



Evaluation of the Effect of Different Glazing Brands on Hardness of Monolithic Zirconia Fabricated By CAD/CAM Technique

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Abstract

The purpose of this study was to evaluate the hardness of different glazing brands materials on monolithic Zirconia. Materials and methods: - A CAD/CAM machine (computer aided design- computer aided manufacturing) was used to manufacture 40 specimens from a zirconia block (VITA Zahnfabric YZ®XT Color, 98.4x14mm height). The Vickers hardness test sample dimensions (diameter 10 mm and thickness 2 mm) were separated into 4 groups based on the brands of glazing materials used (VITA AKZENT® Plus, Ivoclar vivadent, GC Initial spectrum, Soprano glaze) powder and fluid. Data are statistically analyzed using statistical package for social science (SPSS), and the (ANOVA) test and Bonferroni test are used to determine whether the statistical hypothesis is true. Results: - For the hardness readings the higher mean value of Vickers hardness test in Zirconia was found in GC group (544.792±25.416) then Ivoclar group (538.622±18.701) while the lower mean of Vickers hardness was found in Vita group (475.800±15.699) followed by Soprano group (467.895±23.298). There was a statistically significant difference between each two groups (VITA, Ivoclar, GC and Soprano) with p-value < 0.05, except between (VITA & Soprano) and (Ivoclar & GC), there no statistically significant association with p-value >0.05 for both. : Zirconia glazed with GC paste (powder, fluid) has higher hardness than samples glazed with Ivoclar paste (powder, fluid) followed by VITA group then Soprano group that has lower hardness. Conclusion: - Zirconia coated with GC paste (powder, fluid) has a higher hardness than samples glazed with Ivoclar, VITA group and Soprano group.

Introduction:

The names of the Stone Age and the Bronze Age came from the materials that dominated throughout those historical periods. The Modern Era, on the other hand, was dubbed the Era of Ceramics because it was characterized by a growing variety of ceramic materials for industrial or biomedical purposes. Ceramic products called "bio-ceramics" are used in the disciplines of medicine and dentistry. Zirconia technology has sped the creation of metal-free dental minerals throughout time, leading to materials with a high degree of dynamic compatibility, more attractive teeth, and increased robustness (1). For many years, complete crown and bridge restorations have been utilized effectively to keep damaged natural teeth looking good and functioning properly. Dental ceramics are used to make dental prostheses, which are then utilized to replace missing or damaged teeth (2). Zirconia (ZrO₂) is a ceramic material with excellent mechanical properties with a compression resistance of about 2000 MPa. When stabilized with Y₂O₃, it offers the best properties for dental applications. Whenever stress occurs on zirconia surface, a crystalline modification occurs which opposes the propagation of cracks. With fracture toughness twice or more that of alumina ceramics, transformation toughened zirconia represents an exciting potential substructure material (3). Since monolithic zirconia restorations are exposed to the oral environment without any extra glass veneering, they only need to be stained, polished, and glazed (4). The continuing advancements in digital dentistry, particularly the use of computer-aided design (CAD) and computer-aided manufacturing (CAM) technology to dental materials, have increased the efficiency and accuracy of created restorations. Additionally, because of the possibility of technical and human faults happening at various working processes, it has decreased handling errors and saved time and effort (5). Glazing, accompanied by staining of ceramics is a common step in dental laboratories to achieve the final

shade and finish of ceramic restorations. The aim is to seal the open pores on the surface of sintered porcelain and to produce a smooth glossy layer. Despite there being several reports that glazing monolithic zirconia wears off the surfaces in contact with antagonists, the practice of staining and glazing monolithic restorations are commonly employed to achieve an improved and acceptable aesthetics that is superior to that of the monolithic intrinsic color of the crown (6). Glazed surfaces on ceramic surfaces have the potential to reinforce them. Additionally, it reduces the buildup of bacterial plaque and avoids excessive wear on teeth in the opposite jaw. Glazed ceramic materials reduce the amount of time a ceramic restoration is exposed to the oral environment, making the restoration smoother than unglazed ceramic (7). The Vickers hardness of the restorations, which is one of the best ways to gauge a material's hardness, affects the restorations' overall efficiency (8). Therefore, this in vitro study intended to investigate the influence of four different glazing brands (VITA, Ivoclar, GC and Soprano) examines the hardness, the glazing materials have effect on monolithic zirconia's hardness, that appear GC glaze have higher result than Ivoclar, VITA and Soprano in the hardness.

