DOI: https://doi.org/ 10.32828/mdj.v17i1.1014

MDJ

Effect of Different Surface Treatments on Surface Roughness and Vickers Micro-Hardness of Feldspathic Porcelain: An In Vitro Study

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Abstract

Background: Several new all-ceramic systems with superior aesthetic qualities such as translucency similar to natural tooth have been developed over the last two decades in response to the demand for metal-free and more natural-looking restorations. To achieve that, all-ceramic restorations, need characterization and glaze.

Objective: The objective of the present study was to evaluate the effect of glazing and polishing techniques on surface roughness (Ra) and Vickers hardness number (VHN) of feldspathic porcelain.

Materials and methods: Twenty-four layered zirconia discs (10 mm in diameter and 2 mm thickness) were designed by a special Sketchup 3d software program and saved as an (STL) file. All specimens were subjected to the polishing by using 600, 800, and 1200 grit of aluminum oxide paper in sequence. The specimens were divided into three groups each with eight samples (n=8) the first group was treated with glaze (G), the second group was polished with polishing kit (PK), and the third group was polished with polishing diamond paste (DPP). After the surface treatments were performed, the surface roughness was measured by using a profilometer and Vickers microhardness (VHN) was measured by using a digital microhardness tester. The surface characteristics changes were examined using a scanning electron

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microscope (SEM). Data were statistically tested with one-way ANOVA, Post-hoc Tukey's test, and Least Significant Difference (LSD).

Results: Glazing and polishing techniques significantly affected the (Ra) and VHN of feldspathic ceramic. Group G showed significantly the lowest surface roughness (50±0.26) µm in comparison with groups PK (1.00±0.30) µm and DPP (70±0.42) µm. The largest VHN was obtained in a PK group (658.9±66) and the lowest VHN value was shown with the G group (538.4±36), while the VHN of DPP group was (652.8±66).

Conclusions: Glazed surface group had the lowest surface roughness and microhardness compared to the polishing kit and polishing paste groups. Therefore, glazing is recommended for finishing feldspathic porcelain, as it is more clinically acceptable, and it causes less wear to the antagonist's teeth.

Keywords: Feldspathic porcelain, surface roughness, Microhardness, Glaze, CAD/CAM.

Introduction

There is an evolution in using all-ceramic materials, due to the endless patients' demands for dental restorations that imitate the natural teeth appearance (1). Owing to its unique mechanical qualities and high biocompatibility, yttria-stabilized tetragonal zirconia (Y-TZP) is gaining popularity in dentistry. It's now utilized as the core material in all ceramic dental restorations (2), zirconia cores are often veneered with glass-ceramics (3).

For more than 20 years, feldspathic ceramics (FC) have been used as veneering ceramics for porcelain-fused-to-zirconia restorations and porcelain-fused-to-metal reconstructions. Feldspathic ceramic has a high translucency and therefore meets the highest esthetic criteria to mimic the appearance of natural teeth, but it has a lower mechanical strength (4).

CAD-CAM restorations are milled with rotary instruments coated with diamond abrasive particles of various grit sizes. Such rotary instruments cause the restoration to have a high initial surface roughness, which leads to increased wear of neighboring teeth, discoloration of the restoration, or increased plaque accumulation. All these can lead to secondary caries and/or gingivitis. Therefore, the high initial surface roughness must be minimized, either by glaze and stain firing or polishing (5).

Surface finishing methods include polishing with an adjustment kit and diamond polishing paste, as well as glazing (6). The use of diamond polishing pastes for porcelain polishing is a typical practice. These pastes produce effective polishing results (7).

Polishing which is a process that involves the use of abrasive devices to achieve smoothness and a high gloss on a surface (8). Therefore, the use of polishing systems to modify surface roughness is needed to reduce the risk of ceramic deterioration, wear of opposing teeth, biofilm accumulation, gingival irritation, ceramic stains, and fracture (9).

