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An Evaluation of the Effect of Different Surface Treatment on Hardness and Smoothness of Pressable Ceramic (In Vitro Study)

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Abstract:
Background: *to evaluate the effect of five types of surface treatments on the surface roughness and Vickers hardness number of pressable ceramic.*
Materials and Methods*: One hundred and twenty discs shaped specimens were fabricated according to the manufacturer's instructions. The specimens were randomly divided into six groups according to the type of surface treatments. Each group consisted of twenty specimens and the groups were distributed as follows: Group 1: specimens were left without treatment (Contral group), Group2 : specimens were polished with red rubber wheel bur (feeding rate is 300 rpm, polishing time is 3 minutes), Group3 : the same as group 2, then the specimens were glazed, Group 4: the specimens were sandblasted with 50 µm particles for 20 seconds at a pressure of 3 bars and a distance of 50 mm from the sandblast nozzel tip, Group 5: the same as group 4, the specimens were glazed, Group 6: the specimens were glazed only. Each group divided randomly into two subgroups (10 specimens each), ten were subjected to hardness test using Digital microvickers Hardness tester and the other ten specimens of the subgroup were subjected to surface roughness test using Pocketsurf Profilometer device.*
Results*: The statistical analysis revealed that, the superior smoothness values were for the polished and glazed group and the highest Vickers hardness number was for the glazed group.*
Coclusion*: polishing ceramic with rubber bur and glazing produced the smoothest surface, and glazing ceramic increased the surface hardness.*
Keywords: *glazing, Pressable ceramic, sandblast, surface roughness, Vickers hardness number.*

I. Introduction

Metal ceramic restorations have been the preferred complete coverage restoration for long-term clinical success. However, as dentistry evolves, the demand for metal-free materials with increased translucency that mimic the natural dentition has been increasing.[1]

The appeals of ceramics as structural dental materials are based on their esthetics, low density, high hardness, chemical inertness, and wear resistance. A major goal of ceramic research and development is to produce stronger, tougher ceramics that are structurally reliable in dental applications.[2] Over the past decade, increased demand for esthetically pleasing restorations has led to the development of all-ceramic systems, and these esthetically superior restorations are now possible as a result of improvements in dental materials and fabrication techniques, and there are three primary modes of manufacturing all-ceramic crowns: Conventional sintering techniques, fabrication by casting or with a pressure technique, and various direct milling techniques.[3]

The IPS e-max ceramic is an innovative all-ceramic system which covers the entire all-ceramics indication range from thin veneers to 10 units FPDs. IPS e-max delivers high strength and high esthetic materials for the press and the CAD/CAM technologies .[4] The IPS-Empress system was developed at the University of Zurich, at Zurich in Switzerland, in 1983 and the Ivoclar Vivadent took over the development project in 1986 and presented it to the profession in 1990.[5] All-ceramic materials are subjected to different fabrication procedures in the laboratory, and sometimes must be adjusted clinically to allow either proper fitting or occlusion. Glazing can be either the application of a low fusing glass overcoat or auto glazing which is based on firing for a certain time, held at the maximum temperature.[6]

Glazing has always been advocated as the last surface treatment before final cementation. Currently there exists a considerable controversy over applying the best method to achieve the smoothest and strongest porcelain restoration. [7] Ceramic prostheses must be adequately polished to be less susceptible to biofilm and bacterial accumulation, and reduce the potential of wearing opposing occlusal surfaces. Also, the mechanical and physical strength of a ceramic restoration can be impaired by refinishing process due microcracks formation and can be more susceptible to later catastrophic fractures.[8] The processing procedures and/or clinical adjustments are more likely to initiate subcritical flaws or large defects which, upon clinical loading and/or presence of moisture, may grow to a critical situation leading to catastrophic failure. In addition, different surface roughness formed through different finishing procedures can cause various stress concentrations and consequently may be accompanied by a reduction in strength.[6] Hardness may be broadly defined as the resistance to permanent surface indentation or penetration, it is a measure of the resistance to plastic deformation and is measured as a force per unit area of indentation, so it is important in dentistry.[9] The objectives of this study are to evaluate the effect of different surface treatments on hardness and surface roughness of ceramic.