Materials and Methods:

1. Grouping of samples

Four sets of ten monolithic zirconia (VITA Zahnfabrik YZ®XT Color Extra Translucent Zirconia, Germany) samples, each separated into four according to the various brands of glazing materials employed, were utilized to create forty disc-shaped specimens. The first group received (VITA, VITA AKZENT® Plus, glaze LT, Germany) glazing, the second group received (Ivoclar vivadent, IPS e.max ceram glaze and stain liquid, Liechtenstein) glazing, the third group had with (GC Initial spectrum glaze liquid, Austria) glazing, and the fourth group received (Soprano glaze, Cendres+ Métaux SA Rue de Boujean 122 CH- Biel/Bienne) (9).

2. Specimen description

Vickers hardness was measured using a disc-shaped specimen that was created from pure Zirconia (VITA Zahn-fabrik YZ®XT Color Extra Translucent Zirconia, Germany) (Diameter 98.4x14mm height) and milled using a CAD/CAM (Imes-Core, 5 axis, COR TEC 250i dry, Germany) system. The specimen's dimensions were prepared in accordance with a prior study, and they were (10 mm) in diameter and (2 mm) thick (10).

3. Designing of specimens

Monolithic zirconia disc-shaped specimens with a diameter of (10 mm) and a thickness of (2 mm) as shown in Fig. [1] were created using specialist (3D) modeling software called Mesh Mixer. The specimen's drawings were converted into a 3D template that could be milled by a CAD/CAM device, and the model was prepared as an STL file that the system could comprehend (11).

4. Installing STL files into a CAD system

A software application called Computer Numerical Control (CNC) inserts and verifies the data of a scanned model or software model before saving it in a unique file called the STL. All the material selections that are compatible with the CAM machine are present in this software. Before the zirconia blank detail, including dimension (diameter, height), and serial number were input, the type of element (Zirconium) was established. The program's library database, which contains all the previously input workpieces, was updated with this information. The specimens produced by the STL files Fig. [2], were then imported using the program. With the aid of this program, the sort of item to be milled may be chosen (12).

After that, arrange the specimen's model in the appropriate locations on the zirconia blank until it fits and completely fills the blank's dimensions Fig. [3] The specimens were then placed within the blank during milling by placing bars or supporting connections along all their borders. Because the CAD/CAM technique employed was able to extend the zirconia samples to an optimal size to allow for

sintering shrinkage, the specimens were created to precise size without any expansion to accommodate for predicted shrinkage. Sending the workpiece order to the CAM system is the last step before the milling process. The CAM system software reviewed all the blank information that had just been submitted and determined the suitable tools that would be utilized in the milling operation (12).

5. Specimen fabrication

Pre-sintered zirconia that supplied by the manufacturer in large disc-shaped blocks, (VITA Zahn fabrik YZ®XT Color Extra Translucent Zirconia, Germany), Fig. [4], was used for the fabrication of specimens. The zirconia block was shade (A1) with high translucency, with a diameter of 98.4 mm and height of 14 mm.

6. Zirconia specimens' milling procedure

To begin the milling process in accordance with the manufacturer's instructions, the zirconia block (VITA YZ®XT Color, Diameter 98.4x14mm height) was attached within the blank holder in the milling device. Then the request for the digital model of the disc was submitted to the CAM machine. The CAM system software reviewed every blank field that had recently been filled in as well as the suitable equipment that would be used throughout the milling process. With the 5-axis milling unit Fig. [5, A], start the dry milling operation of the disc pre-sintered zirconia blocks Fig. [5, B] were milled using two diamond burs, one of which had a diameter of 2.50 mm for cutting outlines Fig. [6, A] and the other of which had a diameter of 1.00 mm for fine finishing Fig. [6, B]. Each bur was automatically replaced during the milling operation, following the milling of specimens with a thickness of less than 2 millimeters. To prepare for removing the specimens from it, the milled block was taken from the holder using a screwdriver.

7. Cleaning and finishing sprues of specimens

After milling was finished and the block was removed from the milling machine's

holder, the discs were separated from the block at the sprue point using a fissure bur and laboratory engine. After that finishing excess of sprues with a carbide bur and clean specimens with a brush to remove residual particles and dust of the milling procedure for smoothing of edge when the sprue cutting. The foregoing method was carried out in accordance with the manufacturer's guidelines to prepare the specimen for the sintering process (13).

