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Comparative Estimation the Influence of Core Material (Zircon) and Surface Treatment on The Fracture Resistance of Some Ceramic Material

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Abstract

Background: Ceramic is very essential in the science of dental biomaterials. successfully in dentistry zirconia restorations have been utilized because of their good mechanical properties and biocompatibility. Zirconia cores are generally veneered with porcelain duo to lack of translucency, this make restorations weaker by means of miss of the cohesion between veneering ceramic and core material, the goal of the present study to estimate the influence of core material (zirconia) and surface treatment up on fracture resistance of some ceramic material.
Methods: Forty samples of zirconia were fabricated by (Computer adding design/Computer adding manufacture technique. Samples were split randomly for four groups depending on their surface treatment , each group contains 10 samples .Group Zirconia control: Samples without surface treatment (control group).Group Zirconia sand plast: Samples sandblasted with 50µm of AL_2O_3particles.Group Zirconia potassium hydrogen difluoride :samples etched with 70 mg concentration of potassium hydrogen difluoride .Group Zirconia Combination: samples sandblasted with 50µm of AL_2O_3particles and etched with70 mg concentration of potassium hydrogen difluoride. Scanning electron microscope at different magnification was used to detect the morphological alteration of the zirconia following surface treatment.2mm veneering ceramic was put on all samples. Then sintering and glazing. fracture resistance of all samples was measured by universal testing machine. Statistical test perfect utilizing SPSS software. Results: In (Zirconia Combination) group the data analysis manifested that highest mean of fracture resistance values was, while the lowest mean of fracture resistance values was for (Zirconia Control) and (Zirconia Sand Blast) groups. Conclusion: Due to the time constraints of this study, using of different surface treatments with Zirconia substructures were more effective on the values of fracture resistance.

Introduction:

Various factors could affect the success of dental restoration such as type of material used, surface texture, translucency, color, its mechanical properties, and anatomical shape. Because of highly demand for aesthetic purpose, metal free ceramic dental restoration has been used in anterior region of the mouth (1). All ceramic systems have been recently lead by technologies .IPS E-max lithium disilcate crowns and full zirconia crowns have been witnessed an enormous amount of advertising (2). Glasses and ceramics are fragile, that means that they show a height compressive strength however less tensile strength and probably fractured beneath quite minimum strain (3). In fact 1990s was the first introduction of yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) in dentistry .Various characteristics of (Y-TZP) has made it the one of the most commonly used of all metal ceramic substructure material like relative translucency, biocompatibility and mechanical properties.(Y-TZP) has a good characteristic. However it has a negative outcome with the veneering ceramic(4). One of the most clinical problem for veneering ceramics is chipping. and the reasons behind its chipping is, veneering techniques ,mismatch between the substructure and veneering material, or deficient interfacial bonding (5).

Materials and Methods

Preparation of Samples

Forty samples were made from zirconia material fabricated by (CAD/CAM technique) each samples thickness was 0.8 m ceramic. According to manufacturer's instructions the surfaces of the core samples were veneered with their corresponding veneering ceramic. The final thickness of veneered ceramic was 2mm according to the design used and the final thickness of core with veneered ceramic was 2.8 mm.

Sample Grouping

Samples were split randomly for four groups depending on their surface treatment, each group contains 10 samples Group ZC: specimens with zirconia core without surface treatment (control group). Group ZSB: samples with zirconia core sandblasted with 50 µm of aluminum-oxide particles. $ZKHF_2$: samples with zircon core etched with 70 mg concentration of potassium hydrogen difluoride. Group ZCOMB: samples with zirconia core sandblasted with 50 µm of AL_2O_3 particles and etched with 70 mg concentration of potassium hydrogen difluoride.

Tooth Preparation

In the dental model (Nissin Dental Products), the upper right first molar tooth was prepared as follow: 0.8 mm deep chamfer finishing line, 2 mm oclussal reduction with axial reduction 1.5 mm to construct metal die. The CAD / CAM system was used to fabricate the metal die to resemble the form of ideal prepared plastic tooth to receive the all ceramic crowns as shown in Fig.(1).

