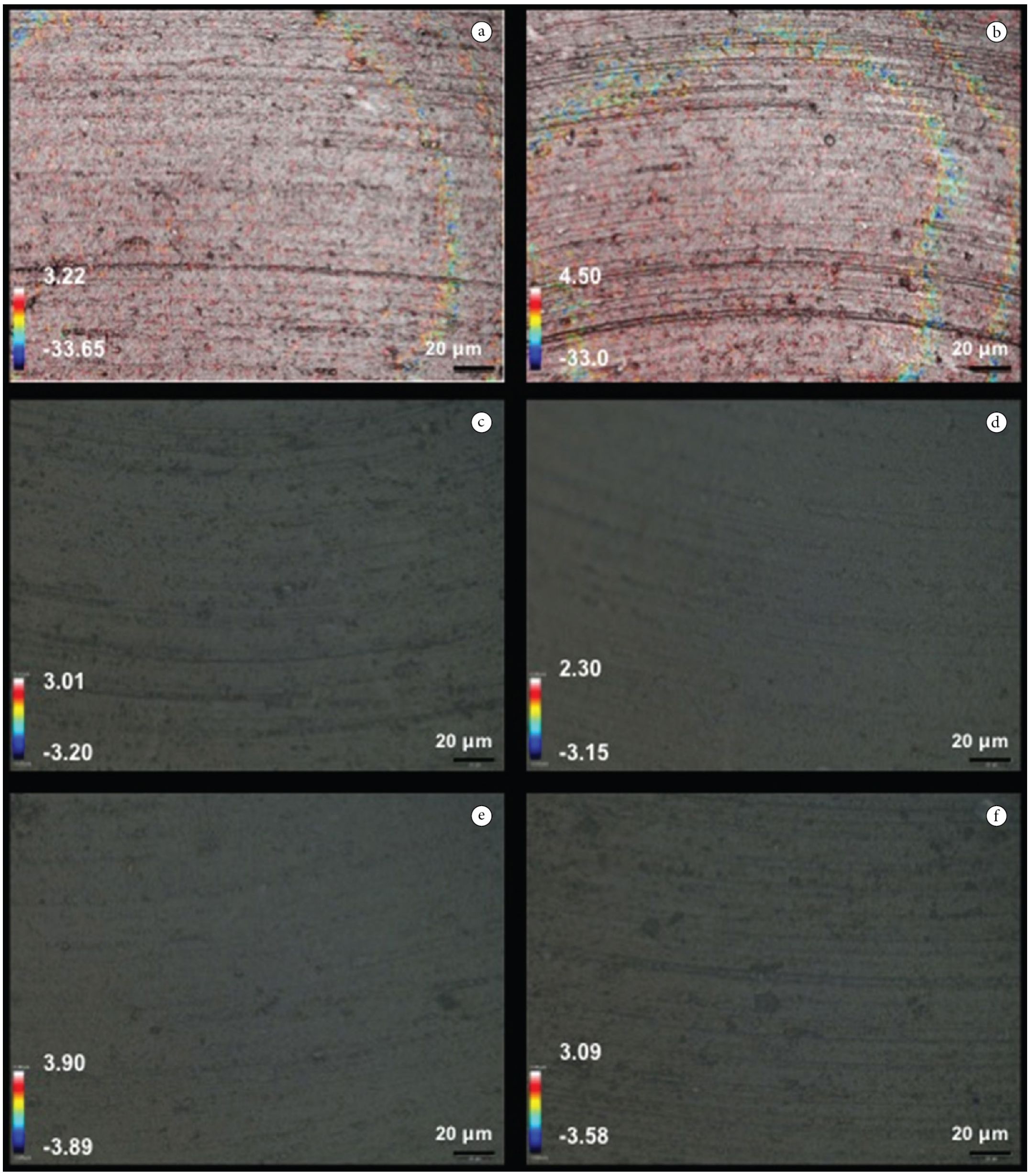

Figure 1. Representative 2D image obtained (a) representative image obtained for Y-TZP-G1: control group (superficial) (50X); (b) representative image obtained for Y-TZP-G1: control group (behind the disk) (50X); (c) representative image obtained for Y-TZP-G2: superficial (50X); (d) representative image obtained for Y-TZP-G2: behind the disk (50X); (e) representative image obtained for Y-TZP-G3: superficial (50X); (f) representative image obtained for Y-TZP-G3: behind the disk (50X) (Bar: 20 µm).

parameter must be carefully selected because Er:YAG can produce temperature increase above the critical threshold to bone safety (10 °C) after 10 seconds[22].

Er,Cr:YSGG has been reported[12] to be safe to titanium and zirconia material besides decontamination of the surface does not improve healing results[28]. Er,Cr:YSGG laser irradiation used to decontaminate implant surface is expected to have a different behavior in oral cavity where the presence of water of the gingival fluid, saliva and blood is different from the in vitro situation. The wavelength of Er,Cr:YSGG laser is highly specific to water and the behavior of the laser treatment to decontaminate superficial implants can be different on clinical situation. Although there are few studies available, there is evidence of improved clinical results[24].

The zirconia material is widely used in the biomedical area due to its good properties[4,5,8]. Zirconia presents lower bacterial adhesion and bacterial biofilm formation in comparison to other current dental material[12].

Under irradiation conditions known not to alter zirconia implant surfaces in vitro, CO_2 laser and diode laser effectively reduced the viability of adhered bacteria[12]. The application of high-energy lasers in dentistry requires special consideration of potential risks of inadvertent tissue and material damage. Different temperature elevations regarding titanium surface; hydroxyapatite-coated implants versus titanium plasma sprayed, sandblasted and acid etched has been demonstrated[29]. There is evidence that titanium implant surface decontamination with CO_2 and GaAlAs laser must be limited in time to allow the implant and bone to cool down[20]. The experimental condition without refrigeration produced an increase of 21.4 °C and cannot be recommended to clinical application due to the risk of bone necrosis. It has been reported that external irrigation of the bone with saline solution during the laser treatment reduced carbonization of the bone[18]. These in vitro observations can produce results that help to confirm safety application in humans as in the group with air/water of 80%/25% cooling that showed a −1.4 °C decrease in the temperature.

Some changes in the implants' surface textures as a function of the type of laser and wavelength that was used has been reported. The lasers' characteristics are important, because of the different reactions they can produce on the implant surfaces[18]. Besides no superficial alteration or differences on roughness parameters were produced after Er:YAG laser irradiation; significant damage to the material behind the zirconia disk[7] has been reported. The present study used Er,Cr:YSGG, but did not find damage to the zirconia surface.

The main reasons for laser application in the treatment of peri-implantites and the oral implants success are the significant reduction in bacteria on the implant surface and the peri-implant tissues during irradiation and the cutting effects associated with the coagulation properties of the lasers[18]. To the best of our knowledge there are no comparable studies and further analysis and its clinical use is necessary.

CONCLUSION

The water refrigeration for Er,Cr:YSGG irradiation is essential to avoid thermal increase in the Y-TZP.

DISCLOSURE

The authors have no interest in any of the companies or products mentioned in this article.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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