8. Sintering process

After milling, the zirconia discs had a chalky-white appearance. They thus required an intensive sintering procedure, which was carried out in a sintering furnace. All disc-shaped specimens were sintered for eight hours at (1450 °C) in a high-temperature ceramic furnace in accordance with the manufacturer's instructions.

The temperature increased steadily until it reached 200 °C, at which point it increased by 4 °C per minute until it reached 1000 °C. The furnace temperature will progressively increase to the highest setting of 1450 °C and be kept at this temperature for 120 minutes. The temperature was then lowered for cooling until it reached (200 °C), at which point the furnace would be turned off. at which point the furnace was slowly opened. After sintering, the zirconia specimens naturally shrank in size by around 20% to 25% volume contraction calculated by A manual dental caliper device was used to check the final diameter and thickness after sintering.

9. Acrylic holder construction

A specially made acrylic holder (14) was created from cold cure acrylic powder and self-cure liquid to make holding specimens during the initial polishing process easier. It has two rectangular pieces joined by two screws and a central hole that is the same diameter as the specimen (10 mm) but is only (1 mm) deep to leave another (1 mm) of the specimen high enough to be polished easily during the polishing procedure. When illustrated, this holder was employed to permit the specimens' insertion and removal as they were being

changed throughout the polishing technique as shown in Fig. [7] (13).

10. polishing of specimens

To achieve a consistent beginning roughness and surface uniformity, all specimens were polished to a flat, mirror finish. Each sample (2 mm thickness- 10 mm diameter) was placed in a specially built container for uniformity to make handling easier when polishing. The pink rubber polishers with diamonds from the VITA SUPRINITY Polishing Set are used to pre-polish the surfaces of the samples at a speed of 7,000 to 12,000 rpm. Then, at a slower speed of 4,000 to 8,000 rpm, high-gloss polishing is done with gray rubber polishers that have been diamond-coated. Because of this, the antagonist is protected from unintentional abrasion by the high polish; the polishing burst was used on 5 samples before being replaced (15). Everything is done in accordance with the manufacturer's instructions.

11. Glazing process

After polishing process, the (40) samples will be divided to (4) groups each group have (10) samples according to glazing materials:

Group 1: VITA glaze: Consist of powder and fluid.

VITA AKZENT Plus GLAZE powder: For all types of dental-ceramic materials, for the layering and press technique and from feldspar ceramic blocks such as VITA blocks to monolithic restorations. Glaze material for a brilliant, glass-like, homogeneous, and dense surface after Firing.

VITA AKZENT Plus PASTE FLUID: The fluid has been especially adjusted to maintain the consistency of the pastes, it is used to mix almost dried and dried pastes again without changing the physical properties of the pastes, the paste fluid can also be used to obtain a thinner consistency of the pastes. As a result, the viscosity and followability of the pastes can be changed if the pastes are thinned excessively, the pastes will have a reduced degree of gloss after firing since the mixture does not contain enough glass powder (from manufacture instruction).

Powder composition: *O*- 48.44, *Si*- 35.75, *Ti*- 5.24, *Na*- 3.75, *Al*- 2.84, *C*- 2.29.

Group 2: IVO- CLAR glaze: Consist of powder and fluid.

IPS e.max Ceram Glaze Powder: is available in both the tried-and-tested paste form and in powder form. The glazing material is applied to all areas of the restoration that have been veneered using IPS e.max Ceram and are thus exhibiting sufficient fluorescence resulting from the layering material.

IPS e.max Ceram Glaze and Stain Liquids: The IPS e.max Ceram Glaze and Stain Liquids (the all-round Liquid), a consistency suitable for conventional processing and drying is achieved. Powders mixed with the all-round Liquid demonstrate a shorter processing time (from manufacture instruction).

Powder composition: *O*- 43.15, *Si*- 38.46, *Ti*- 7.20, *Na*- 2.83, *Al*- 3.42, *C*- 1.68, *Cr*- 1.91.

Group 3: Soprano glaze: consist of powder and fluid and have two types:

Soprano@10: Silicate glass ceramic for veneering frameworks made of lithium disilicate as well as zirconium dioxide (this type of use in this study).

