Effect of different surface treatments on the roughness of porcelain layer for all ceramic restoration

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Background: porcelain layered zirconia restoration fractures are serious and create an aesthetic and functional dilemma for the patients and the dentist. This demands the development of practical repair options that do not necessitate removing and remaking entire restorations. The roughness of the porcelain surface before repairing material application is considered a critical step.
Objectives: investigated the effect of sandblasting, fractional co2 laser, and hydrofluoric acid as a surface treatment on the roughness of porcelain layered zirconia restorations Method: forty-two zirconia blocks prepared by CAD/CAM technology in dimensions of (10 mm width × 10 mm length×3 mm thickness). Divided into three study groups according to corresponding methods of surface treatment: sandblasting group PS (N=14), fractional CO2 laser group PCO2(N=14), and hydrofluoric acid group PHF (N=14). all the specimens were subjected to surface roughness measurements using a profilometer.
Result: There was a greater surface roughness for the laser group (6.24 um) than for sandblasting surface treatments (2.59 um) and hydrofluoric acid, which shows a similar result with no statistically significant difference from sandblasting (2,14 um).
Conclusion: all surface treatments create roughness on the porcelain surface, and no significant differences were observed between sandblasting and hydrofluoric acid. Better results were observed in the CO2 laser group.
KEYWORD: Laser; Porcelain repair, surface treatment, sandblasting, surface roughness, hydrofluoric acid treatments

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Introduction

Many all-ceramic systems have been presented in the search for the optimal cosmetic, restorative material. On the other hand, Zirconia stands out from other high-strength dental ceramics because of its attractive esthetic and long-lasting mechanical capabilities. Zirconia is resistant to corrosion and abrasion and adapts well to temperature fluctuations. Furthermore, due to its dense crystalline phase, it appears to be fairly opaque. [1]
the application of porcelain over the Zr core improves the aesthetics of the Zr core by overcoming the intrinsic deficiency of Zr's lack of translucency. [2] However, due to the lack of adhesion between the two chemically dissimilar materials, the bonding between the Zr core and the veneering ceramic layer weakens these veneered Zr restorations k. [3]
Glass-ceramics veneer fracture can be classified into grades 1,2,3.Grades1 and 2 refer to those that can be treated with intraoral finishing and polishing, while grades 3 refer to those requiring a complete prosthesis repair. [4]
Chipping the layered ceramic in the esthetic zone of the mouth or posterior region may constitute a dental emergency, affecting function and sometimes injuring the tongue.[5]
In this situation, the physician will spend significant time removing the restoration and potential damage to the abutment. In addition, the patient will incur additional costs for removing and reconstructing the fractured prosthesis.
Therefore, many repair kits have been pre-

sented to repair the prosthesis intraorally, which needs first ceramic preconditioning to enhance the bond strength. Several techniques for preconditioning ceramic surfaces include chemical, mechanical, and laser irradiation. [6] Hydrofluoric acid causes topographical changes, including surface dissolutions, allowing micromechanical retention.[7] Etching using hydrofluoric acid is a popular method for conditioning surfaces. [8]
The other surface treatment method was sandblasting; airborne-particle abrasion, performed with aluminum oxide particles under pressure, is a conventional surface treatment method that creates an irregular surface and improves micromechanical retention by increasing the surface area and the adhesion energy of repairing material to all-ceramics. [9,10]
Different lasers have been used for surface modification of ceramic, including neodymium-doped yttrium aluminum garnet (Nd: YAG)[11] and erbium-doped yttrium aluminum garnet (Er: YAG), While carbon dioxide, which is commonly used for intraoral soft tissue surgery because of its high water absorption, within the last years is used for ceramic surface treatment in a wavelength of (10600 nm).[12]
In the current study, the effect of three different methods of surface treatments on porcelain layer zirconia core was investigated since surface roughness consider a critical step in repairing fracture restoration.

