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The effect of Er:YAG laser irradiation debonding treatment on the optical and mechanical properties of zirconia and lithium disilicate ceramics

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Abstract:

Statement of problem: Erbium-doped yttrium-aluminum-garnet (Er:YAG) laser debonding has recently emerged as an alternative method for removing zirconia and lithium disilicate restorations. The optical and mechanical properties are critical factors influencing the success of ceramic restorations. However, limited research has focused on how the Er:YAG laser impacts the optical and mechanical properties of these ceramic materials.

Objectives: To investigate the effect of Er:YAG laser debonding treatment on the inherent optical and mechanical properties, and surface roughness of different zirconia and lithium disilicate ceramic materials.

Material and methods: Forty disc-shaped specimens (14 × 1.2 mm) were fabricated of three different tetragonal zirconia polycrystal (TZP) materials based on their yttria (Y) concentration (3Y-TZP, 4Y-TZP, and 5Y-TZP) and lithium disilicate (IPS E.max) as a control group (n=10 per group). Each specimen was irradiated with the Er:YAG laser at 335 mJ, 15 Hz, 5.0 W, and 50-microsecond pulse duration (super short pulse mode). Color change ($\triangle E_{00}$), translucency parameter (TP), biaxial flexural strength (MPa), surface roughness (Ra) values were measured before and after laser irradiation. Data were statistically analyzed using ANOVA and Tukey HSD post-hoc tests ($P<0.05$) at the 95 percent level of confidence.

Results: For $\triangle E_{00}$, except for 3Y-TZP, all groups displayed an increase in color change beyond the defined acceptability threshold of 1.8. No significant changes in the mean values following Er:YAG laser treatment, except for 3Y-TZP zirconia group ($P < 0.05$). TP values showed no significant differences ($P > 0.05$), except for the IPS E.max group, where TP increased significantly after laser treatment ($P < 0.05$). Regarding biaxial flexural strength, mean values revealed significant increase in the 5Y-TZP zirconia and IPS Emax groups ($P < 0.05$). No significant change in surface roughness values was reported ($P>0.05$).

Conclusion: Er:YAG laser debonding treatment altered some optical and mechanical properties of certain dental ceramics. Nevertheless, the reuse of ceramic restorations remains a feasible and clinically valuable option in dental practice.

Introduction

There have been tremendous improvements in the mechanical and optical properties of contemporary dental ceramics. The ability to adhesively bond these restorations to natural teeth or implant abutments is of significant clinical importance.[1-3] Combined with increasing patient demand for enhanced esthetics, these developments have led to a widespread adoption of all-ceramic restorations in modern dentistry. A thorough understanding of the mechanical and optical properties of dental materials is essential to meet these expectations and to ensure the functional and esthetic success of restorations for damaged or missing teeth.[1,3]

Despite these material improvements, dental ceramics remain susceptible to various types of complications and failures, i.e., functional, biological, or esthetic failures.[4] Hence, removing already cemented fixed dental prostheses may become clinically essential.

The removal of ceramic restorations is widely considered a challenging and time-consuming procedure. Traditionally, this process is performed using rotary instruments and cutting burs. Over the years, various techniques and instruments have been developed for mechanical removal of ceramic/metal prostheses. However, all existing removal methods typically result in irreversible damage to the restoration and potentially to the underlying tooth structure. [5-9] Consequently, the need for a replacement restoration increases the overall time and financial burden for both clinicians and patients. [9]

With the growing application of pulsed lasers in dentistry, particularly the erbium-doped yttrium aluminum garnet (Er:YAG) laser laser-assisted crown removal has been explored as an alternative technique to conventional methods.[10-12] Studies have demonstrated that Er:YAG laser debonding is safe, effective and clinically predictable method to debonding ceramic restorations.[10,11,13,14] Notably, all-ceramic prostheses removed using erbium laser have been shown to be suitable for reuse.[11,15]

Previous research investigating the impact of Er:YAG laser on debonding IPS E.max veneers reported successful removal without fractures, with potential for reuse in certain cases. [16,17] Similarly, Rechamann et al.[5] documented the effective removal of 20 IPS E.max CAD crowns using an Er:YAG laser, with no visible damage to any of the crowns. More recent findings suggest that while Er:YAG laser debonding treatment did not affect the mechanical properties of lithium disilicate glass ceramic, it may alter their optical properties, further supporting the possibility of restoration reuse.[18]

