Qualitative and quantitative evaluations of topography for CAD/CAM all ceramic zirconia after different surface treatments

Sazan M. Azeez[1]; Shatha A. Salih[2]

Background and objectives: The purpose of this in vitro study was to evaluate the effect of grinding, reglazing and polishing procedures on the surface roughness of monolithic zirconia qualitatively and quantitatively.
Materials and methods: Thirty-six disc-shaped yttrium-stabilized zirconium oxide specimens were milled from pre-sintered zirconia blanks using CAD-CAM machine with a diameter of 12mm and thickness of 1.4mm for twenty-seven discs while 12mm and 1.2mm for nine discs as a control group. After that, they were sintered and overglazed. The control group (GA) left untouched while the other twenty-seven specimens were subjected to standardized wet grinded with a coarse diamond rotary instrument. Then they were randomly divided into three groups (nine specimens for each): grinded group (GB) without any additional surface treatment; reglazed group (GC) by adding galze material; polished group (GD) polishing with an intraoral zirconia polishing kit Kenda in a 2-step procedure. Then specimens were evaluated under a stereomicroscope. The surface roughness values were measured with a profilometer for all groups. The mean of surface roughness values was calculated and analyzed using one-way ANOVA and using LSD significant difference tests for comparison between groups (a = 0.05).
Results: Stereomicroscopic images revealed that the grinded specimen showed grooves and scratches, reglazed surface showed the same criteria as control with a little bit more evidence of irregularities. While polished specimen appeared smoother and more homogeneity. Statistically significant differences were noted among the experimental groups, in which GB resulted in the highest roughness, GD with the lowest roughness. While GC was close to GA.
Conclusions: Roughness significantly increased after grinding, but polishing decreased roughness significantly while glazing restores the smoothness.

Keywords: Cad/Cam, Zirconia, surface treatments, roughness, stereomicroscope.

(1)Department of Conservative Dentistry, College of Dentistry, Hawler Medical University, Erbil, Iraq.
(2)Department of Conservative Dentistry, College of Dentistry, Hawler Medical University, Erbil, Iraq.

Introduction

The introduction of zirconia to the dental field opened up the design and application limits of all-ceramic restorations. The superior mechanical properties of zirconia combined with the state of the art CAD/CAM fabrication procedure allowed for the production of restorations with high accuracy and success rate.[1-3]

There are two types of zirconia restorations used; these are zirconia veneered with feldspathic porcelain (ZVP) and monolithic zirconia (MZ).[4] But mostly a clinical failure of zirconia supported restorations, is due to chipping of the veneering ceramic (adhesive failure).[5-7] The mechanism for chipping of the veneering porcelain has been linked to the difference between the coefficient thermal expansion between zirconia and veneering materials, and tempering stresses created during rapid cooling.[8] As a result monolithic zirconia dental restorations are becoming a popular alternative to bilayered zirconia-based dental restorations, used as all zirconia restoratives, so-called ‘‘Full Contour’’ without covering the veneering porcelain.[9] With ceramic restorations, the glazing process helps to achieve a smooth surface and retains high luster for a long period of time. Sometimes, after the glazed restoration has been permanently cemented additional surface modifications may be necessary to correct minor interferences. Because of high surface hardness of zirconia, diamond burs are used to carry out clinical adjustment which may cause loss of glaze layer and surface smoothness.[10] These additional adjustments, before or after cementation, to the glazed ceramic surface, can lead to the removal of the surface glaze and exposure of the underlying unglazed rough ceramic surface. Unglazed ceramics may increase plaque retention,[11,12] increase wear on the opposing teeth,[13] and reduce the strength of the ceramic material.[14,15]

In the past, a glazed surface was thought to produce smoother, more cleansable surfaces and stronger mechanical properties that’s why glazing was always advocated as the last surface treatment before final cementation.[16] A Polishing was not done routinely for fear that it would introduce more surface flaws and weaken the material. With advances in polishing instruments, it became possible to achieve acceptable surface smoothness by using rotary equipment. In addition, polishing may also produce surfaces, which are less abrasive than glazed surfaces.[17] Surface profilometry is suitable for quantitative assessment of surface roughness.[18,19] However, in some cases the roughness values do not truly represent the actual topography of ceramic surfaces because only some parts of the surface are probed by the profilometer.[20] Therefore in the present study stereomicroscopic images were used also to yield more comprehensive results.[21,22]