METHOD

Sample preparation

Zirconia core: From Upcera Dental Zirconia, 42 pre-sintered square zirconia blocks prepared by CAD/CAM technology in dimensions of (10 mm width × 10 mm length×3 mm thickness) were used as a core for the porcelain layer.
Porcelain layer. The veneer ceramic powder, liquid, and layering procedure were used to combine the materials, and the resulting slurry was entirely layered on zirconia blocks in 2mm thickness, Figure1.
Grouping according to specimen's surface treatments
Surface treatment with Sandblasting
N= 14 specimens were sandblasted using an intraoral sandblasting device to form a (PS) group. Air abrasion was done using (AQUA CURE SINGLE, Aquacare / velopex USA) (Fig. 2A) device at bar pressure 2.5, and Using aluminum oxide powder with a grain size of 50 um, the air particle abrasion method was used for 20 seconds.
Standardization equipment (dental surveyor) and a customized metal base, Figure 2.B were employed to guarantee a consistent distance of 10 mm and a right angle between the sample disk and nozzle of the air abrasion device.

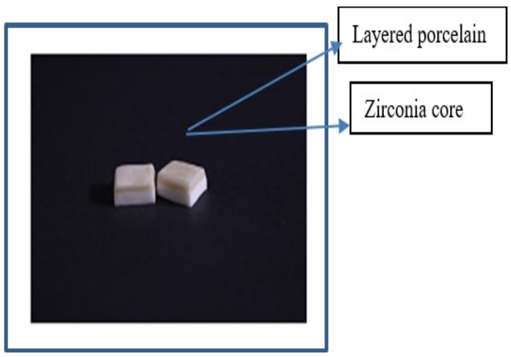

Figure 1: porcelain samples

Grouping according to specimen's surface treatments

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Fractional CO2 laser: N=14 specimens were irradiated with a Fractional CO2 laser (Laser Brochure, JHC1180, China) system and the device properties presented in Table 1, Figure 3A to form a Pco2 group; a custom-made holder was used to fix the distance between the specimen surface and the tip of the handpiece (50 mm from the lens), Figure 3B.
The laser energy was delivered at parameters (power 30 W, pulse duration 2 ms, time interval 1, the distance between spots o.3, and the number of scans 4) and the irradiating area 7 mm diameter, Figure4.
Hydrofluoric acid (HF)group: N=14 were treated with 9.5%hydrofluoric acid to form PHF. For each specimen, 0.5 mm from the hydrofluoric acid was applied to cover the sample surface for 90 seconds, then washed and dry.
Surface roughness measurement
After surface treatment, each sample was subjected to surface roughness measurement. The surface roughness (Ra) values of samples were measured using a profilometer (TIME3200 TR200 profilometer), Figure 5A. The Ra value describes the average roughness value for a surface that the profilometer has traced. A smoother surface has a lower Ra value. Three readings were taken on three lines (one in the center and the other 2mm above and 2mm below the center), Figure 5B. Then the average for each sample reading was recorded before averaging each group.