II. Materials And Methods

1. Specimens preparations: One hundred and twenty disc shaped wax specimens were fabricated from a sheet of modeling base plate wax (2 mm in thickness). Then punched with copper ring (10 mm in diameter) to produce the specimens.
2. Investing the wax pattern: The investment powder and the special liquid (IPS Press Vest for different Ivoclar Vivadent press ceramic, Ivoclar, Vivadent AG, FL-9494 Schaan Liechtenstein, Germany) were mixed according to the manufacturer's instructions. The mix then poured inside the silicone ring, and the ring gauge positioned on the silicone ring with a hinged movement , and the investment allowed to set as in Figure 1.
3. Burn out of the wax specimens and pressing of ceramic: The ring gauge and ring base removed with a turning movement. The investment ring was pushed out of the IPS Silicone ring carefully, then the disc shaped specimens were burned out by electrical furnace. The investment ring removed from the preheating furnace immediately after completion of the burnout procedure. The IPS e.max Press ingot placed into the hot investment ring, and the IPS Alox Plunger coated with IPS Alox Plunger Separator, and then the IPS Alox Plunger placed into the hot investment ring. The pressing of ceramic started in porcelain furnace (Computarized porcelain furnace for pressable ceramic (Programat EP 3000, Ivoclar,Vivadent, Germany) (Figure 2). At the end of the press cycle, The investment ring was placed on a cooling grid and allowed to cool.
4. Divesting of the specimens: Then the specimens were divested using sandblast machine with 50µm particles and a pressure of 3 bars. The sprues were separated from the specimens using diamond cutting wheel saw.
5. Sample grouping: The specimens were divided into 6 groups (20 specimens each group), according to the following surface treatment:

Group 1: specimens were left without treatment (Contral group).
Group (P): specimens were polished with red rubber wheel bur (feeding rate is 300 rpm, polishing time is 3 minutes).
Group (PG): the same as group 2, then the specimens were glazed.
Group (S): the specimens were sandblasted with 50 µm particles for 20 seconds at a pressure of 3 bars and a distance of 50 mm from the sandblast nozzel tip.
Group (SG): the same as group 4, the specimens were glazed.
Group (G): the specimens were glazed only.
Then each group were divided randomly into two subgroups; and (10 specimens each), ten were subjected to hardness test using Digital microvickers Hardness tester (subgroup 1) (as in Figure 3) and the other ten specimens of the subgroup were subjected to surface roughness test using Pocketsurf Profilometer device (subgroup 2).

III. Results

The mean Vickers Hardness Number VHN (in GPa), Standard Deviation (SD), minimum, maximum values are illustrated in Table 1, the highest VHN was for the glazed group , while the lowest VHN was for the control group. The mean surface roughness values (Ra in µm), Standard Deviation (SD), minimum, maximum values are illustrated in Table 2, the highest surface roughness value was for sandblasted group and the lowest surface roughness value was for polished group followed by glazing.

One – Way ANOVA test was done for estimation of any significant differences among groups of Vickers Hardness Number VHN as in Table 3 and there was a high significant difference found among groups so, LSD test (least significant difference test) was followed to estimate the source of significance in Table 4 for surface hardness. The results revealed that, there was a high significant difference among all groups, except when comparing between control and sandblast group, there was no significant difference between them.

One – Way ANOVA test was done for estimation of any significant differences among groups of surface roughness values as in Table 5 and there was a high significant difference found among groups so, LSD test (least significant difference test) was followed to estimate the source of significance in Table 6 for surface roughness. The results revealed that, there was no significant difference when comparing between sandblast and sandblast followed by glazing, a significant difference when comparing between polished followed by glazing and glazed groups, while for the other groups, the comparison among them revealed non significant difference.

IV. Discussion

The increasing demand for aesthetic materials in Dentistry has pushed on the development of novel all-ceramic systems. Besides excellent esthetics, these materials have high strength, good color stability, high resistance to wear, and high biocompatibility.[1] A number of all-ceramic systems are currently available for dental restorations. Among these, glass-ceramics are one of the most popular due to their good marginal fit, good mechanical properties and low porosity compared to conventional feldspathic porcelains.[10] Recently, IPS e-max is an innovative all-ceramic system which covers the entire all-ceramics indication range from thin veneers to 10 units FPDs. IPS e-max delivers high strength and high esthetic materials for the press and the CAD/CAM technologies,[4] so it was selected in this study because of its improved mechanical properties.