Since manual polishing and glazing have different effects on the surface roughness and appearance of dental ceramics, it seemed worthwhile to see if roughness differed depending on the finishing procedures (10). Because there are a variety of polishing kits. These are made up of a wide range of materials, including diamond burs and abrasive, rubber cups, diamond polishing pastes, and felt wheels, (11). However, there is no gold standard for ceramic surface finishing, especially for CAD/CAM ceramic (12).

Clinicians typically struggle to select the best appropriate material and finishing process due to the wide selection of ceramic materials available on the market. Glazing the ceramic restoration is a laboratory technique that seals the pores on the fired ceramic's surface, resulting in a glossy finish. The glaze layer is recommended as a protective layer to prevent wear, staining, and color changes. Glazing is accomplished by either applying a thin layer of clear glass to the surface or heating the framework to glazing temperatures for 1 to 2 minutes to achieve shining glass surfaces (13), (14), (15). Before final cementation, glazing has always been recommended as the last surface treatment. There is now a lot of argument over the optimum process for achieving the smoothest and strongest porcelain restoration (16).

A variety of studies have been conducted to assess surface roughness of different ceramics. Some researchers observed the superior smoothness of glazed porcelain compared with polishing technique (17), (18), (19). Others, on the other hand, showed that polishing of porcelain can match or even exceed the smoothness of glazed porcelain (4, 20), (21).

The null hypothesis assumed that the glazing, as well as polishing techniques will not affect the surface roughness and microhardness of feldspathic porcelain.

Materials and Methods

Experimental design

A total of twenty-four disc-shaped zirconia blocks

(UPCERA, FDA, HT, 89 ×16 mm, China) were designed using three-dimensional modeling software (Sketchup 3D design software, Version 2016), with dimensions of (10 mm diameter and 1mm thickness), as shown in figure (1). A dry milling machine (Imes-Icore, 5-axes, COR TEC 250i dry, Germany) was used for milling the specimens, as the latter sintered in a furnace (VITA, Germany) according to the manufacturer’s instructions (1530 °C) for 8 h. After cleaning the specimen with a soft brush, a 1 mm thickness layer of feldspathic porcelain was added by a custom made silicone mould to the zirconia substructure to make the final thickness of specimens (10 mm in diameter and 2 mm in thickness). The dimensions of the sample were chosen based on the previous studies (22), (17).

Veneer build-up

For layering the ceramics, a thin layer of wash bake was added to the clean and dry zirconia surface using a fine brush. The firing is then done in a zirconia furnace according to the manufacture's recommendations. All zirconia specimens were inserted into a custom-made silicone mould for the application of porcelain layers. The mould was coated with a separating medium (Renfert, Germany) to facilitate removal of the veneering material. To form a slurry in a creamy consistency (according to the manufacture recommendations), a mixture of ceramic powder (VITA VM®9, Vita Zahnfabrik, Bad Sackingen, Germany) with its modeling liquid was used. The slurry was loaded in the mould and excess liquid was removed with absorbent paper. Then, the disc-shaped ceramic mass was removed from the mould and taken to the programmable vacuum furnace (Program at P 300, Ivoclar, Vivadent) for firing at a final temperature of (910 °C), according to the manufacturer’s instructions. After cooling the first layer of dentine added another layer of enamel in the same procedure at a final temperature of (900 °C).

To ensure standardization a grinder/polisher machine (DAP-5, STRUERS, Denmark) underwater cooling was used to create the baseline roughness specimens using 600, 800, 1200 grit aluminum oxide paper (AL-Alamain Ghalib, KSA), (23). After the final grinding, the thickness of each sample was determined with a digital caliper (LOUISWARE, china) of 0.01 mm accuracy.

Specimens grouping

The total of 24 discs shaped specimens were randomly divided into three groups (n=8) according to the surface treatments. The first group is polishing kit (PK), the second group is diamond polishing paste (DPP), and the third group is glazing (G).