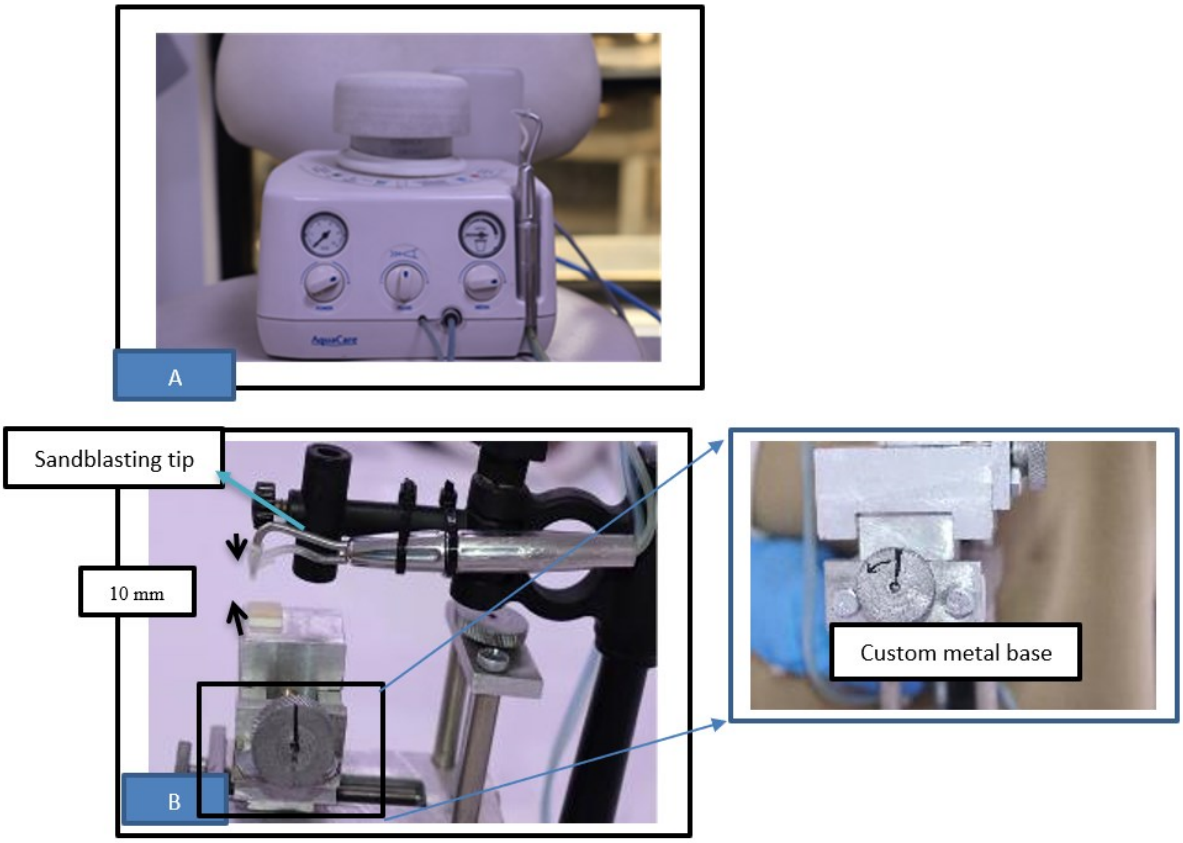

Figure 2: A. sandblasting device. B: dental surveyor with sandblasting handle

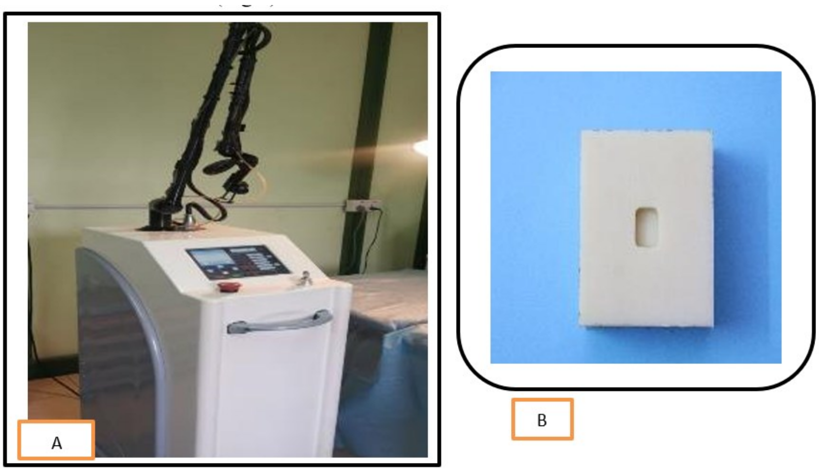

Figure 3: A: Fractional Co2 laser system, B: plastic mold

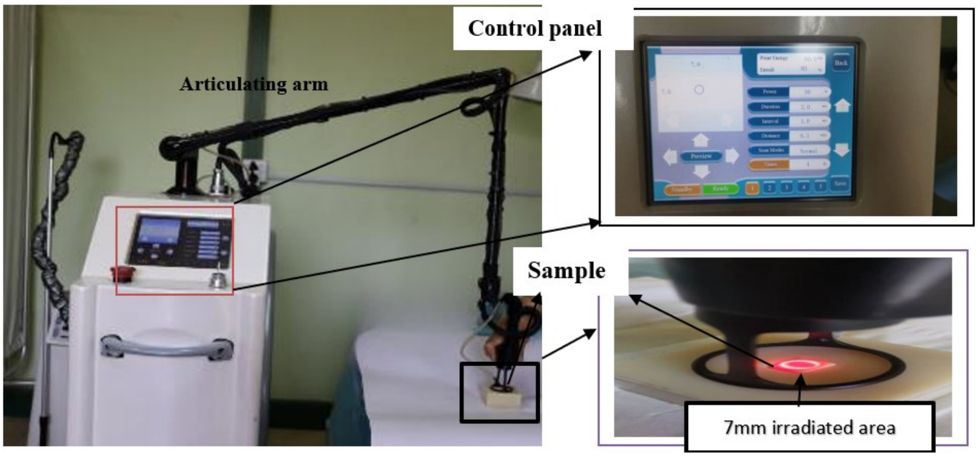

Figure 4: fractional CO2 laser setting and sample irradiation

Table 1: properties of fractional CO2 laser

Laser wavelength	**10600**nm
Output power	30≥W
Pulse Duration Time per spot	10-0.1ms adjustable
Spots distance	2.6 – 0.1mm adjustable
Interval time (time between pulses)	0.1ms-500 ms adjustable
Pulse energy:	maximum 300 mJ
Area of Focal Spot	0.05mm2
Optical system	7articulated arms

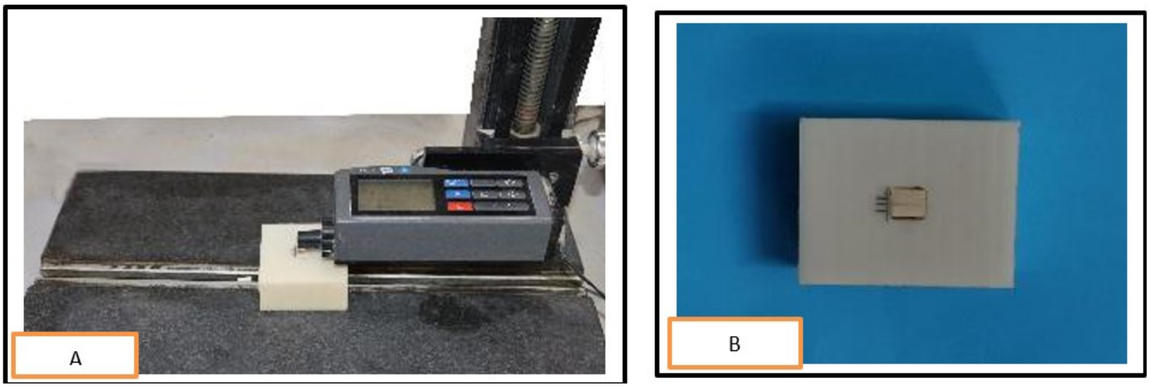

Figure 5: A. profilometer B. Plastic mold with sample

STATICAL ANALYSIS

Data were analyzed using the Statistical Package for Social Sciences (SPSS, version 25). Shapiro-Wilk test was used to test for the normality of data. Wilcoxon signed ranks test was used to compare the medians of the same sample but at two different periods. Kruskal-Wallis test was used to compare the mean ranks of three groups, and a post-hoc_ test (Dunn-Bonferroni) was used to compare every two groups of the mentioned three groups. The value of ≤ 0.05 was considered statistically significant.

Result

Result of surface roughness: It is evident in Table 3 that the median surface roughness increased significantly from 0.81µm before surface treatment to become 2.63µm after the use of sandblasting (p = 0.001), 6.42µm after the use of Co_2 Laser (p = 0.001), and to 1.92 µm after the use of HF.

It is evident in Table 4 that, there were significant differences in the surface roughness between the surface treatment groups (p = 0.008), with a highly significant for the CO2 group compared with sandblasting and HF. But the post-hoc test showed no significant (p = 1.000) difference between sandblasting and HF surface treatments (Table 3)

Discussion

Despite the popularity and high clinical suc-

Table 2. description of the data before treatments

Surface Treatment	Number	Median	Mean (SD)
Sandblasting	**14**	**0.81**	**(0.19) 2.59**
Co_2 Laser	**14**	**0.81**	**(0.08) 6.42**
HF	**14**	**0.81**	**(0.55) 2.14**