Hardness is considered an important property when comparing restorative materials. It is a measure of the resistance to permanent surface indentation or penetration. The significance of measuring hardness in dental material is that it delineates the abrasiveness of a material to which the natural dentition may be submitted.[11] Several properties of a material are related to its hardness as strength, proportional limit and ductility. Indentation hardness testing is a convenient means of investigating the mechanical properties of a small volume of materials. Among a variety of indenter geometries used in hardness testing, the Vickers indenter is one in most widespread use. The Vicker Hardness Test was selected because it is suitable for determining the hardness of small areas as used by previous investigator.[4] Rubber wheel burs were used since they are recommended by the Ivoclar Company for polishing IPS e – max press ceramic and the mechanical polishing of ceramic with rubber wheels can be clinically indicated, especially in areas with limited access such as with the occlusal surface of posterior teeth.[12]

Effect of surface finish on hardness of ceramic

The results of the present study revealed that the highest VHN was for the glazed ceramic surface followed by polished and reglazed ceramic surface with no significant differences between the two groups and the lower VHN was for control group. The aim of glazing is to seal the open pores in the surface of fired porcelain. Dental glazes are composed of colorless glass powder, applied to the fired crown surface, so as to produce a glossy surface.[13] In this study, glazing procedure was done by the application of low fusing over coat followed by firing for a certain time. This result is in agreement with Baharav et al., [14] a study explained this increase in VHN followed glazing is believed to increase the strength of ceramic materials by reducing the depth and/or sharpness of critical flaws, so it increases its resistance to crack propagation.

The application of glaze layer will fuse with the underlying ceramic during heating to form smooth homogenous coating that that fills in surface flaws, reducing their depth, and blunting the flaw depth. This will provide resistance to chemical erosion and generates compressive stresses while filling the surface defects.[15]
This could be explained on the basis of surface compressive stress. Since the glaze is placed on the surface of the porcelain, it will generate compressive stress if the underlying ceramic contracts more on cooling to place the surface glaze in compression. This surface compressive stress can result in appreciable strengthening by inhibiting crack growth from the surface through the body of porcelain.[15]

The increased VHN for the glazed groups is related to the crystalline structure of IPS e – max press ceramic. It was produced by controlled crystallization method, in which the crystalline phase (Lithium disilicate $Li_2Si_2O_5$) are nucleated and grown in glass by means of heat treatment. These elongated interlocked crystals form 65% of the microstructure of glass ceramic.[10] IPS e.max lithium disilicate is composed of quartz, lithium dioxide, phosphor oxide, alumina, potassium oxide, and other components. This composition produces a highly thermal, shock-resistant glass ceramic as a result of the low thermal expansion that occurs when it is processed.[16]

The thermal expansion mismatch between lithium disilicate crystals and glassy matrix is likely to result in tangential compressive stresses around the crystals, potentially responsible for crack deflection and strength increase. The interlocked microstructure and layered crystals are also likely to contribute to strengthening since the crack propagation is easy along the cleavage planes, but more difficult across the planes, leading to multiple crack deflections due to an array of crystal orientations. The higher resistance to crack propagation is in the direction perpendicular to crystal alignment.[17] This also could be attributed to the technology of fabrication; the e – max press is softened by heat in the pressing step, then subjected to a removal of the reaction layer then subjected to heat treatment.[4]

Pressing of lithium disilicate glass ceramic is a high plastic deformation process that can align the crystals in an alignment parallel to pressing direction; this could be attributed to increase VHN.[11] The results of the present study showed no significant difference in VHN when comparing between the control group and the sandblast group. This non significant difference is due to submitting the control group to sandblasting during divesting.[6]

Effect of surface finish on smoothness of ceramic

In this study, the Ra parameter obtained with a profilometer is used to describe the surface texture of the porcelain specimens in µm. This parameter describes the overall roughness of a surface and can be defined as the arithmetical average value of all absolute distances of the roughness profile from the center line within the measuring length.[18]

The results of the present study showed that, the highest surface roughness value was for sandblasted ceramic, while the lower surface roughness value was for polished and reglazed ceramic. This reduction in surface roughness value may be obtained from a combination of compressive residual stress and the removal of larger surface flaws formed during processing. Larger defects that are generated during fabrication may be removed during grinding and polishing procedures, so some of the flaws that may become cracks are eliminated to increase fracture resistance.[15]