Soprano@14: Silicate glass ceramic for ceramic veneering of precious metal and non-precious metal alloys.

Soprano® POWDER Stain & Glaze Universal, 7g: Universal powder stains for every ceramic.

Soprano® fluid Stain & Glaze Universal, 25ml: The shades are highly fluorescent, and the materials can be used universally on zirconium oxide, lithium disilicate and veneering ceramics (from manufacture instruction).

Powder composition: *O*- 45.05, *Si*- 40.80, *Ti*- 3.74, *Na*- 4.40, *Al*- 2.11, *C*- 1.51, *Fe*- 1.92.

Group 4: GC glaze: consist of powder and fluid.

GC Initial Spectrum Glaze Powder, 10g: Fine glaze powder to be mixed with the glaze or glaze paste liquid. The glaze powder can be adapted to the preferred consistency of the user by using the glaze or the glaze paste liquid.

GC Initial Spectrum Glaze Liquid, 25ml: The standard low viscosity type of mixing liquid allowing a fine application (from manufacture instruction).

Powder composition: *O*- 32.18, *Si*- 60.99, *Ti*- 0.33, *Na*- 2.22, *Al*- 4.28, *C*- 0.00.

Two layers of glazing material (VITA, Ivoclar, GC, Soprano) were applied to each group, and each layer will be burned at the same temperature. As directed by the manufacturer, the powder was mixed with the liquid until it had a consistent, creamy texture. The mixture was then coated uniformly on one side of the specimens' complete surface while being held in some tweezers, and the specimens were then burned in a furnace using the appropriate firing schedule for each one. To limit variability, one operator completed all the specimens (9).

12. Energy-Dispersive X-Ray Analysis

Energy-dispersive X-ray analysis (EDAX) is a technique used for the measurement of nanoparticles by SEM. In this technique, the nanoparticles are analyzed by activation using an EDS X-ray spectrophotometer, which is generally present in modern SEM. The individual separated nanoparticles are deposited on a suitable substrate that does not interfere in the characterization of nanoparticles. This method has found some limitations about accurate dimensional and elemental characterization (16).

13. Hardness test

All samples are tested using a digital micro-Vickers Hardness tester machine (N). Each sample is positioned in the horizontal stage of the tester machine and subjected to a load of 9.8 N (1k) for 15 seconds using a diamond Vickers indenter (17), as shown in Fig. [8]. Three tests were performed on the samples (left, center, and right) (18). Each sample's hardness value may be automatically determined by the tester equipment.

Result:

Statistical package of social science (SPSS) software version twenty-four was utilized to analyze this study. Also,

Microsoft excel 2016 was used for graphics presentation.

In Table [1], Mean values of microhardness test for four groups of ten specimens showed high mean value in GC followed IVOCLAR then VITA and least Soprano.

In Table [2] and Fig. [9] the highest mean of hardness values was in (GC) group followed by (Ivoclar) group then (VITA) group while the lowest mean of hardness values was for (Soprano).

In Table [3], Levene's test for homogeneity of variances showed no statistically significant difference between the variances of the groups for hardness with P-value > 0.05.

In Table [4], the one-way ANOVA test revealed a high statistically significant difference between the four involved groups for hardness with P-value (4.571E-11).

In Table [5], Post Hoc Test (Bonferroni) shows a statistically significant difference between each two of the studied groups (VITA, Ivoclar, GC and Soprano) for hardness with p-value < 0.05, except for two, there no statistically significant association between (VITA & soprano) glaze and between (Ivoclar & GC) glaze with p-value > 0.05 for both.

In Table [6], Energy-Dispersive X-Ray Analysis show the effect of the glazing materials on hardness will be related to one elemental composition Al weight % (7), which is used in this study. While the glazing material (powder) had more Aluminum (Al) in GC group than Ivoclar, VITA and Soprano.