Tooth Scanning

Prepared tooth was scanned by 3D dental light scanner. A 3D image was taken to enable the clarity of all surfaces and finishing line of plastic die .To begin milling process of the metal die the digital model of the die transferred to the CAM software. The dental stone type IV has been used for the base construction of the metal die. The metal die was placed inside the scanner unit and fixed on scan stage by special clay. After complete the scanning process, the final 3 dimension (3D) virtual model was appeared on the computer monitor (6) , after that the margin line was detected, undercut was checked , crown border were checked.. Finally complete design of the samples was constructed by imes- icore software as shown in Fig.(2).

Milling Process

The type, size of block and positioning of virtual crown after determination, all the information were sent to the milling machine to start milling process. The grinded zirconia samples were sintered in rise temperature furnace depending on the recommendations that provided by manufacturer's . The heat was elevated for 1450 C◦ in two hour then kept at final heat (1450 C◦ to two hour) samples were quietly cooled to under than 100 C◦ to one hour (6). Samples were ready to surface treatment.

Surface Treatment

Ten samples of zirconia core group were not treated to any surface treatment and were used as controls. Ten zirconia core group were sandblast together with 50 µm alumina particles to 10 second for each surface at a 1.5 bar air compression and at a space of 20 mm by using sand blast machine each sample was cleaned using steam jet for 10 s at distance 10 mm (7) as shown in Fig.(3 a. b).

Samples Firing

Ten samples of zirconia core group were powder coated with KHF_2 acid (70 mg) then, were warmed in a furnace of porcelain (Ivoclar vivadent) to temperature of 280 C◦ according to the manufacturer’s instructions. Steam cleaner then was used to clean all samples to 15 second followed by compressed air to 15 second. After 30 min, whole samples were kept in distilled water at 37C◦ to 24 h. (8). Ten samples of zirconia core group were treated by a combination of sand blast particle with 50 µm alumina particles to 10 second at a 1.5 bar compressed air and at a distance of 20 mm by using sand blast machine. The samples was then cleaned using steam jet. Then samples were powder coated with KHF_2 acid (70 mg) , and were heated in a porcelain furnace at temperature of 280 C◦ according to the manufacturer’s instructions.

Cleaning of Specimens

Before veneering, all samples were cleaned completely from any remnants of sandblast particles dust and acid etching by steam jet for 10 s and running water (6).

Specimens Scanning

A scanning electron microscope at different magnification (200µm) was used to detect the morphological alteration of the zirconia following surface treatment (6). To obtain the desired dimensions of veneering ceramic (2mm), silicon mold is made. Final dimensions of veneering ceramic specimen must be 2.8 mm. then glazed and it put on the firing tray and was inserted in the ceramic furnace and heating to 730 C◦ was done without vacuum according to the manufacturer’s instructions as shown in Fig.(4 a,b,c,d).

Fracture Resistance Test

Fracture resistance of all samples was measured by using A universal testing machine . A 500 Kg of force was applied vertically at the center of the occlusal surface of all samples of zirconia by small round stainless steel ball with 5.7 mm diameter at cross head speed of (0.5 mm\ min) as shown in Fig.(5). (9). One-Way ANOVA and Student t- test were utilized to determine the difference in surface treatments and fracture resistance

Results

The descriptive statistics of the values of fracture resistance involving: the lowest , the highest, means, standard deviation and standard error for each Zirconia ceramic groups as shown in Tables (1). The maximum mean of fracture resistance values was in (ZCOMB) group, while the minimum mean of fracture resistance values was for (ZC) and (ZSB) groups.

According to Table (2) as shown in Fig (6), one- way ANOVA test manifested that there was statistically highly significant difference in fracture resistance among whole Zirconia groups at level $P<0.001$.

Least Significant Difference test (LSD) For Zirconia groups:

LSD test have been utilized in the present study to decide the source of variance among the subgroups for each major groups as shown in Table (3).