As the abrasive contacts the surface of the material, compressive stresses can be generated that affect flaws oriented perpendicular and parallel to the surface, but depend upon the parameters of the polishing process. The area of compressive stress beneath each abrasive particle can overlap, producing a layer of compression. The resulting surface finish and stress state will have a major influence on the mechanical properties of the material. Residual compressive stresses have been found to occur in a wide range of ceramic materials following polishing.[15,19]The creation of surface compression layer can be achieved by thermal tempering, machining and polishing and the application of a glazing layer with a lower coefficient of thermal expansion than the adjacent ceramic material.[19,20,21] Such overheating can assist in producing plastic deformation and also generates thermal mismatch between the outer and inner layers of the ceramic specimens that may lead to development of tensile stresses in the inner layer.[20,21]This result is in agreement with those of Embong et al., [22] a study found that polishing and reglazing are combined rather than used alone to produce a smoother porcelain surface , Chu et at., [23] a study concluded that reglazing of polished porcelain surfaces significantly improved the surface texture and strength of the porcelain, and agree with Al – Wahdani,[24] a study found that the reglazed polished ceramic surface are more homogenous. The results of the present study disagree with those of Sarikaya and Güler, [18] a study claimed that polishing porcelain surface produced the same results as glazing. These differences in results between these studies are related to number of parameters that were able to interact with each other and the type of ceramic used in such studies and other studies that used feldspathic porcelain, polishing tools coarseness and wear, abrasive particle types and fineness, polishing process and feed rate. Thus the polishing process was quite complex, involving numerous materials and parameters.

V. Figures And Tables

Fig.1: Waiting for the investment material to set

Fig. 2: Computerized porcelain furnace for pressable ceramic

Fig.3:Digital microvickers Hardness tester

Table 1: Mean, SD, Min, Max of VHN in GPa

	C 1	P1	PG1	S1	SG1	G1
Mean	4.669	7.055	7.785	4.724	6.3694	7.845
SD	1.1011	1.3006	1.3297	1.0779	2.0838	2.1148
Min	4.5.4	6.921	7.666	4.578	6.114	7.61
Max	4.784	7.189	7.99	4.846	6.626	8.08

Table 2: Mean, SD, Min, Max of Surface Roughness Values in μm

	Control 2	P2	PG2	S2	SG2	G2
Mean	2.5	0.67	0.46	2.81	2.712	0.84
SD	0.223607	0.022361	0.025495	0.041231	0.043818	0.038079
Min	2.2	0.64	0.43	2.76	2.65	0.79
Max	2.8	0.7	0.49	2.86	2.77	0.89

Table 3: One – Way ANOVA test for estimation of any significance among groups

	F-test	P-value	Sig
Between groups	419.449	P<0.01	HS

Table 4: LSD test (least significant difference test) for estimation the source of significance

	Mean difference	P-value	Sig
Control& P1	-238.6	P<0.01	HS
Control& PG1	-311.6	P<0.01	HS
Control& S1	-5.50	0.583	NS
Control& SG1	-170.04	P<0.01	HS
Control& G1	-317.6	P<0.01	HS
P1&PG1	-73.0	P<0.01	HS
P1&S1	233.10	P<0.01	HS
P1&SG1	68.56	P<0.01	HS
P1&G1	-79.0	P<0.01	HS
PG1&S1	306.10	P<0.01	HS
PG1&SG1	141.56	P<0.01	HS
PG1&G1	-6.00	0.549	NS
S1&SG1	-164.56	P<0.01	HS
S1&G1	-312.1	P<0.01	HS
SG1&G1	-147.56	P<0.01	HS

Table 5: One – Way ANOVA test for estimation of any significance among groups

	F-test	P-value	Sig
Between groups	664.58	P<0.01	HS

Table 6: LSD test (least significant difference test) estimation of any significance among groups

Table 6	Mean difference	P-value	Sig
Contro2& P2	2.043	P<0.01	HS
Contro2& PG2	1.830	P<0.01	HS
Contro2& S2	-0.310	P<0.01	HS
Contro2& SG2	-0.212	0.002	S
Contro2& G2	1.660	P<0.01	HS
P2&PG2	-0.210	0.002	S
P2&S2	-2.35	P<0.01	HS
P2&SG2	-2.25	P<0.01	HS
P2&G2	-0.38	P<0.01	HS
PG2&S2	-2.10	P<0.01	HS
PG2&SG2	-2.04	P<0.01	HS
PG2&G2	-0.17	0.010	S
S2&SG2	0.098	0.123	NS
S2&G2	1.970	P<0.01	HS
SG2&G2	1.872	P<0.01	HS

VI. Conclusion

Within the limitations of the present study, the following conclusions are:

1. The application of glaze layer following sintering of ceramic had significantly improved surface hardness of ceramic material.
2. The application of glaze layer following polishing of ceramic had significantly improved surface smoothness of ceramic.
3. Polishing of ceramic with rubber wheel following sintering had increased surface smoothness significantly.

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