Group I Three Steps Polishing of specimens (PK)

Group PK specimens were polished with a special all-ceramic restorations polishing kit which is available for dental laboratories (NHT, HIGH TECHNOLOGY, Korea). This technique was used in 3 steps starting from coarse then medium and finally with fine bur. To accomplish this procedure an electric hand piece (MARATHON-3, Korea) at a speed of 30,000 rotations per min (rpm) was used under dry conditions, with regular and repeated stroking motions in a single direction (24).

Group II Two Steps Polishing with diamond paste (DPP)

The specimens were polished with a rubber polisher (NHT, HIGH TECHNOLOGY, Korea) for 30 seconds. Then a small quantity of diamond polishing paste (Renfert Polish, all-in-one, Germany) with a brush was used for finalizing the surfaces for 1 min (25). The same operator performed the manual polishing procedures for all the specimens' groups.

Group III Glazing (G)

After the sintering process, one side of each disc was coated with glaze and stain liquid (VITA AKZENT® Plus, GLAZE LT, Germany), fired at (900 °C). Two glaze application techniques have been used, following the manufacturer's instructions. Powder was mixed with its liquid until a homogeneous and creamy consistency was achieved. The mixture was then applied with a thin brush to the porcelain layer, accompanied by the necessary glaze firing in (Program at P 300, Ivoclar, Vivadent, Germany) furnace.

Surface roughness (Ra) Analysis

Before the surface roughness test, all specimens were ultrasonically cleaned with distilled water for 10 min (1) by using ultrasonic cleaning machine (MESTRA CALYPSO, Spain). Then a contact stylus profilometer (Pocket Surf, USA), was used to examine all specimens from each group as shown in figure (2). The roughness evaluation settings for the profilometer were set with a speed of 5.08 mm/s, display resolution of 0.01 μ, maximum stylus force of 1500 mgf /15.0 mN, and a cutoff value of (0.8 mm) (26). Measuring accuracy were meets ASME B46.1, ISO and DIN standards and MIL specifications. Three readings per specimen were taken and the mean average values of each specimen were calculated.

Micro Hardness Testing (VHN)

A Digital micro hardness tester was used to evaluate surface micro-hardness on mirror-polished disc-shaped specimens (Digital Micro Vickers Hardness Tester TH714, China), (Fig. 3). Three Vickers indentations per specimen were used to determine the mean hardness, with loads of 9.8 N applied for 15 seconds (27). The hardness value was determined by averaging the three readings.

Scanning Electron Microscope (SEM) Evaluation

SEM was performed on one sample from each group at random to test the sample's topography (28). The specimens were coated with a gold alloy spray by using a vacuum sputter coater (MTI CORPORATION, USA). Then were examined using an SEM (Vega, TESCAN, Czech Republic) at voltage of 20.000 kV, distance of 9 mm, a scale of 50 μm, and magnification of (1000 X).

Statistical Analysis

Statistical analysis was performed with SPSS software to measure the mean and standard deviation of the test parameters. For multiple comparisons, one-way ANOVA followed by Tukey's post hoc tests for VHN and LSD test for surface roughness. The statistical significance of the mean difference of each parameter was measured at a significant level of 5% was set for comparison between the groups.

Results

Figure (4) showed the mean (Ra) values in microns (µm) and standard deviations (SD) for the three studied groups. The smallest Ra values (50 ± 0.26 µm) were found in groups (G) while, the largest values (1.00 ± 0.30 µm) were in the (PK) group. (DPP) group was in the middle of the two values (70 ± 0.42 µm).

According to one-way ANOVA test (Tab. 1), no significant difference was found between the Ra of (G) group and the Ra of (DPP) group (p-value 0.326). However, the comparison between the mean Ra values of (G) group and (PK) group showed a significant lower Ra of (G) group when compared to (PK) group (P-value 0.002). The same result was showed with (DPP) and (PK) groups (P-value 0.029).