Understanding the effect of different surface treatment as, grinding, polishing and reglazing on the surface roughness and surface damage of all-ceramic restorations is therefore critical in the achievement of successful restorations. But to date; assessment of surface damage has been limited. Thus, the objective of this study is to evaluate the effect of different surface treatments on roughness and surface damage of zirconia for full contour restoration.

Materials and methods

Specimen preparation. In this in-vitro study, thirty-six standardized monolithic zirconia discs were constructed from pre-sintered full contoured partially yttrium-stabilized zirconium dioxide (Y2O3 3mol %), translucent monolithic zirconia blocks (ICE Zirkon, Zirconzahn, SRL, Gais/South Tyrol, Italy), using CAD/CAM technology, composition of material are shown in (Table 1). Design of zirconia discs having 12 mm diameter with 1.4 mm thickness for twenty-seven specimens and a 1.2mm thickness for nine specimens as a control group was performed by using the CAD/CAM system software (Figure 1), and then sintered at 1500°C according to the manufacturer’s instruction. Then each specimen was glazed by using glazing material (powder & liquid), (Vita Akzent* plus, Zahnfabrik, Germany), and fired in a ceramic furnace (Programat P300, Ivoclar Vivadent) at 930°C according to manufactures instructions (Table 2), The specimen’s dimensions were checked using digital caliper (Aickar, Germany) (Figure 2).

Table 1: Description of material used.

Material	Main composition	manufacture
Presintered zirconia blanks (Yttrium partially stabilized zirco-nia)	ZrO_2 (Specifications), Y_2O_3 (4 – 6 %), Al_2O_3 (< 1 %), SiO_2 Max. (0.02 %), Fe_2O_3 Max. (0.01 %), Na_2O Max. (0.04 %)	ICE Zirkon, Zirconzahn, SRL, Gais/South Tyrol, Italy
Glaze material	powder & liquid	Vita Akzent*plus, Germany
Zirconia polishing system: medium grit polisher (Blue cup), Fine grit polisher (Red yellow cup)	Silicon dioxide matrix, diamond abrasive	Kenda Zircovis- Liechtenstein

Table 2: Parameters used in glazing procedure.

Zirconia specimens	Glazing procedure
Closing time	3 min
Starting temperature	135°C
Temperature rise	60°C/min
Final temperature	930°C
Holding time of final temperature	3 min
Vacuum	No

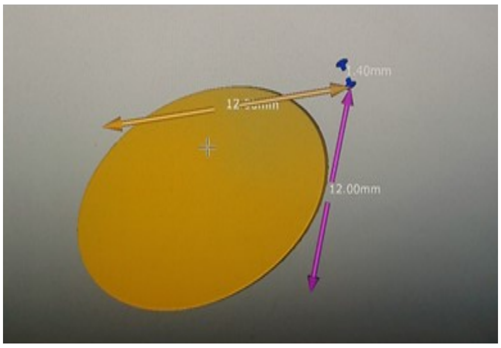

Figure 1: Design of zirconia sample using CAD/CAM software program

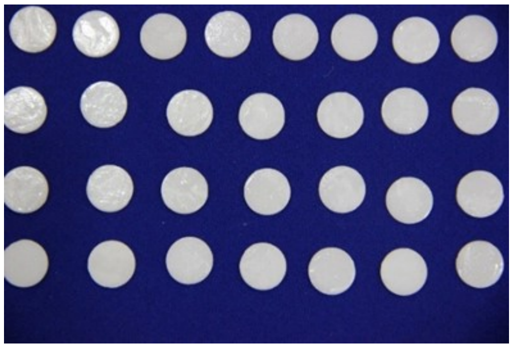

Figure 2: Glazed zirconia discs.