In Table (3), the outcomes of the LSD manifested there was highly significant difference among (ZC) group with (ZSB) and both ($ZKHF_2$) and (Z comb) groups and (ZSB) with (Z comb) groups and ($ZKHF_2$) groups with (Z comb). While there was non-significant difference between (ZSB) group and ($ZKHF_2$) group.

Discussion

The progressive improvement in the properties of dental ceramics has led to an increase in all ceramic restorations (10).These characteristics : high compressive strength ,chemical stability, biocompatibility, low thermal conductivity, fluorescence , thermal diffusivity, translucence, a coefficient of thermal expansion resemble to that of tooth parts and thermal diffusivity (11).

One of the most clinical complication of zirconia based restoration is chipping . Chipping is superficial cohesive fracture of veneering ceramic, which mostly reported by various studies (12).

In this study, layering technique have been used for zirconia samples with their corresponding veneering ceramic (IPS E.max ceram) according to instructions of manufacturer's to ensure the compatibility of coefficient thermal expansion between cores and veneering ceramic to avoid tensile stress occurred over the core-veneer interface and lead to crack initiation and propagation (13).

Fracture resistance test was utilized in order to enable evaluation of fracture test properties and calculation fracture resistance of all ceramic samples. Zirconia groups showed significant differences at ($p < 0.05$) in the fracture resistance when fracture resistance outcomes appeared.

Airborne particle with $AL_2O_3$was chosen because its potentiality to remove any organic impurities from the ceramic surface and aluminum oxide may produce the highest amount of the monoclinic-phase, which gives results for bonding transformation from tetragonal to monoclinic phase that combined with local volume enlargement, that would improve the strength of zirconia as it generates compressive stress and prevents further crack propagation (14).

While potassium hydrogen difluoride(KHF_2) in this study was selected because the process of using KHF_2 in melt etch technique can produce in fluoridated surface which has attached hydroxyl groups following using the water cleaning technique that elevate the adhesion outcome (15). In addition, other researchers reported that mechanical and chemical etching methods can be used together (16). Combination technique was selected to increase fracture resistance of ceramic substructure by improve bond strength between samples and veneering ceramic. In the current study, sandblasting for zirconia samples was done with 50 µm of aluminum-oxide as this particles size showed a higher degree of surface roughness with less material removal from the surface when compared with other particle size (10). Air abrasion with zirconia perhaps due to its capability to remove any organic contamination from AL_2O_3 and the ceramic surface may produce the highest amount of the monoclinic-phase, that is well for bonding (14). The results of the current study manifested 50 µm of sandblasting particles with zirconia samples (ZSB) group produced a highly significant increase in the mean of fracture resistance when compared with control group (ZC) no treatment. The results of current study agreed with (Nakamura etal , Liu etal , Su etal).studies proved that there is a significant effect of sandblast particles on bond strength between zirconia and veneering material. The results of the current study disagree with the result of de (7.20) studies reported that 50µm of sandblast particles with zirconia samples didn't enhance the bond strength between zirconia core and veneering ceramic. The SEM evaluation proved that, AL_2O_3 sandblasting produced an elevated irregularities and roughness with grooves and sharp edges these were considered to be essential for the interlocking of the Y-TZP ceramic samples to the veneering ceramic. (K HF_2) with melt etch technique can have resulted in fluoridated surface which has attached hydroxyl groups followed by water and steam ,increasing influence of the cohesion (15).