Figure (5) showed the mean distribution and standard deviations of (VHN) of the three tested groups. The Polished kit (PK) group recorded the highest average (VHN) mean values (658.9±66) followed by (DPP) group (652.8±66) while the lowest average (VHN) mean values were recorded for (G) group (538.4 ± 36).

According to the results of one-way ANOVA which were represented in table (2), a statistically significant difference was shown between G and DPP groups with P-value (0.004) and between G and PK groups with P-value (0.002). However, DPP and PK groups were non-significantly different with a P-value (1.000).

Different surface topographies were observed for different surface treatments. Figure (6) showed SEM images at a magnification of 1000X for all of the tested groups. Surface treatments altered the topographic pattern of feldspathic porcelain. The glazed group had the smoothest, uniform, and homogeneous surface, with the fewest flaws, pores, and grooves (Fig. 6.a) The (PK) group revealed deep defects, and well-defined pores, as shown in figure (6.b). The (DPP) showed many defects, scratches, and irregularities (Fig. 6.c) but it does not have pores as much as PK.

Discussion

Various forms of all-ceramic systems have been developed to move toward metal-free restorations over the last 30 years to meet the increased demand for highly aesthetic, biocompatible, and long-lasting restorations (29).

The goal of the present study was to investigate the effect of glazing and two polishing techniques on (Ra) and (VHN) of feldspathic porcelain. According to the findings, (Ra) and (VHN) influenced by different surface treatments. Based on these results, the null hypothesis that the surface treatment does not affect the (Ra) and (VHN) of feldspathic porcelain was rejected.

It's difficult to make a clear comparison between studies since there are inconsistencies in the findings that can be explained by the use of different methods, time, and materials. The results of the present study agreed with Aakriti et al., (17) who found that polishing cannot be a substitute for the glazed ceramic surface.

The results which present in this investigation are in agreement with the Celtra glazed group in term of micro-hardness, but in term of surface roughness, with Roxana et al., (13), who reported that the glazed group had higher surface roughness and lower micro-hardness. The difference in surface roughness result may be related to the use of heat-pressed glass-ceramic contrary to the present study which used hand layered glass-ceramic. The other expected cause may be the use of a polishing machine while the present study used manual polishing.

The most significant issue with applying glaze to zirconia is the poor interface between the vitreous material and the zirconia. This creates a fragile region that leads to peeling or creates essential defects, resulting in the material's loss of strength (30). This could be considered as an explanation for the decrease (VHN) of the G group (538.4 ± 36), compared to PK (658.9 ± 66) and DPP (652.8 ±66**)**, which have higher (VHN) than G group.

Glaze application causes a fill-up process (healing effect), in which the glaze penetrates the existing micro-cracks, scratches, and porosity on the ceramic surface. This results in a smooth, defect-free surface (31). Therefore, the G group was the smoothest among all groups due to this property.

Surface roughness was minimized by polishing with diamond paste, but there was no significant difference about the glazing systems. These results agreed with Deise et al., (8), who also found that the polishing with diamond paste did not significantly reduce the surface roughness.

The surface roughness of (DPP) treated group (0.70 ± 0.42 µm) was lower than that of (PK) treated group (1.00 ± 0.30 µm). This may be due to the porosities of the DPP which were filled with fine and uniformly sized small diamond particles and the surface looked smooth.

The Ra values of healthy human enamel range from 0.45 to 0.65 µm (32). G and DPP groups have values that were comparable to those recorded for enamel. Therefore, Glazing and polishing considered as adequate finishing procedures for smoothing ceramic surfaces to a clinically acceptable standard. On the other hand, PK **(**1.00±0.30 µm**)** did not achieve results within the given average recorded for enamel, so that polishing with PK is not adequate for finishing feldspathic ceramic.