Discussion:

Due to its exceptional biocompatibility, low cytotoxicity, chemical stability, high mechanical strength, superior fatigue resistance, high fracture resistance, and hardness, zirconia is frequently utilized in prosthetic dentistry, the creation of novel manufacturing processes utilizing CAD/CAM (computer-aided design/manufacturing) technology; zirconia is treated using CAD-CAM milling in this context. Zirconia works as a very homogeneous material that is easier to mill, decreasing production delays,

machinery wear, and surface defects. These manufacturing processes may be carried out in dental offices or labs (19). A mixture of colorless glass powder and liquid is used in the laboratory process of glazing to smooth out the ceramic surface, close any pores, and decrease roughness (20). One of the most often used devices is the Vickers indenter. The Vickers hardness test was chosen because it may be utilized, to determine the hardness of tiny regions, as earlier researchers have done (21). Because there isn't a layer of porcelain veneering, the zirconia surface is in direct touch with the opposing tooth, hence the monolithic zirconia's hardness is an important consideration (22).

According to the results of the current experiment, different glazing brand materials produced a statistically significant variance in the hardness of zirconia. In terms of Vickers hardness, there was a substantial difference between various glazing brand materials, with referring to Table [2] and Fig. [9] for the result that found after performing the micro-hardness test shows that the GC glaze have a high hardness value and followed by Ivoclar glaze while the lower value was found in vita glaze then soprano glaze. The reason behind these results was the mechanical properties of glazing layer that enhanced by Alumina. The amount of alumina in the glaze materials according to the analysis done by energy-dispersive X-ray analysis (EDAX) test, this agrees with (Moosa et al., 2021) Increased Alumina concentration will result in more crystal phases forming, raising the glazing layer's Vickers hardness number, which in turn affects zirconia's surface resistance and shortens the lifespan of artificial teeth (7). The explanation for the decreased micro-hardness results in Vita and Soprano brand glazing materials may be because the monolithic zirconia glaze groups were heated throughout the glazing process to the sintering temperature. This feature may be explained by the fact that the particle size increases as the sintering temperature and time increase. Zirconia's mechanical properties are influenced by the particle size. Zirconia loses stability at a certain size. Sintering conditions can affect the final product's stability and

mechanical properties (Yener et al., 2015) Reduce the hardness in glazing groups as well, perhaps because glazing with a brush result in a layer with a variety of inner faults (i.e., bubbles) (23). These imperfections might act as stress concentrators, raising the risk of failure at the zirconia/glaze interface and jeopardizing the durability and strength of zirconia restorations. this cause also supported by (Zucuni et al., 2019) (24). The last anticipated cause of decreasing micro-hardness during glazing may be because zirconia weakens and changes from tetragonal to monoclinic when heated during glazing surface treatments. And this agrees with (Park et al., 2017) (25).

Conclusion:

Under the limitations of this in vitro study, the following conclusions were drawn:

- 1- Increase percentage of Alumina in glazing materials lead to increase hardness.
- 2- There was no difference between (Vita & Soprano) and (Ivoclar & Gc) groups in terms of Vickers hardness for monolithic zirconia.

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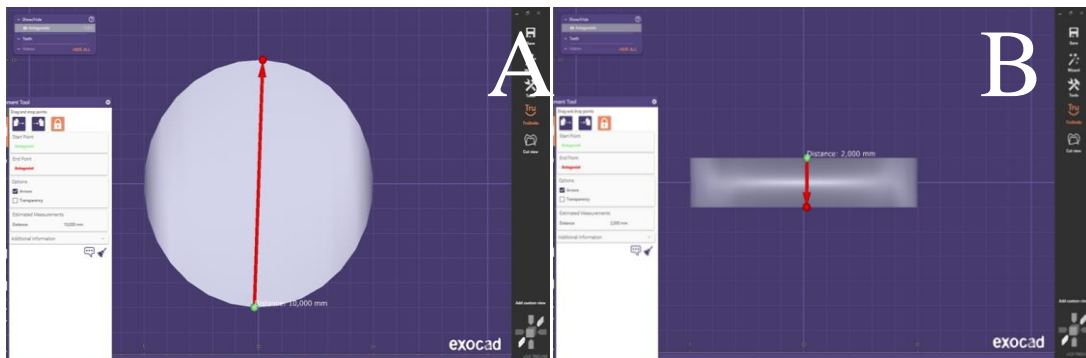


Fig. (1): Designing of specimens A: Diameter of specimen (10 mm), B: Thickness of specimen (2 mm)

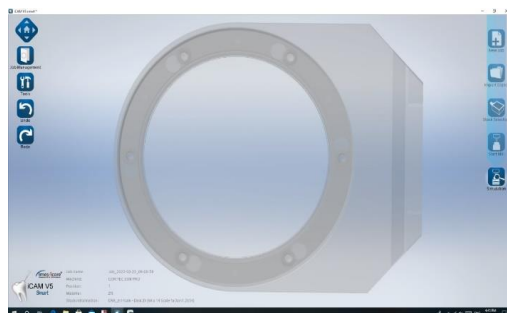


Fig. (2): Software of CAD unit



Fig. (3): Arranging the discs models on the blank



Fig. (4): Monolithic zirconia disc as it provided by the manufacturer.

