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Surface treatment of dental porcelain with CO_2 laser: Porosity analysis and AFM

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Purpose: The effect of CO_2 continuous laser irradiation on the surface properties of veneering porcelains has already been tested. The surface observed after laser irradiation is similar to that achieved by auto-glaze in terms of roughness and color parameters (Sgura R, et al. Dental Materials 2011;27(Suppl. 1):e72–73). The purpose of this study was to analyze the surface porosity of porcelain discs after CO_2 laser treatment and compare it to auto-glaze treatment, in furnace. A morphological analysis of the porcelain surface was conducted using atomic force microscopy (AFM) and conventional optical microscopy (OM).

Methods and materials: 60 disks (diameter 3.5 mm × 2.0 mm) of veneering porcelain for Y-TZP frameworks (VM9 – VITA Zahnfabrik) were sintered and had one of their faces mirror polished. The specimens were divided into groups ($n = 10$) according to surface treatment: no treatment – control (C); auto-glaze in furnace following manufacturer's instructions (G); and CO_2 laser (45 or 50 W/cm^2) applied for 4 or 5 min (L45/4, L45/5, L50/4, L50/5). OM (HMV – Shimadzu – 100×) was conducted and the images were analyzed with Image J software (public domain) for the determination of the porosity parameters: area fraction, average size and Feret's diameter. Mean values were submitted to ANOVA and a Tukey post-hoc test ($p < 0.05$) when the data were homecedastic. For non homocedastic data, the Kruskall–Wallis test was used. Contact AFM ($50 \times 50\,\mu m^2$ – Nanoscope IIIA, Veeco) was performed at the center of one sample of each group, except for group L45/5. 3D image processing was carried out with MS×M 5.0 software (Nanotech).

Results: The area fraction of pores after laser irradiation was similar to that obtained for group G. For irradiated specimens, AFM showed the formation of valleys and elongated peaks with rounded edges. OM images revealed surface grooves in 50 W/cm^2 groups.

Conclusion: Both irradiances (45 and 50 W/cm^2) produced a surface comparable to auto-glaze in terms of surface porosity. The irradiance of 50 W/cm^2 resulted in changes in surface morphology for VM9 porcelain, observed under optical microscopy.

Pores	C	G	L45/4	L45/5	L50/4	L50/5
Area fraction (%)	1.7 (0.9)a	3.6 (1.4)abc	4.3 (1.2)bc	5.4 (1.4)c	4.4 (2.4)c	2.4 (1.4)ab
Average size (μm)	67 (43)bc	43 (17)bc	39 (12)ab	34 (10)a	58 (22)c	60 (24)c
Feret's diameter (μm)	12.4 (3.6)b	7.3 (1.1)a	7.8 (2.6)a	7.8 (1.1)a	7.1 (1.3)a	8.5 (2.0)a

Different letters indicate a statistical difference ($p < 0.05$).

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Effect of CNT reinforcement on the optical and mechanical properties of Y-TZP: A pilot study

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Purpose: The objective of this study was to evaluate and compare the density after sintering, color difference (ΔE), contrast ratio (CR), Vickers hardness and fracture toughness of yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) with a ceramic composite of Y-TZP reinforced by multi-walled carbon nanotubes (CNT).

Methods and materials: Initially, CNT were coated with zirconium oxide and yttrium oxide particles to form a powder (CNT/ZYO) using the hydrothermal synthesis process to facilitate dispersion in the Y-TZP matrix. The final powder of the composite consisted of 99 vol% of Y-TZP and 1 vol% of CNT/ZYO. Three disc-shaped specimens were prepared for each material ($n = 3$) by uniaxial pressing. After sintering in argon atmosphere, specimens were mirror polished (diameter = 1.5 mm/thickness = 1.3 mm). The density was measured by Archimedes' method in water. The ΔE values were calculated by comparing the Lab coordinates obtained in a spectrophotometer for the Y-TZP versus the Y-TZP + CNT/ZYO. CR was obtained by dividing the total reflectance in standard black and white backgrounds. The Vickers hardness and fracture toughness were measured by the indentation method (Niihara et al., 1982). The density data were subjected to t-Student test ($\alpha = 0.05$), and the relative densities (RD) were calculated based on the theoretical values for the materials tested. Hardness, fracture toughness and CR data were submitted to t-Student test ($\alpha = 0.05$).

Results: No difference was observed ($p = 0.14$) between the final densities of Y-TZP ($5.76 \pm 0.08\,g\,cm^{-3}$; DR = 95.3%) and Y-TZP + CNT/ZYO ($5.74 \pm 0.29\,g\,cm^{-3}$; DR = 94.9%). The ΔE value obtained for the comparison between both materials was 6.0 ± 3.1. The CR value for Y-TZP (0.9967 ± 0.0025) was similar ($p = 0.12$) to the Y-TZP + CNT/ZYO (0.9929 ± 0.0018). There

was no significant difference between hardness ($p = 0.25$; Y-TZP: 10.14 ± 1.27 GPa; Y-TZP + CNT/ZYO: 8.87 ± 0.89 GPa) and fracture toughness ($p = 0.39$; Y-TZP: 4.63 ± 0.52 MPa $m^{1/2}$; Y-TPZ + CNT/ZYO: 4.98 ± 0.30 MPa $m^{1/2}$) for both materials.