The Ra values of polished specimens have been stated to vary depending on the polishing method, pressure period and volume device rotation speed, presence or absence of water during finishing, and kind of ceramic to be polished (13). This was clear in SEM images which showed that the polishing process cause surface defect were found to have a direct relationship with the final surface roughness. According to the surface topographical features obtained from SEM as it shown in figure (6.b), the well-defined pores were increased and more numerous, resulting from the abrasive action of the polishing wheel.

The surface roughness and (VHN) of the glazed surface was the lowest among other treatments. This is a benefit for the antagonist's teeth because it causes less wear. For these reasons, glazing is recommended for finishing vita feldspathic porcelain.

The present study has some limitations such as the polishing procedures which performed on disc-shaped specimens, are not identical to the actual restorations. Also, the intraoral environment in terms of variables including temperature and humidity is not simulated.

Conclusion

Within the limitations of this in vitro study the following conclusions can be drawn:

Different surface treatments significantly affected the surface roughness and (VHN), of the tested feldspathic porcelain. Glaze application produced a more homogeneous and smoother surface. However, polishing by using the polishing kit and polishing with diamond paste produce a rougher surface than the glaze group in terms of surface characteristics (roughness and topography). The polished feldspathic porcelains with the polishing kit and polishing paste showed higher (VHN) in comparison to the glazed surfaces.

Conflicts of Interest

The authors reported that they have no conflicts of interest.

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Table (1): Statistical analysis (ANOVA) to compare the difference in average surface roughness values between different surface treatments

(I) Groups	(J) Groups	Mean Difference (I-J)	P-Value	Sig.
Layered-Glazing (G)	Layered-Diamond Paste (DPP)	-.1563	.326	NS
	Layered-Polishing Kit (PK)	-.5125*	.002	S
Layered-Diamond Paste (DPP)	Layered-Polishing Kit (PK)	-.3563*	.029	S

* The mean difference is significant at the 0.05 level.

Table (2): Statistical analysis (ANOVA) to compare the difference in Vickers micro-hardness number (VHN) values between different surface treatments

(I) Groups	(J) Groups	Mean Difference (I-J)	P-Value	Sig.

Layered-Glazing (G)	Layered-Diamond Paste (DPP)	-114.3667*	0.004	S
	Layered-Polishing Kit (PK)	-120.4250*	0.002	S
Layered-Diamond Paste (DPP)	Layered-Polishing Kit (PK)	-6.0583	1.000	NS

* The mean difference is significant at the 0.05 level.

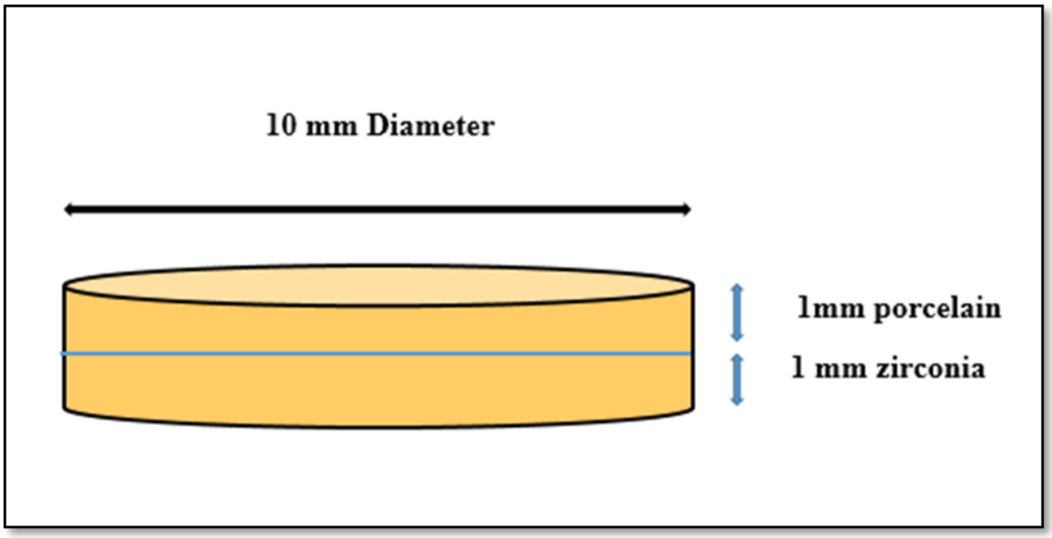

Figure (1): Disc shaped specimen with 10 mm diameter and 2 mm thickness (1mm zirconia substructure and 1 mm porcelain layer)