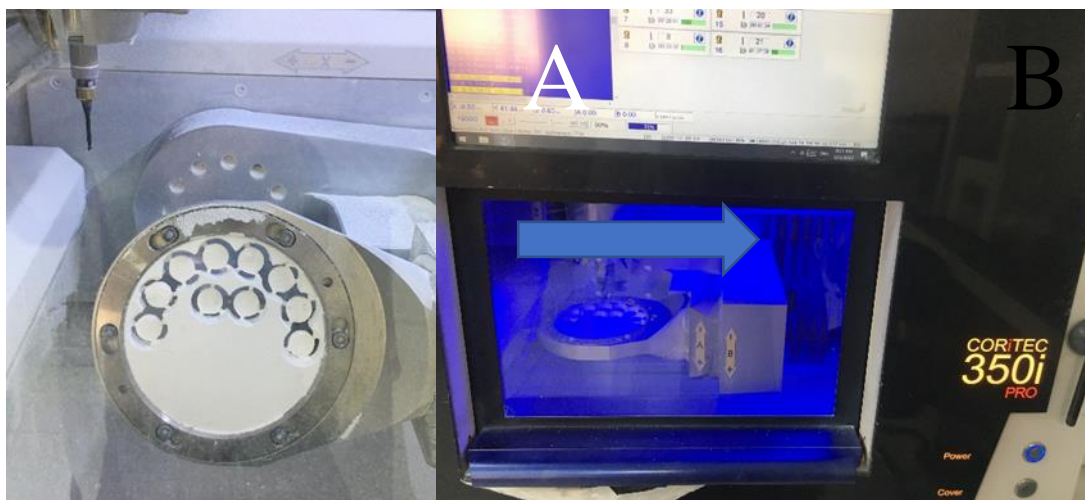


Fig. (5): 5-axis milling
A: Dry milling machine
B: Close-up image for specimens during milling procedure



Fig. (6): Diamond burs used for milling procedure.
A: 2.50 mm in diameter B: 1.00 mm in diameter



Fig. (7): Acrylic holder of specimens



Fig. (8): A: Digital micro-Vickers hardness tester, B: Close-up view of a specimen on the stage of device

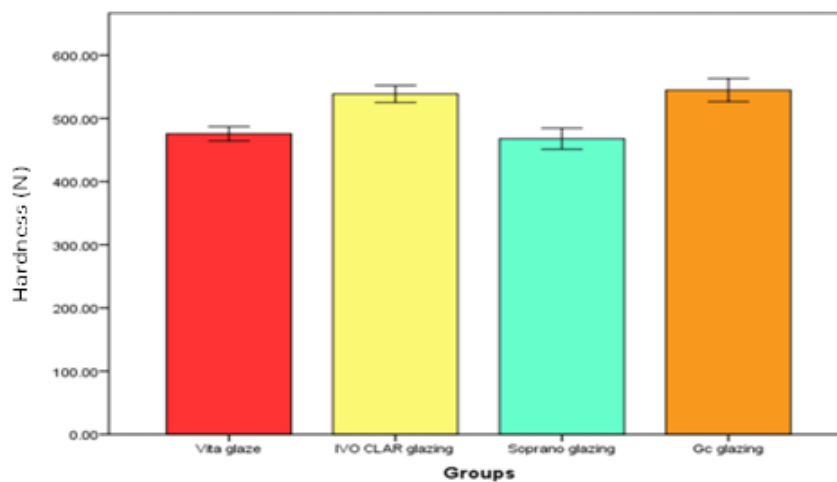


Fig. (9): Bar chart showing the mean distribution and standard deviations of hardness (N) values of the studied zirconia groups (VITA, Ivoclar, GC, Soprano).