The effectiveness of the etching is depending on the affinity of F^- for Zr^4 , the evaporation of water and dissolution of Zr_2 in the molten K [F.H.F] (21). Molten KHF_2 and dissolved zirconia, caused chemical reaction, resulting in sediments containing (ZrF_4). This product surface irregularities and porosities the grains produced the best of interlocking outcome surface for zirconia samples, which then enhanced the bond strength between specimen and veneering ceramic (8). The outcomes of the current study found, 70 mg of potassium hydrogen difluoride acid produce a highly significant difference in the mean of fracture resistance when compared with control group. This demonstrated that etching with KHF_2 chemically changed zirconia in to fluoride compound. The outcomes of the current study in agreement with a study of, (Akazawa etal, Kvam etal , Ruyter etal , Kato etal) studies reported that, Fusion of the fluoride compounds KHF2 on polished and ground Y-TZP award a coarse etched surface proper for perfect and durable cohesion for a zirconia samples. The SEM evaluation showed that etching zirconia samples with KHF_2 create deep groves with a rough surface of exposed zirconia grains. Furthermore, samples etched with difluorides manifest to have comparable morphology to that samples etched with hydrofluoric acid. A combination of more or two treatments perhaps high beneficial. One treatment can act by enhancing one characteristic of the material, whilst the other treatment can act by optimizing the other characteristic of the same material. This comes in consistent with study done by (23) a study concluded that a combination of two or more treatments manifested a significant influence on the bond strength of Y-TZP because of the cumulative effect of the treatments (24). The outcomes of the current study manifested that the combination treatment with AL_2O_3 and KHF_2 has given significantly higher fracture resistance among all zirconia subgroups than both sandblasted and potassium hydrogen difluoride etching. The SEM evaluation showed that zirconia samples treated with the combined of etching with KHF_2 acid and subsequent 50µm AL_2O_3 sandblasting particles a high surface roughness and porosities when compared with control group.

Conclusions

By the restrictions of the current research:

1-Using of different surface treatments with Zirconia substructures were more effective on the values of fracture resistance .

2-A combination of Zirconia surface treatments represented an effective method on the fracture resistance because of the cumulative effect of these treatments.

3-Airborne particles of 50µm manifested appositive effect for conditioning of the Zirconia surfaces.

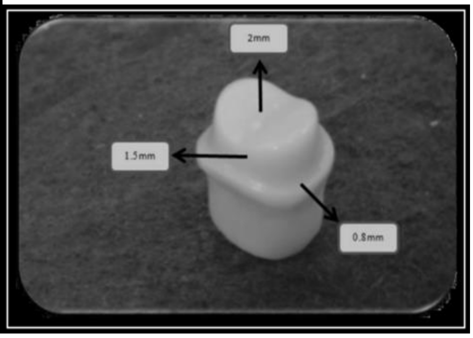
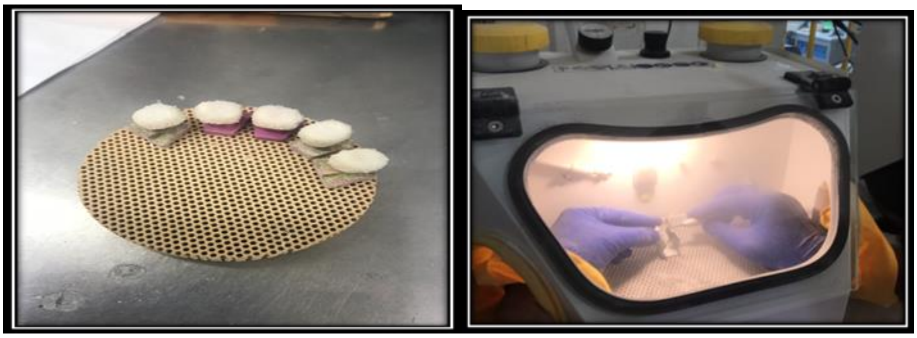


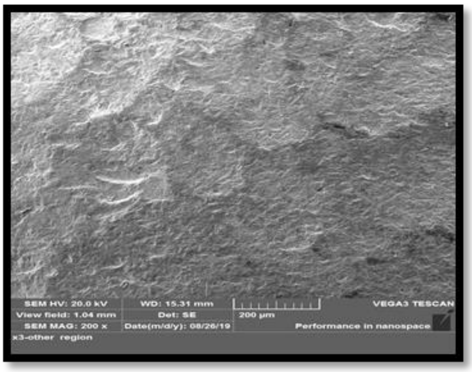
Fig.(1): Final dimensions of plastic die