Despite the increasing use of Er:YAG laser for debonding in restorative dentistry, limited research has examined the effects of this laser treatment on the inherent properties of ceramic materials. The optical and mechanical properties of ceramic restorations play a critical role in their clinical success.[18,19]_A comprehensive evaluation of how laser irradiation impacts these properties is needed, particularly when considering the potential reuse of restorations. Accordingly, this study was conducted to evaluate and compare the effects of Er:YAG laser irradiation debonding treatment on the optical and mechanical properties, as well as surface roughness of different types of zirconia (3 mol%, 4 mol%, and 5 mol% Y-TZP) and lithium disilicate (IPS E.max) materials. The null hypothesis was that Er:YAG laser irradiation has no effect on the optical or mechanical properties, nor on the surface roughness, of the tested ceramic materials.

Materials and Methods

The total sample size was determined to be 40 (n=10 per group) based on sample size calculations using a software program (G*Power v. 3.1.9.3; Heinrich-Heine-Universität Düsseldorf). Input values were set as effect size f = .40, α error probability = .05, and power (1-β error probability) = .967. For specimens' preparation, disc-shaped specimens (14 × 1.2 mm) were milled using a milling machine (PM7 Milling Machine; Ivoclar AG) A total of four groups (n=10) were fabricated from discs of each of the three zirconia types 3Y-TZP (G1), 4Y-TZP (G2) and 5Y-TZP (G3) (Katana HTML. STML, UTML; Kuraray Noritake Dental Inc, Japan) and lithium disilicate IPS E.max (G4) (IPS E.max; Ivoclar Vivadent, Liechtenstein) as a control. Specimens were sintered according to the manufacturer's instructions. After sintering, the 1.2 ± 0.05 mm thickness of the specimens was obtained by grinding and polishing with a sequence of 380-, 600-, and 1200-silicon carbide papers (MicroCut; Buehler) under running water, all prepared by a single experienced operator (S.S.). Final specimen dimensions were checked for thickness by precision digital calipers (Digimatic Micrometer; Mitutoyo Corp). Specimens were cleaned ultrasonically in distilled water for five minutes and air-dried for 20 seconds.

Specimens in each group were examined for color difference (ΔE_{00}), transparency parameter (TP), and biaxial flexural strength (FS), and surface roughness (Ra).

Laser irradiation was applied by using Er:YAG laser (LightWalker; Fotona, Ljubljana, Slovenia) at 2940 nm with the following parameters: 335mJ; 15Hz; 5.0W, 4 water/4 air, operation mode: a 50-microsecond SSP mode with a tip-less handpiece (HO_2, Fotona) at a distance of 5-8 mm and irradiation directed perpendicular to the disc on the drawn circle of 8 mm in diameter. The irradiation time was calculated for all four groups as a percentage of surface area based on time required to debond various ceramics from abutment teeth in previous studies.[13] This provided irradiation exposure to disks that was commensurate with time required to debond that type of ceramic from the abutment. Since our previous study observed the longest debonding times for 3Y zirconia and shortest for lithium disilicate, the irradiation time of experimental samples reflected the length of irradiation required to debond a restoration, was 60-180 seconds for the zirconia groups, and 30-60 seconds for IPS E.max group, per disc. Throughout the irradiation procedure, air and water sprays were utilized. The irradiation was performed with continuous axial motion on the disc, simulating clinical scenarios, and was performed by the same experienced operator (J.D.).

Optical Measurements

To evaluate color difference (ΔE_{00}) and translucency parameter (TP) before and after laser irradiation, a reflection spectrophotometer (CI7600, X-rite, Grand Rapids, Michigan) was used. The CIE L (lightness), C (chroma), and H (hue) values were determined over a white background using the CIE D65 illuminant and the CIE 2° standard colorimetric observer. Each specimen was calculated according to the CIEDE2000 formula (ΔE_{00})[20]:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_c S_c}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

where ΔL, ΔC, and ΔH are the changes in CIE L2, C0 , and H0, respectively. The Specular Component Excluded (SCE) and Specular Component Included (SCI) geometries were determined according to the CIEDE2000 color scale using standard illuminant D65 over white and black backgrounds. Calibration of the spectrophotometer was performed before measurement of each specimen. Then the TP of each specimen was obtained by calculating the color difference between the specimen against the white background and against the black background using the following equation:

$TP = [(Lb * -Lw*)2+ (ab * -aw*)2+ (bb * -bw*)2]^{1/2}$

Flexural Strength Measurements

All specimens were subjected to biaxial flexural strength testing with a universal testing machine (Model 4411; Instron) according to ISO standard 6872.[21]

The specimens were secured on three symmetrical stainless-steel balls (Ø4.5 ±2mm) positioned at 120° creating a Ø11±1 mm support circle. A steel antagonist was directed perpendicularly to the center of the specimen at a downward moving rate of 1 mm/min by a steel antagonist of a Ø1.4±0.2 mm. Fracture loads were recorded through the software program associated with the universal testing machine (TestWorks; MTS).

The biaxial flexural strength was calculated according to the following formula:

$S=-0.2387P (X-Y)/d^2$, where S=biaxial flexural strength (MPa); P=fracture load (N); d=specimen disk thickness at fracture origin (mm); $X=(1+n) \ln (B/C)^2+[(1-n)/2](B/C)^2$; $Y=(1+n)\ln (A/C)^2+[(1-n)/2](A/C)^2$, where n=Poisson coefficient (ceramic=0.25, ISO 6872); A=radius of support circle (mm); B=radius of loaded area (mm); and C=radius of specimen disk (mm).

Surface Roughness Test

The surface roughness was assessed using a confocal laser scanning microscope (Keyence VK-X1000; KEYENCE CORPORATION) at magnification ×5. Surface scans were made before and after laser treatment to determine arithmetic mean surface roughness (Ra) by measuring peaks and valleys along two roughness profiles (one in the long axis and one perpendicular to the long axis) along the surface of the specimen. Specimens were gently rinsed with water and cleaned using soft, anti-static, anti-lint microscope wipes (Kimwipes; kimtech Science) before scanning to avoid contamination. The surface roughness (Ra) was calculated following International Standards Organization (ISO 21920) using the following formula[22]:

- $Ra = \frac{1}{\ell r} \int_0^{\ell r} |Z(x)| dx$
- Ra=Arithmetic mean roughness, ℓr=reference length, Z(x)=the dimensionless fourth power of the reference length.

Statistical analysis

A Kolmogorov-Smirnov test (K-S test) was applied to determine whether the datasets were normally distributed. Since the L*, C*, and H* values did not follow normal distribution, nonparametric analyses (Kruskal-Wallis test and U test) were used ($P = 0.05$). The $\triangle E_{00}$, TP, CR, SR, and flexural strength values, which exhibited a normal distribution, were analyzed by one-way ANOVA, and post-hoc comparisons were made with the Bonferroni test ($P = 0.05$). The Spearman correlation test was used to evaluate correlations between the properties and the different laser parameters ($P < 0.05$).

Results

Mean values and standard deviations (SD) of color change (ΔE_{00}) of the different tested groups are summarized in Table 1. Intergroup comparisons showed a statistically significant difference (ΔE_{00}) between G1 versus G2 ($p = 0.0010$), G1 versus G3 ($P = 0.0001$), and G1 versus G4 ($p = 0.0000$). Except for G1, all color changes of the specimens (G2-G4) were higher than the clinically acceptability threshold (1.8).[23]

Mean values (±SD) of translucency parameter (TP), biaxial flexural strength (MPa) and surface roughness (Ra), before and after Er:YAG laser irradiation of the tested groups are summarized in Table 2-4.

A statistically significant increase in the TP was observed only in G4 following Er:YAG laser irradiation ($P = 0.0001$) Table 2. G4 showed an increase in TP beyond the defined translucency acceptability threshold of 2.6.[24]

Biaxial flexural strength (MPa) showed a statistically significant increase for both G3 and G4 following Er:YAG laser irradiation. In contrast, G1 and G2 showed no significant differences after Er:YAG laser irradiation ($P > 0.05$) (Table. 3)

For surface roughness (Ra), no statistically significant differences were observed between the pre- and post-laser irradiation measurements in any of the groups ($P > 0.05$) (Table 4). Scanning electron microscope images (SEM) of the different ceramic surfaces before and after Er:YAG laser irradiation are presented in Figure 1. Er:YAG laser irradiation did not result in significant changes to the surface topography of the investigated ceramic surfaces.