Grinding procedure. All of the specimens (n = 27) except the control group (n = 9), were subjected to the grinding procedure to stimulate clinical chairside adjustment, each specimen was fixed within a specialized mold which was held on a dental surveyor (one surface from each specimen previously premarket subjected to grinding), using a coarse diamond straight fissure bur (VerDent, 1434, UE), underwater coolant in continuous forward-backward motion attached to a high-speed handpiece on a dental surveyor in a standardized condition a constant load of 100 g is used, by applying free weight on the holding arm of the high-speed handpiece. This protocol supported by Al-Makramani et al,23 and Khayat et al.24 Grinding was done in a sweeping motion forward and backward for sixty seconds for each specimen. The final dimension of the discs was 12mm in diameter and (1.2 ± 0.1 mm) in thickness with a digital caliper.

Following grinding all specimens were ultrasonically cleaned for 15 minutes in distilled water to remove any ZrO_2 residues. Then all the grinded specimens (n = 27) were randomly divided into 3 groups GB (grinded), GC (reglazed), and GD (polished), according to the different surface treatments. While the control group; GA (n = 9) received no surface treatments,

Reglazing procedure. Glazed material (Vita Akzent*plus, Zahnfabrik, Germany), was applied on the grinded surfaces of group C specimens using a ceramic brush until all glaze material was evenly distributed on the surfaces and heated in ceramic heating device (Programat P300, Ivoclar Vivadent) at 930°C for twenty-two minutes according to the manufactures instructions (Table 2). Two coating layers of Glazing has applied and this procedure was supported by Auškalnis et al.25

Polishing procedure. The grinded surfaces of group D specimens were polished by specific polishing kit (Kenda Zircovis Diamond, Liechtenstein) in a two-step procedure: blue rubber (medium) and red rubber (fine) (Figure 3). With a low-speed handpiece (EX-203, Japan) for sixty seconds. Polishing was performed with an intraoral zirconia polishing system. The sweeping motion was done in the forward and backward direction as in the grinding procedure (the specimen was fixed within a specialized mold which was held by a dental surveyor). Polishing was performed for thirty seconds by using medium grit polishing bur at 10,000 rpm. after that the fine grit polishing bur was used in the same direction for another thirty seconds in a sweeping movement, this procedure repeated for the whole samples. A new polishing instrument was used for each specimen.

Figure 3: Kenda polishing kit optimized specially for zirconia.

Surface topography evaluation by using Stereomicroscope. In this study qualitative topographic evaluations were taken by using stereomicroscope (Olympus, 220688, Japan) (Figure 4). Micrographs were obtained at the center of the specimens at ×250 magnification.

Figure 4: Qualitative assessment of surface topography using stereomicroscope.

Surface roughness evaluation. The quantitative surface roughness of specimens was measured using a mechanical contact profilometer (Tayler-Hobson, U.K) (Figure 5). Three measurements were made per specimen one in the center and the other three mm above the center and three mm below to it. Using a stylus speed of 0.25 mm/second. The mean surface roughness (Ra) of the 3 Ra values was calculated for each sample in each group.

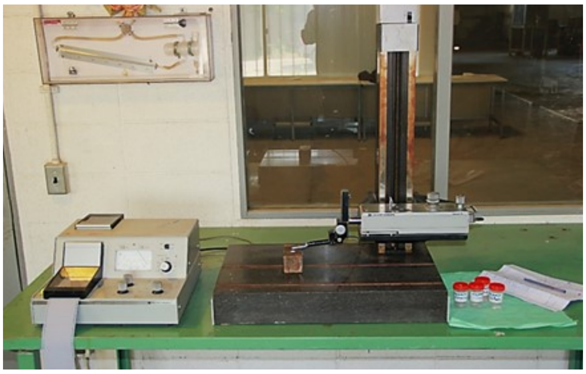

Figure 5: "Profilometer" for surface roughness testing.