Table (1): Mean values of microhardness test for four groups of specimens

Groups	Sampl e 1	Sampl e 2	Sampl e 3	Sampl e 4	Sampl e 5	Sampl e 6	Sampl e 7	Sampl e 8	Sampl e 9	Sampl e 10	Mean
Group I (VITA)	453.47	466.67	472.63	468.17	456.27	494.30	495.53	474.53	496.73	479.70	475.80
Group II (IVO CLAR)	559.96	543.97	562.56	527.37	538.60	520.33	505.80	546.2	556.3	525.13	538.62
Group III (SOPRANO)	434.40	475.20	473.10	439.43	450.73	490.40	498.33	487.57	484.13	445.66	467.89
Group IV (GC)	537.03	566.50	517.73	532.00	517.43	573.30	548.10	549.60	589.53	516.70	544.79

Table (2): Descriptive statistic of the Vickers hardness (N) for different glazing materials of Zirconia groups

Groups	N.	Mean	Std. Deviation	Std. Error	Range	
					Min.	Max.
Vita glaze	10	475.800	±15.699	4.964	453.470	496.730
IVOCLAR glaze	10	538.622	±18.701	5.914	505.800	562.560
Soprano glaze	10	467.895	±23.298	7.367	434.400	498.330
Gc glaze	10	544.792	±25.416	8.037	516.700	589.530
Total	40	506.777	±40.941	6.473	434.400	589.530

Table (3): Test of homogeneity of variances

	Levene's statistic	Df1	Df2	P-value	Sig
Hardness	1.456	3	36	0.243	NS

* NS: Non- significant at p value > 0.05.

* DF: Degree of freedom

Table (4): one way ANOVA test for hardness among all groups

Groups	Sum of Squares	df	Mean Square	F	P- value	Sig
Between Groups	49306.287	3	16435.429	36.832	4.571E-11	HS
Within Groups	16064.154	36	446.226			
Total	65370.441	39				

* HS: Highly significant at p- value < 0.01.

Table (5): Bonferroni test for multiple comparison of Vickers hardness among four groups.

Multiple Comparisons of Bonferroni for surface hardness test							
(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P- value	Sig	95% Confidence Interval	
						Lower Bound	Upper Bound
Vita	Ivoclar	-62.822*	9.446	5.69E-7	HS	-89.197	-36.446
Vita	Soprano	7.905	9.446	0.893	NS	-18.470	34.280
Vita	Gc	-68.992*	9.446	7.917E-8	HS	-95.367	-42.616
Ivoclar	Soprano	70.727*	9.446	4.576E-8	HS	44.351	97.102
Ivoclar	Gc	-6.170	9.446	0.983	NS	-32.545	20.205
Soprano	Gc	-76.897*	9.446	6.700E-9	HS	-103.27	-50.521

*. NS: Non- significant at p- value > 0.05.
 **. HS: Highly significant at p- value <0.01

Table (6): EDX results for glazing materials (powder) for all groups in weight %.

Element Group	Vita	Ivoclar	GC
	Weight %	Weight %	Weight %
Oxygen (O)	48.44	43.15	32.18
Silica (Si)	35.75	38.46	60.99
Titanium (Ti)	5.24	7.20	0.33
Sodium (Na)	3.75	2.83	2.22
Aluminum (Al)	2.84	3.42	4.28
Carbon (C)	2.29	1.68	0.00

References:

- Salman Z, Zaidan SA, Hubeair K, editors. Influence of titanium oxide additions with co2 laser treatment on the microstructural properties of glazes layer-dental zirconia ceramics. IOP Conference Series: Materials Science and Engineering; 2020: IOP Publishing.
- Sundaram RK, Varghese B. All Ceramic Materials in Dentistry: Past, Present and Future: A Review. 2020;7:2.
- Rashid H. The effect of surface roughness on ceramics used in dentistry: A review of literature. European journal of dentistry. 2014;8(04):571-9.
- Caglar I, Ates SM, Duymus ZY. The effect of various polishing systems on surface roughness and phase transformation of monolithic zirconia. The journal of advanced prosthodontics. 2018;10(2):132-7.
- Corbani K, Hardan L, Skienhe H, Özcan M, Alharbi N, Salameh Z. Effect of material thickness on the fracture resistance and failure pattern of 3D-printed composite crowns. Int J Comput Dent. 2020;23(3):225-33.
- Singh RG, Li KC, Lyons KM, Waddell JN. Effect of Two Brands of Glaze Material on the Flexural Strength and Probability of Failure of High Translucent Monolithic Zirconia. Materials. 2021;14(22):7022.
- Moosa JM, Abdulzahraa HG, Zaidan SA, Abed HY. Reinforcing Glaze Layer of Restorative Dental Zirconia by Adding Nano Alumina Ceramics. NeuroQuantology. 2021;19(6):73.
- Tanaka Y, Seino Y, Hattori K. Automated Vickers hardness measurement using convolutional neural networks. The International Journal of Advanced Manufacturing Technology. 2020;109(5):1345-55.