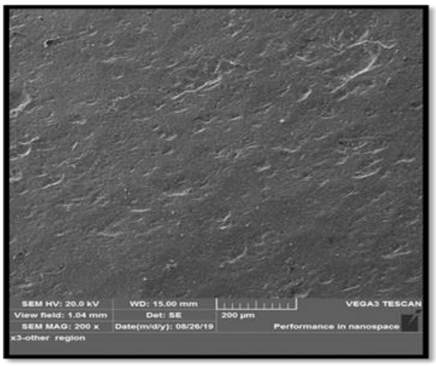
Fig.(2): virtual model of prepared plastic die



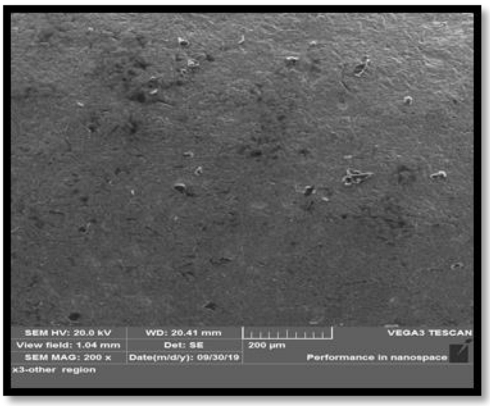
(a) **(b)**

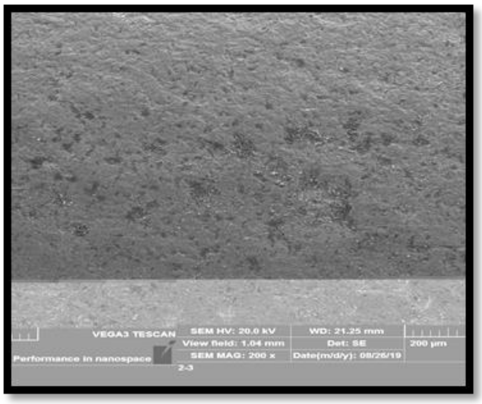
Fig.3.a.zirconia core sand blasting with alumina, b. zirconia core coated with KHF2 acid





(a) **(b)**





(c) **(d)**

Fig.4.a. SEM for zirconia Specimens untreated, b. SEM for zirconia specimens treated with Al2O3, c. SEM for zirconia Specimens treated with KHF2, d. SEM for zirconia specimens treated with combination

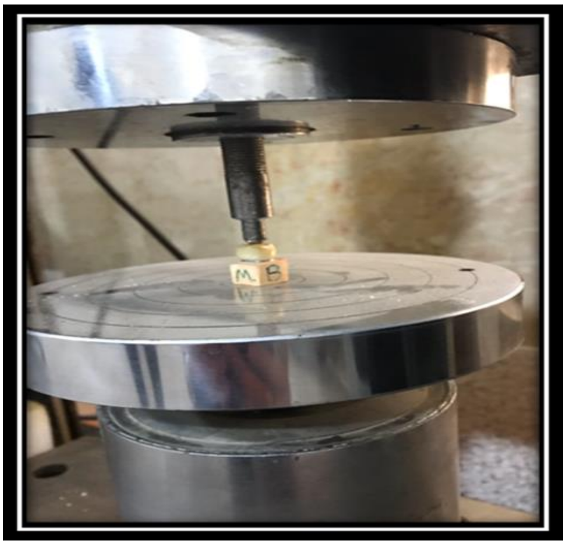


Fig.(5): The core with base placed on the base of the universal testing machine.