Conclusion: The ceramic composite Y-TZP + CNT/ZYO showed a small color difference in comparison to the control, however the mechanical properties were not significantly affected by the addition of CNT. Since a tendency of higher fracture toughness was observed for the composite, future studies should focus in increasing the composite density and sintering quality, aiming at significant mechanical improvements.

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Biological characterization of implant surfaces—In vitro study

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Purpose: The aim of this study was to evaluate the biological performance of titanium alloys grade IV under different surface treatments: G1, sandblasting and etching (Neoporos, NEODENT); G2, surface with wettability increase (Acqua – NEODENT) on response of preliminary differentiation and cell maturation.

Methods and materials: Immortalized osteoblast cells were plated on G1 and G2 titanium discs. The polystyrene plate surface without disc was used as control group (C). Cell viability was assessed by measuring mitochondrial activity (MTT) at 4 and 24 h ($n = 5$), cell attachment was performed using trypan blue exclusion within 4 h ($n = 5$), serum total protein and alkaline phosphatase normalization was performed at 4, 7 and 14 days ($n = 5$). Data were analyzed using one-way ANOVA, Kruskal–Wallis and Dunn's tests ($P < 0.05$).

Results: The values of cell viability were: 4 h: C- 0.32 ± 0.01A; G1- 0.34 ± 0.08A; G2- 0.29 ± 0.03A. 24 h: C- 0.43 ± 0.02A; G1- 0.39 ± 0.01A; G2- 0.37 ± 0.03A. The cell adhesion counting was: C- 85 ± 10A; G1- 35 ± 5B; G2- 20 ± 2B. The amounts of serum total protein were 4 d: C- 40 ± 2B; G1- 120 ± 10A; G2- 130 ± 20A. 7 d: C- 38 ± 2B; G1- 75 ± 4A; G2- 70 ± 6A. 14 d: C- 100 ± 3A; G1- 130 ± 5A; G2- 137 ± 9A. The values of alkaline phosphatase normalization were: 4 d: C- 2.0 ± 0.1C; G1- 5.1 ± 0.8B; G2- 9.8 ± 2.0A. 7 d: C- 1.0 ± 0.01C; G1- 5.3 ± 0.5A; G2- 3.0 ± 0.3B. 14 d: C- 4.1 ± 0.3A; G1- 4.4 ± 0.8A; G2- 2.2 ± 0.2B. Different letters related to statistical differences.

Conclusion: The surfaces tested exhibit different behavior at dosage of alkaline phosphatase normalization showing that the G2 is more associated with induction of cell differentiation process and that G1 is more related to the mineralization process.

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Effect of thickness and processing of bilayer ceramic on flexural strength and stress distribution

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Purpose: To determine the influence of thickness and processing technique of veneer ceramic of a bilayer ceramic system on flexural strength and stress distribution.

Methods and materials: Thirty-two bar-shaped specimens ($20 \times 4 \times 1\,mm^3$) of yttria-stabilized tetragonal zirconia (Y-TZP), Vita-Ceram In 2000 YZ Cubes, Vita, were fabricated following ISO 6872, and randomly divided into four groups ($n = 8$). Two different veneer ceramic, PM9 and VM9, were applied in two different thickness, 1 and 3 mm, and then four groups according to the "processing technique" and "thickness". The veneer ceramics were applied on the bottom side of the bar-shaped specimens and then mechanically cycled (2 × 106 cycles, 84 N, 3.4 Hz), with the veneer ceramic under tension. The specimens were tested in 4-point bending (1 mm/min, load 100 kgf), also with the veneer ceramic under tension, and the maximum load was recorded at the first sign of fracture. The flexural strength was calculated, and the mode of failure was determined by stereomicroscopy (30×). Data (MPa) were analyzed statistically by 2-way ANOVA and Tukey's test ($p = 0.05$). To visualize the influence of the two factors on stress distribution inside the bar-shaped, a same experimental setup was designed for finite element analysis using 236,000 hexahedron element and the Maximum proximal stress values and the gradient was analyzed.

Results: ANOVA showed that the factor "thickness" ($p = 0.0017$) was statistically significant, unlike the factor "processing technique" ($p = 0.7382$). The predominant mode of failure was cracking. The samples with 3 mm of thickness showed higher values of maximum principal stress, thus occur the higher probability of failure. The ceramic VM9 showed higher tensile stresses on the surface of the veener ceramic.

Conclusion: The increased thickness of the veneer ceramic significantly decreased the mechanical strength of the bilayer ceramic system, regardless the processing technique.

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