Statistical Analysis. The statistical analysis was performed using the SPSS software package (Version 24.0, IBM SPSS Inc., Chicago, Illinois, USA). Descriptive analysis for the samples means values, range and standard deviation were calculated and One-Way ANOVA analysis was used. Then the mean values were compared using LSD test (Less Significant Difference). The level of statistical significance was set at $P<0.05$.

Results

Stereomicroscope. Stereomicroscope images of zirconia samples were obtained at x250. GA image as a control revealed that the surface is with homogeneity but some porosity is present. While image after grinding with diamond bur showed evident surface leveling and scratching in the GB picture and obvious surface damage is observed after the surface reduction by grinding bur. In (GC) picture, which is the surface immediately after reglazing, some pores are still visible. While in GD surface smoothness is apparent and it is clear that pores disappeared after polishing, but some surface unevenness is observed due to polishing instruments usage (Figure 6).

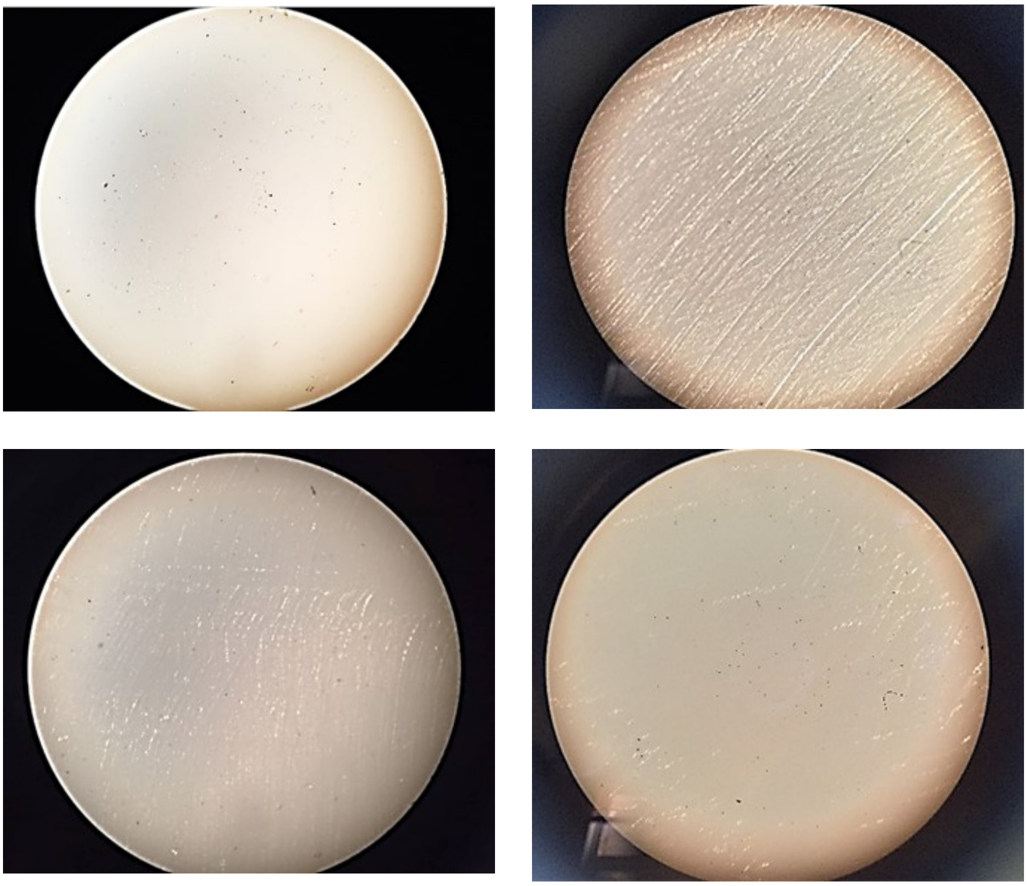

Figure 6: Stereomicroscope images of zirconia samples at x250 of GA: Control group, GB: Grinded group, GC: Reglazed group and GD: Polished group.