Figure (2): A contact stylus profilometer for quantitative evaluation of surface roughness with a speed of 5.08 mm/s, resolution of 0.01 μ, stylus force of 1500 mgf /15.0 mN, and a cutoff value of (0.8 mm)

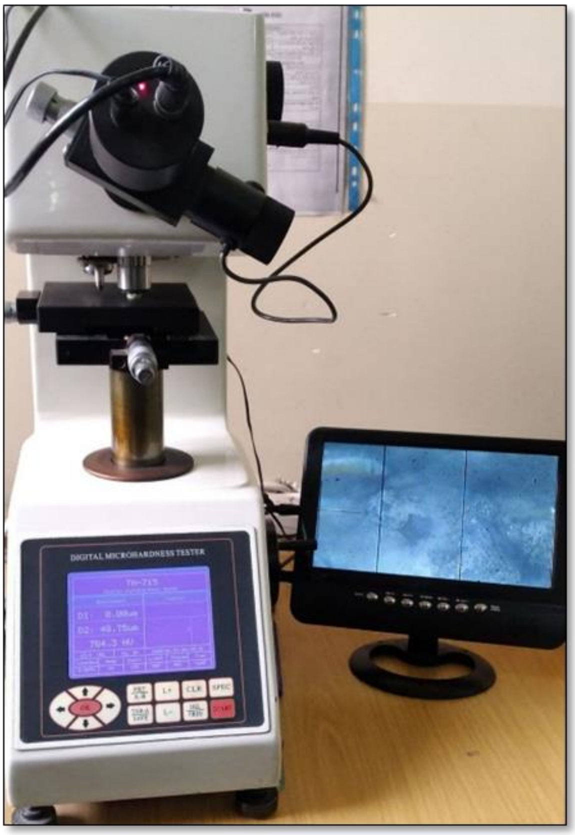

Figure (3): A Digital micro hardness tester for evaluation of surface micro-hardness