Discussion:

Er:YAG laser has been introduced as a conservative alternative for the removal of ceramic restorations.[13,25]_Previous studies have suggested that ceramic restorations debonded with the Er:YAG lasers may retain their integrity and potentially be reused.[26-28] However, the current literature provides limited evidence regarding the effect of laser irradiation on the optical and mechanical properties of ceramic materials. The laser parameters used in this study were established based on previous studies. [5,11,13] Three different types of zirconia ceramics (3Y-TZP, 4Y-TZP, and 5Y-TZP) and lithium disilicate (IPS E.max) as a control group were previously investigated for feasibility and effectiveness of debonding in our previous study [13] and were thus selected for this study to assess mechanical and optical feasibility of their reuse in clinical setting. The null hypothesis, which postulates that Er:YAG laser treatment would not affect the optical properties of ceramics, was partially accepted. There was a significant color change of ΔE for all groups beyond the acceptability threshold except for 3Y-TZP, which displayed the least amount of color change. Er:YAG laser irradiation procedures did not affect the the TP of zirconia groups, while the TP of lithium disilicate increased significantly following Er:YAG irradiation treatment The other portion of the null hypothesis that Er:YAG laser treatment would not affect the mechanical properties of ceramics was rejected. This conclusion is supported by a significant increase in biaxial flexural strengths observed in the 5Y-TZP and lithium disilicate groups. Finally, Er:YAG laser treatment did not affect the surface roughness in any of the materials tested.

The ΔE_{00} value of G2-G4 exhibited a significant change in color, with values exceeding the acceptable threshold of 1.8 as established by Paravina et al. [23] The least amount of color change (1.22) was observed in G1, which was less than the acceptability threshold of 1.8 but above the perceptibility threshold of 0.8. This finding was consistent with the findings of a previous study conducted by Kurtulmus-Yilmaz et al.[19], which indicated that the colors of zirconia ceramics were altered by a 4W Er,Cr:YSGG laser surface treatment at ΔE = 1.4. This value was higher than the CIEDE2000 perceptibility threshold (ΔE = 0.8) but lower than the acceptability threshold (ΔE = 1.8). Zhang et al.[29] found that the ΔE values did not significantly differ across the four laser groups (4, 5, and 6W). However, the value somewhat increased with increasing the Er:YAG laser energy, with the 6W laser subgroup presenting the greatest value. The Er:YAG laser doesn't directly interact with the chromophores (color-causing chemicals) in the visible spectrum through a photochemical process. Instead, its infrared energy turns into heat, which then causes different physical and chemical changes in the ceramic material. These changes can include changes in the electronic states of ions, the types and concentrations of defects, the crystal structure, or the surface morphology.[30] All these changes can show up as a change in color. The exact way and extent of color change will depend largely the composition of ceramic, its starting color, the laser settings (energy, pulse duration, frequency), and the presence of water or hydroxyl groups.[31] Our experiments avoided settings at 6W as these high energy parameters result in higher intra-pulpal temperature increases and color changes.

Regarding the TP, no statistically significant difference was found among the groups, except for the lithium disilicate control group, which exhibited an increase in TP following laser irradiation. This indicates that the laser treatment led to enhanced translucency of the lithium disilicate ceramic and beyond the acceptability threshold of 2.6.[19] A plausible explanation for this outcome is the thermal effect of the laser on the surface texture of the glass ceramic, potentially causing surface melting and smoothing, which may enhance light transmission. A smoother surface minimizes the amount of diffusely scattered light as it enters and departs the material. Less surface scattering allows more light to pass through in a more direct (but still diffuse) manner, improving perceived translucency. [32] Moreover, the abrupt change in refractive index between the material and the air/void within the pore causes pores and defects to function as scattering centers. By decreasing the number or size of these particles, the internal scattering near the surface is reduced, thereby enabling a greater amount of light to pass through.[33] Similar findings have been reported in previous studies.[19,34,35]

On the other hand, some studies have reported that the thermal effects induced by laser irradiation can increase surface roughness and alter the texture of ceramic materials, potentially reducing their translucency.[18,34] These contrasting findings suggest that the impact of laser irradiation on translucency may be influenced by factors such as ceramic composition, laser parameters, and surface treatment protocols.