Surface roughness evaluations. The mean ± standard deviation (SD) values of surface roughness Ra (μm) are presented in table 3 and figure 7. Comparison between Ra values by one-way ANOVA revealed significant differences among the groups (Table 4). The post-hoc (LSD) test showed a statistically significant difference between grinded and other groups ($P<0.05$). GB was with the roughest surface (Ra = 1.4493). The Ra value after glazing (Ra = 0.5144) which was nearly similar to that of the control group (Ra = 0.5556), and there was no statically significant difference between them ($P=0.696$). This indicates that reglazing procedure restores the surface smoothness near to the control group. The Ra values obtained after polishing was the lowest value among all the groups (Ra = 0.2681), and there was a statically significant difference between polished and reglazed group ($P<0.05$). Mean that the polishing restored surface smoothness much better than reglazing procedures (Table 5).

Table 3: The descriptive statics of the mean roughness (Ra & SD) for all groups.

Groups	N	Minimum	Maximum	Mean	Std. Error	Standard Deviation	Variance
Control (GA)	9	0.35	0.73	0.5556	0.05840	0.17520	0.031
Grinded (GB)	9	0.93	1.63	1.4493	0.07042	0.21125	0.045
Reglazed (GC)	9	0.22	0.90	0.5144	0.09510	0.28530	0.081
Polished (GD)	9	0.13	0.73	0.2681	0.06625	0.19876	0.040

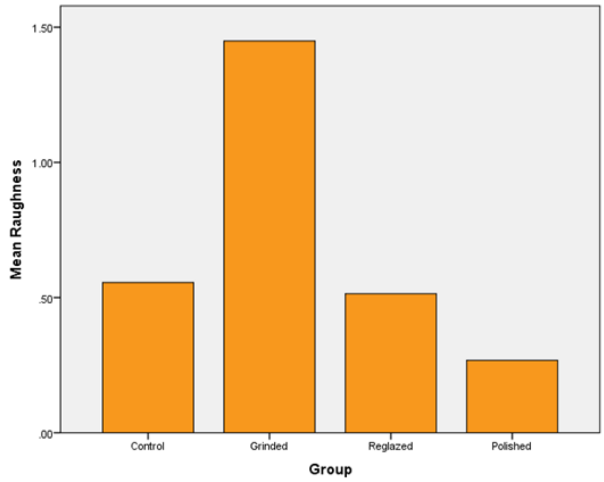

Figure 7: Mean Ra values of all groups.

Table 4: One-way ANOVA of mean Ra values of zirconia samples.

Roughness	Sum of Squares	Df	Mean Square	F	P value
Between Groups	7.228	3	2.409	49.116	<0.001*
Within Groups	1.570	32	.049		
Total	8.798	35			

Indicate statically significant difference between the groups.
Indicate mean difference is significant when *p*<0.05.

Table 5: Results of post hoc tests (LSD) showing the mean Ra values of all zirconia samples.

Group			Mean Difference	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	Control	Grinded	-.89370*	0.10441	<0.001	-1.1064	-0.6810
		Reglazed	0.04111	0.10441	0.696	-0.1716	0.2538
		Polished	.28741*	0.10441	0.010	0.0747	0.5001
	Grinded	Reglazed	.93481*	0.10441	<0.001	0.7221	1.1475
		Polished	1.18111*	0.10441	<0.001	0.9684	1.3938
	Reglazed	Grinded	-.93481*	0.10441	<0.001	-1.1475	-0.7221
		Polished	.24630*	0.10441	0.025	0.0336	0.4590
	polished	Grinded	-1.18111*	0.10441	<0.001	-1.3938	-0.9684
		Reglazed	-.24630*	0.10441	0.025	-0.4590	-0.0336