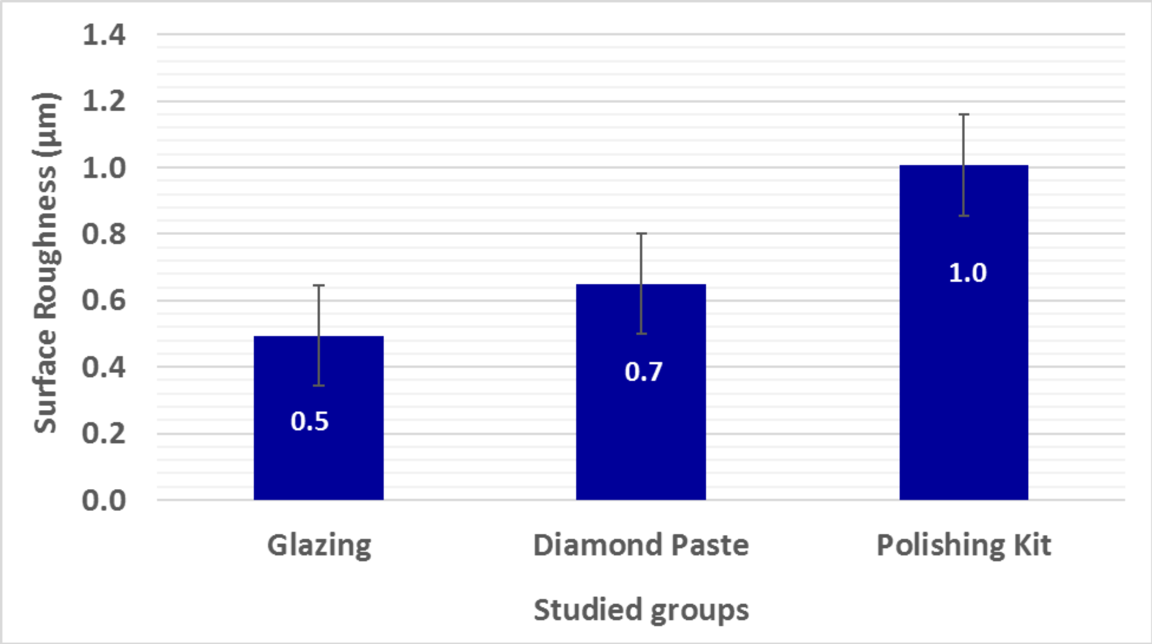

Figure (4): Bar chart shows the mean and standard deviations of surface roughness (Ra) values in μm of the studied groups treated with glazing (G), polishing diamond paste (DPP), and polishing kit (PK)

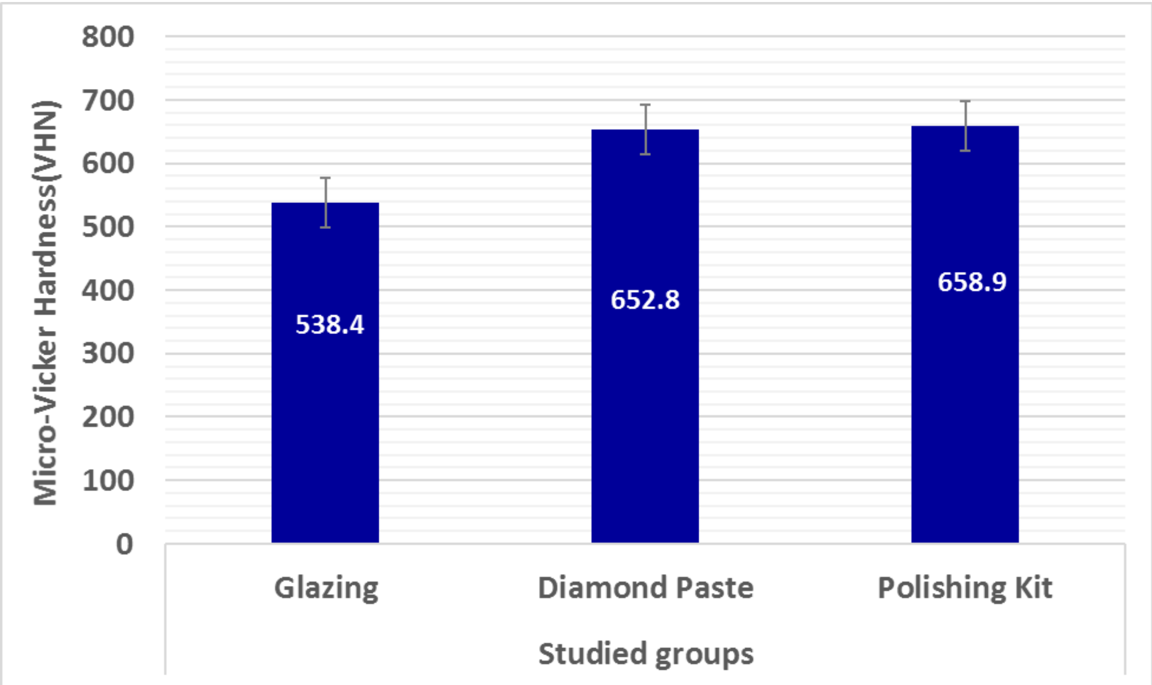

Figure (5): Bar chart shows the mean and standard deviations of Vickers micro-hardness number (VHN) of the studied groups treated with glazing (G), polishing diamond paste (DPP), and polishing kit (PK)