The findings of the present study demonstrated a statistically significant increase in the biaxial flexural strength of 5Y-TZP zirconia and lithium disilicate specimens after laser treatment, while other material groups showed no significant changes in their biaxial flexural strength after laser treatment. The most probable explanation for the increase in biaxial flexural strength following controlled Er:YAG laser irradiation is a combination of surface defect healing/blunting and the induction of a compressive surface stress layer, with potential minor contributions from surface densification. The Er:YAG laser can induce the localized melting of a very thin surface layer by means of its photothermal effect, which involves the strong absorption of water/hydroxyls, resulting in heat. These surface defects can be filled by the molten material that can flow into them. Upon rapid solidification, the flaws may be "healed," which effectively reduces their size or blunts their sharp tips, thereby increasing the stress necessary to initiate a fracture.[36] The residue compressive stresses in the surface layer can be induced by the rapid heating of the surface by the laser, followed by rapid cooling (quenching effect as heat dissipates into the bulk material and surroundings). This principle is comparable to that of thermal tempering in glass. The initiation and propagation of tensile fractures are impeded by a compressive surface layer, as the applied tensile stress must initially exceed the existing compressive stress.[37]

If the 5Y-ZP surface contains a certain degree of microporosity, the localized melting induced by the Er:YAG laser can result in the densification of the surface layer, thereby sealing the pores. Pores serve as sites for fracture initiation and stress concentration. Reducing porosity, especially at the surface, directly contributes to higher strength.[38]

In contrast, Zhang et al.[18] reported that Er:YAG laser-assisted debonding did not affect the mechanical properties, in which the mean flexural strength and Vickers hardness values of glass ceramic specimens after Er:YAG laser irradiation revealed no significant changes. Similarly, Ozdogan et al.[39] found no statistically significant differences in flexural strength when glass ceramics and zirconia ceramics were subjected to Er:YAG laser (300 mJ, 10 Hz, short pulse mode). Conversely, Kurtulmus-Yilmaz et al.[19] observed a significant reduction in the flexural strength of lithium disilicate ceramic following erbium laser irradiation (2–3 W, 10 Hz, 140 μs pulse duration, MG6 sapphire tip). These discrepancies among studies may be attributed to differences in material thickness, ceramic composition, and variations in experimental protocols and analytical methodologies.

Surface roughness of ceramic restorations is considered a crucial factor influencing bacterial adhesion, wear of opposing dentition, and optical characteristics, thereby affecting the long-term clinical performance of these restorations.[39,40] The energy of the Er:YAG laser (2940 nm) is powerfully absorbed by water and hydroxyl groups that are present on the surface or within the superficial layers of certain ceramics.[41]

This absorption results in localized, rapid heating. A very thin surface layer of the ceramic can be melted without causing catastrophic ablation or significant material removal if the laser parameters are meticulously selected to deliver the appropriate amount of energy. When this thin layer melts, surface tension forces can move the molten material, which can smooth out bumps and valleys that are already there and maybe even fill in minor holes or faults in the surface.[36] The heat quickly spreads through the bulk material, which causes the smoothed molten layer to harden again quickly, giving the surface a "glazed" or polished look.[32] In a recent study,[29,39,40] the effects of Er:YAG laser irradiation on various zirconia ceramics and reported no significant differences in surface roughness among the treated groups, a finding that aligns with the results of the present study. The Er:YAG laser will undoubtedly make the surface rougher if the laser settings are not right (for example, if the fluence or power is too high). This is because ablation, thermal cracking, microcracks, and irregular melting and solidification make the surface more disordered.

A limitation of the current study is that different laser parameters were not tested, and no precise simulation of intraoral circumstances was achieved. Additional research is required to investigate the effects of different laser power densities and pulse modes on color change, translucency, surface roughness of ceramic crowns, and rebonding strength of ceramic restorations debonded by laser irradiation. The ceramic specimens were not bonded to the tooth structure because the primary goal of the study was to explore changes in the optical and mechanical properties of the ceramic material itself after Er:YAG laser irradiation. This investigation was conducted independently of bonding, and the testing methodology required ceramic materials with specified dimensions, such as length, width, and height, which the tooth structure did not offer.