Table 3: surface roughness after and before treatments

		Surface roughness				
		Before surface treatment		After surface treatment		
Surface treatment	Mean (SD)	number	Median	Mean (SD)	Median	P*
Sandblasting	(0.14) 0.75	14	0.81	(0.19) 2.59	2.63	0.001
Co_2 Laser	(0.14) 0.75	14	0.81	(0.08) 6.42	6.42	0.001
HF	(0.14) 0.75	14	0.81	(0.55) 2.14	1.92	0.001

Table 4: compared between surface treatments

Surface treatments	N	Mean	)SD)	P*	Post-hoc groups	P**
A) Sand blasting	14	2.59	(0.19)		AXB	0.023
B) Co_2 Laser	14	6.42	(0.08)	0.008	AXC	1.000
C) HF	14	2.14	(0.55)		BXC	0.022

cess rates of zirconia-based fixed restorations, a considerable amount of veneering ceramic material fracture has been reported by some clinical studies. [15,16]

The efficacy of sandblasting depends on various factors like the size of particles, air pressure, distance, angle, and duration of the procedure.[17] The current study selected 50µm as a sample size not only because 50µm particles are the most commonly used alumina particles for sandblasting [18] but also small particle size of 50µm easily flows out of a spray tip with a greater number of particles than coarse powder of 110µm. Sandblasting with 110µm and 250µm aluminum Al2O3can remove significant amounts of substances and could affect the clinical adaptation of the prostheses. [19]

Air abrasion pressure was selected at 2.5 bars as it causes insignificant damage to the surface. According to the literature, surface cleaning should be performed using abrasion with 30–50 µm alumina particles at 2.5 bar pressure at a distance of 10 mm perpendicular to the zirconia surface for 10–20sec (20). According to Zeighamis study, The 2.8 bar group showed higher surface roughness compared to the 1 bar group, and it is not that different from the pressure parameter, which was dependent on this study.[21]

Hydrofluoric acid was used in this study to dissolve the crystalline and the glassy phases and produces a porous irregular surface that increases the surface area and facilitates the penetration of the resin into the microretentions of the etched ceramic surfaces. Increasing silica content in ceramic allows for more surface roughness, especially when Hydrofluoric acid is used for etching, as HF reacts selectively with silica and produces hexafluorosilicate complex, which is responsible for surface roughness and facilitates interlocking of the resin composite.[22]

CO2 laser emits at a wavelength of 10600 nm: this wavelength is appropriate to be absorbed by the ceramics and can create cavities using superficial heat (23); these microcavities can enhance mechanical strength between ceramics and resin. There are some advantages related to a CO2 laser (fractional type), like affecting several points with distinct borders with a single emission; this feature leads to a decrease in hand-piece movements and making a homogenous surface on the sample.[24,25]

In this study, the laser parameter was selected in agreement with Abdulsatar Hussein, [26] who used different laser parameters, and found that (power 30 W, pulse duration 2 ms, time interval 1, the distance between spots o.3, and number of scan 4) is the best parameters with high SBS and no microcracks, so the laser beam was enough to interact with porcelain surface without reveled adverse effect of heat accumulation. And in agreement with Alhassani and Jawad [27] who used the same parameter and found that height SBS with lower temperature increases. Ahrari et al [28] state that no crack was observed after applying fractional laser parameters (power 30 W, pulse duration 2 ms, time interval 1, the distance between spots o.3, and number of scans 4) for porcelain structure.

Surface roughness increased following treatment with each (sandblast, CO2, HF). CO2 surface treatment shows the highest roughness compared to sandblasting, this finding is related to the efficacy of fractional CO2 laser in roughening the surface through the process of thermo-mechanical ablation. The effect of laser is related to the vaporization of the surface -material.[29,30] The vaporization is considered as a micro explosion of portions of material heated above the melting point [31] that Leads to increased surface roughness. After CO2 laser application over the ceramic, surface topography showed a unique shape termed "conchoidal tears", which positively affects the bond strength of repairing material as documented by Yavuz et.al. [32]

CONCLUSION

All surface treatments procedure gives a rough surface; The Fractional CO2 laser created a rougher surface than the other surface treatment methods ($p < 0.05$). There were no significant differences in surface roughness between HF acid etching and sandblasting.

Conflict of interest

The author reported no conflict of interests.

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