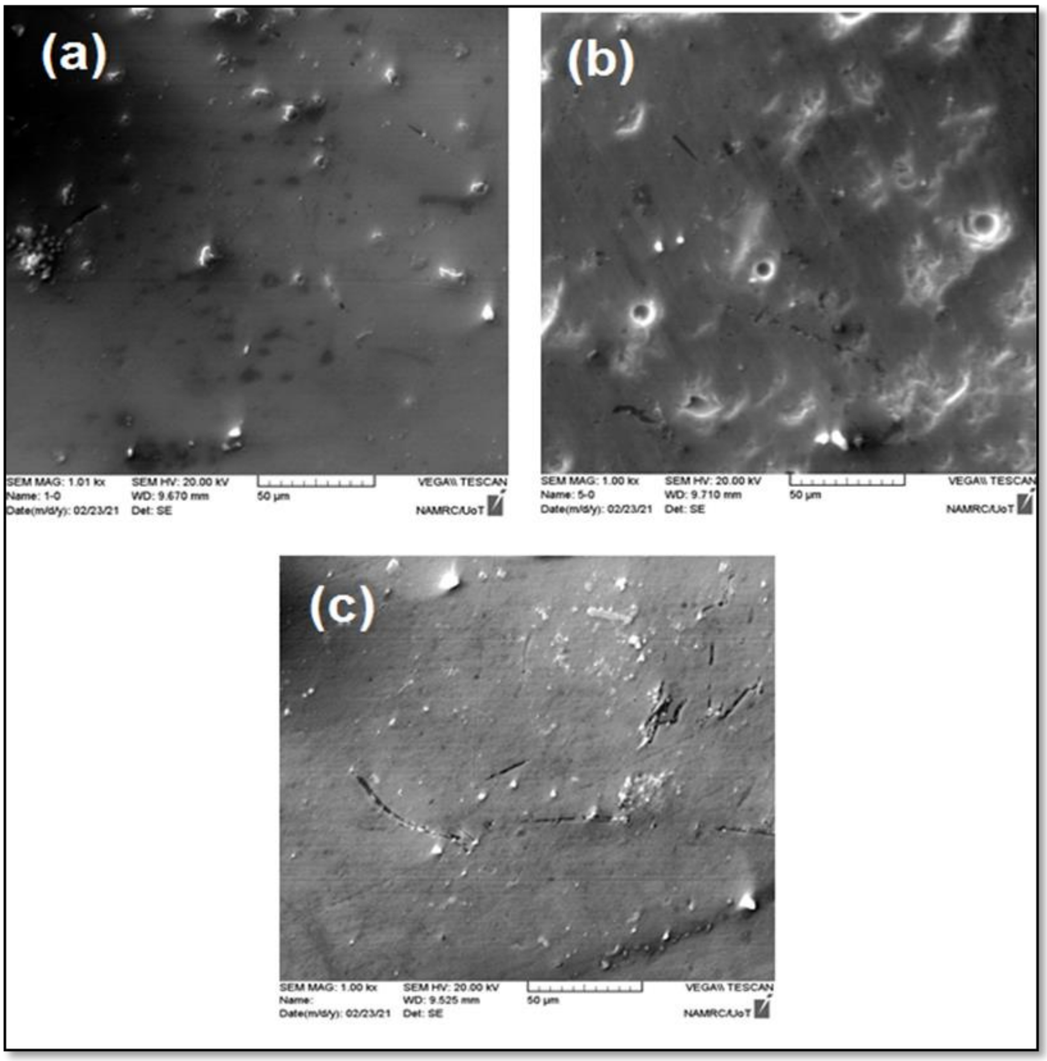

Figure (6): SEM images at (1000X Magnification) for (a) Glazing, (b) Polishing Kit, (c) Diamond Polishing Paste treated groups