Conclusion

Based on the findings of this study, the following conclusions were drawn:

1. Er:YAG laser irradiation causes significant color change in 4 and 5 mol% yttria stabilized tetragonal zirconia and lithium disilicate glass ceramics.
2. Er:YAG laser irradiation increases the translucency of the lithium disilicate ceramic while the zirconia ceramics are unaffected.

3. The Er:YAG laser treatment significantly increases the biaxial flexural strength of the 5 mol% yttria stabilized tetragonal zirconia and lithium disilicate glass ceramics.
4. Surface roughness (Ra) is not affected by Er:YAG laser treatment.

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Table 1. Mean values and standard deviations (SD) of color change (ΔE_{00}) among the tested groups after Er:YAG laser irradiation.

Groups (n=10)	**Color change (ΔE_{00}) (mean±SD)**
3Y-PSZ Zirconia (G1)	**1.22±0.38^{a*}**
4Y-PSZ Zirconia (G2)	**2.37±0.75^{b**}**
5Y-PSZ Zirconia (G3)	**2.63±0.86^{b**}**
IPS E.max /Control (G4)	**2.67±0.24^{b**}**

Same superscript letter indicates no statistical significance ($P>0.05$)
* ΔE_{00} is below the acceptability threshold of 1.8.
** ΔE_{00} is above the acceptability threshold of 1.8.

Table 2. Mean values and standard deviations (SD) of translucency parameter (TP) before and after Er:YAG laser irradiation.

Groups (n=10)	**Mean±SD (Before Er:YAG laser Irradiation)**	**Mean±SD (After Er:YAG laser Irradiation)**	***P***
3Y-PSZ Zirconia (G1)	6.37±1.75[a]	7.10±0.78[a]	0.9423
4Y-PSZ Zirconia (G2)	6.42±1.98[a]	7.56±1.5 [a]	0.6229
5Y-PSZ Zirconia (G3)	8.23±0.74[a]	6.71±1.10[a]	0.2514
IPS E.max /Control (G4)	8.46±1.41[a]	13.96±1.52[b*]	0.0001

Same superscript letter indicates no statistical significance (P>0.05)
*Change in translucency is beyond the acceptability threshold of 2.6.

Table 3. Mean values and standard deviations (SD) of biaxial flexural strength (MPa) before and after Er:YAG laser irradiation.

Groups (n=10)	Mean±SD (Before Er:YAG laser Irradiation)	Mean±SD (After Er:YAG laser Irradiation)	*P*
3Y-PSZ Zirconia (G1)	985.91±44.15[a]	983.30±74.29[a]	1.0002
4Y-PSZ Zirconia (G2)	622.12±65.88[a]	629.50±78.78[a]	1.0000
5Y-PSZ Zirconia (G3)	377.57±24.94[a]	502.92±96.64[b]	0.0007
IPS E.max /Control (G4)	338.50±11.96[a]	430.76±54.81[b]	0.0302

Same superscript letter indicates no statistical significance (P>0.05).

Table 4. Mean values and standard deviations (SD) of surface roughness (Ra) before and after Er:YAG laser irradiation.

Groups (n=10)	Mean±SD (Before Er:YAG laser Irradiation)	Mean±SD (After Er:YAG laser Irradiation)	*P*
3Y-PSZ Zirconia (G1)	1.39±0.18[a]	1.25±0.27[a]	0.9706
4Y-PSZ Zirconia (G2)	1.29±0.18[a]	1.30±0.17[a]	1.0002
5Y-PSZ Zirconia (G3)	0.96±0.32[a]	0.93±0.32[a]	1.0000
IPS E.max /Control (G4)	1.34±0.48[a]	1.29±0.36[a]	1.0000

Same superscript letter indicates no statistical significance (P>0.05).

Figure 1. Scanning electron microscope images of the different ceramic surfaces used in this study. (A) 3Y-PSZ Zirconia, (B) 4Y-PSZ Zirconia, (C) 5Y-PSZ Zirconia, (D) IPS E.max/Control. Left column before Er:YAG laser irradiation, right column after Er:YAG laser irradiation. Er:YAG laser irradiation did not result in significant changes to the surface roughness of ceramic materials.