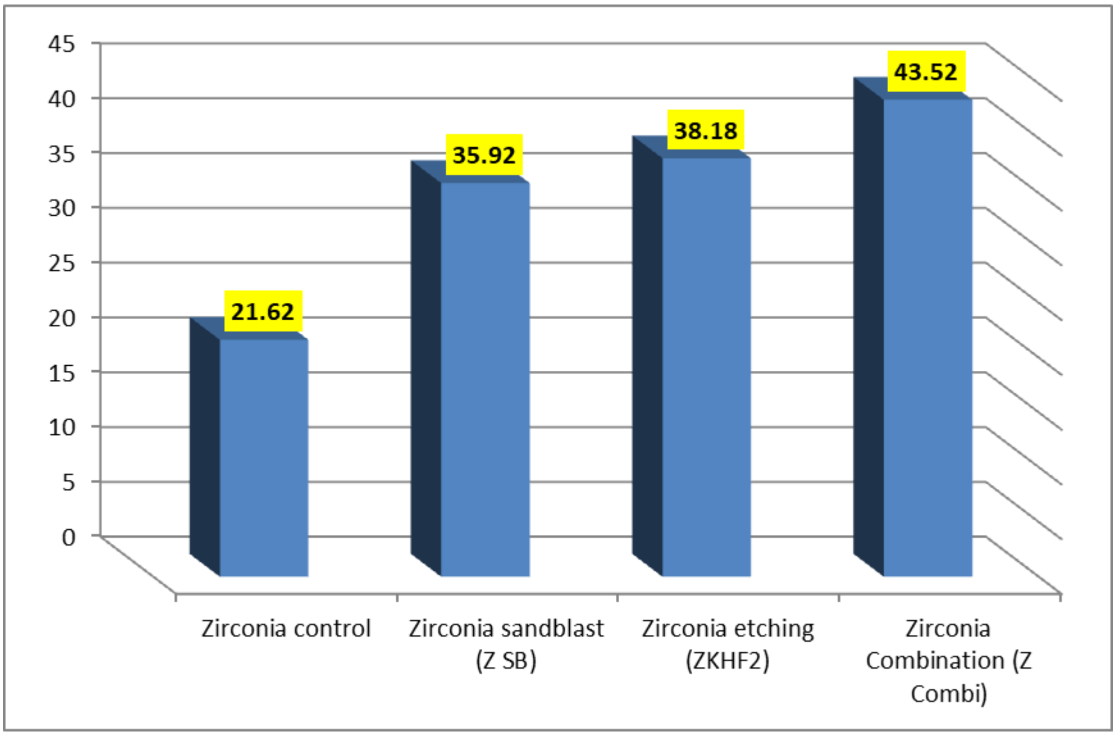


Fig.6. Bar Chart Demonstrating the Means Difference in Fracture Resistance of Zirconia ceramic Groups.

Table (1): Descriptive Statistics of Fracture Resistance of Zirconia Ceramic Groups (ZC, ZSB, ZKHF$_2$,and ZCOMB)in newton.

Groups	N	Minimum	Maximum	Mean	Std. Error	Std .Deviation
Zirconia control	10	20.00	23.70	21.6200	.45966	1.45358
Zirconia sandblast	10	30.50	39.90	35.9200	1.05428	3.33393
Zirconia etching	10	31.40	45.70	38.1800	1.30986	4.14214
Zirconia Combi	10	40.70	45.90	43.5200	.62748	1.98427

Table(2):One-Way ANOVA test for Fracture Resistance among Zirconia ceramic subgroups.

Zirconia Groups	F	P-value	Sig
Among Groups	101.946	.000	HS

**P<0.001 High significant

According to Table (2), one- way ANOVA test manifested that there was statistically highly significant difference in fracture resistance among whole Zirconia groups at level P<0.001.

Table (3): LSD test of Fracture Resistance among zirconia groups.

Groups			Mean Difference	P-value	Sig
LSD	Zirconia control	Zirconia (Z SB)	-14.30000-*	.000	HS
		Zirconia (Z KHF_2)	-16.56000-*	.000	HS
		Zirconia (Z comb)	-21.90000-*	.000	HS
	Zirconia (SB)	Zirconia (Z KHF_2)	-2.26000	.093	NS
		Zirconia (Z comb)	-7.60000-*	.000	HS
	Zirconia (KHF_2)	Zirconia (Z comb)	-5.34000-*	.000	HS

*P<0.001 High significant

**P>0.05 Non significant

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