*** The mean difference is significant at the 0.05 level.**

Discussion

Preparing a smooth surface for ceramic restorations are considered as an important step because increased surface roughness associated with improper surface treatment can increase the wear rate of the opposing teeth and can compromise the clinical performance of the restorations.[26,27] The results of this in-vitro study documented that grinding, polishing, and reglazing would influence surface roughness. This study revealed that surface grinding with a coarse grit diamond fissure bur at high rotational speed increased surface roughness, but polishing after grinding using zirconia polishing kit significantly decreased the surface roughness. While, reglazing restored the surface roughness in a high percentage, which is close to the control group. These findings are in agreement with Hmaidouch et al, who reported that lower roughness values were achieved after polishing compared to glazing procedure.[28] Also, Mohammadi-Bassir et al, found that grinded zirconia specimens were significantly rougher than reglazed and polished groups.[29]

While in argument the glazed surface was found smoother than polished and grinded surface in a study by Sabrah et al.[30] However, controversial results have been obtained in Janyavula et al,[31] which found that the surfaces of monolithic zirconia that were polished were smoother than glazed surfaces. Similarly, Mitov et al,[2] documented that polished zirconia showed a lower surface roughness than glazed and grinded zirconia. These differences may be due to the different polishing (machine or manual) and glazing (glass coating, firing) techniques, or different study protocols as documented by Özkurt-Kayahan.[32] It was known that machine polishing results in a significantly higher surface gloss of ceramics than manual polishing with tools for intraoral polishing.[13]

While, in this study, the highest surface smoothness was achieved after manual polishing, and these findings were in an accordance with the result of Hmaidouch et al,[28] Surface roughness after polishing of the grinded specimen, smooth surface was obtained. This was possible due to the removal of weakly attached surface grains and elimination of the grinding trace lines by using the specific polishing kit for zirconia. They concluded that polished surfaces were better than glazed surfaces and produce less wear on the opposing enamel as documented by Hmaidouch et al,[28] and Jung et al.[33]

Few studies have used specific polishing kits indicated for zirconia.[34,35] The present study used a specific polishing kit that was optimized for polishing zirconia restorations because zirconia is much harder than other dental ceramics and therefore requires specialized equipment for polishing as documented by Dupriez et al.[36] A recent studies compared different types of zirconia intraoral polishing systems and reported significant differences between systems but few differences between the steps in each system.[35,37] Each polisher was used for thirty seconds to represent an average amount of time a clinician would spend polishing a restoration as was performed by Chavali et al,[37] and Alhabdan & El-Hejazi.[38] For standardization the center of the specimens was chosen for quantitative and qualitative surface topography evaluations.

Quantitative surface roughness measurement in the current study was done by contact profilometer because mechanical contact profilometer produces more accurate results compared to non-contacting profilometry and is not affected by differences in surface material properties such as colour or transparency. While in non -contact devices usually used a light beam or lasers to scan the surface. However, in non-contact profilometry method can lead to false values when used with a shiny surface such as ceramics this is due to the scattering effect of the reflected light.[39]
Stereomicroscope was used to evaluate the surface roughness of zirconia qualitatively in addition to surface roughness assessment using profilometer. Because surface profilometry is suitable for quantitative assessment of surface roughness.[18,19] However, in some cases the roughness values do not truly represent the actual topography of ceramic surfaces because only some parts of the surface are probed by the profilometer.[20] Therefore, microscopical pictures have been recommended to yield more comprehensive results.[21,22]

Very often the glazing does not reduce the surface roughness as the polishing group, this is might be due to that the coating layer is insufficient thick to effectively complete the ceramic surface micro-cracks and grooves as documented by Kenneth et al,[40] although, in this study, zirconia ceramic samples were reglazed with two layers, unlike in earlier discussed study.[41] So in the current study, the polishing system effectively smoothed sharp relief elevations caused by coarse diamond bur. So if occlusal adjustments are required, gently grinding with diamond burs and careful polishing with recommended polishing kits for zirconia is an acceptable procedure.

One of the main study limitations was that all preparation procedures were performed in the discs shape sample surfaces which are not identical to the dental ceramic restorations. Surface roughness was also studied not through the entire surface length.

Conclusion

Within the limitations of this study, grinding on zirconia by using coarse diamond bur, causes significant decreasing in surface smoothness. Reglazing can restore surface smoothness while polishing procedure increased surface smoothness significantly.

Conflicts of interest

The authors reported no conflict of interest.

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