9. Vasiliu R-D, Porojan S-D, Bîrdeanu M-I, Uțu I-D, Porojan L. The effect of thermocycling and surface treatments on the surface roughness and microhardness of three heat-pressed ceramics systems. *Crystals*. 2020;10(3):160.
10. Gaonkar SH, Aras MA, Chitre V. An in vitro study to compare the surface roughness of glazed and chairside polished dental monolithic zirconia using two polishing systems. *The Journal of the Indian Prosthodontic Society*. 2020;20(2):186.
11. Mohammed NA, Yassen IN. Evaluation the Effect of Different Thicknesses Core on the Micro-Hardness of Zirconia Ceramic Material. *Al-Nisour Journal for Medical Sciences*. 2019;1(2).
12. Abdul-Kareem NA, Yassen IN. Evaluate the Flexural Strength of Zirconia Fixed Partial Denture with Different Connector Designs. *Journal of Oral and Dental Research*. 2020;7(2).
13. Hashim AR, Mansoor NS. Effect of Different Surface Treatments on Surface Roughness and Vickers Micro-Hardness of Feldspathic Porcelain: An In Vitro Study. *MUSTANSIRIA DENTAL JOURNAL*. 2021;17(1).
14. Hasan SF, Abood AZ. Effect of Various Particle Size of Sand-blast on Roughness and Shear Bond Strength of Ips E. max Press With Ceramic Veneer Materials (An in Vitro Study). 2018.
15. Hasan SF, Abood AZ. Evaluation the effect of hydrofluoric acid and grinding treatment on shear bond strength of Ips e. max press with ceramic veneer material (in vitro study). 2017.
16. Raval N, Maheshwari R, Kalyane D, Youngren-Ortiz SR, Chougule MB, Tekade RK. Importance of physicochemical characterization of nanoparticles in pharmaceutical product development. *Basic fundamentals of drug delivery: Elsevier*; 2019. p. 369-400.
17. Ozdogan A, Yesil Duymus Z. Investigating the effect of different surface treatments on Vickers hardness and flexural strength of zirconium and lithium disilicate ceramics. *Journal of Prosthodontics*. 2020;29(2):129-35.
18. Abd Kati F, Al-Kaabi AFJ. Effect of oil paint addition on micro hardness of acrylic ocular prosthesis. *Iraqi Dental Journal*. 2016;38(2):87-9.
19. Ispas A, Iosif L, Murariu-Măgureanu C, Craciun A, Constantiniuc M. Zirconia in dental medicine: a brief overview of its properties and processing techniques. *Human and Veterinary Medicine*. 2021;13(1):33-9.
20. Toma FR, Bîrdeanu MI, Uțu I-D, Vasiliu RD, Moleriu LC, Porojan L. Surface Characteristics of High Translucent Multilayered Dental Zirconia Related to Aging. *Materials*. 2022;15(10):3606.
21. Ilie N, Hilton T, Heintze S, Hickel R, Watts D, Silikas N, et al. Academy of dental materials guidance—Resin composites: Part I—Mechanical properties. *Dental materials*. 2017;33(8):880-94.
22. Candido L, Miotto L, Fais L, Cesar PF, Pinelli LA. Mechanical and surface properties of monolithic zirconia. *Operative dentistry*. 2018;43(3):E119-E28.
23. Yener ES, Ozcan M, Kazazoglu E. A comparative study of biaxial flexural strength and Vickers microhardness of different zirconia materials: Effect of glazing and thermal cycling. *Brazilian Dental Science*. 2015;18(2):19-30.
24. Zucuni CP, Pereira GKR, Dapieve KS, Rippe MP, Bottino MC, Valandro LF. Low-fusing porcelain glaze application does not damage the fatigue strength of Y-TZP. *Journal of the Mechanical Behavior of Biomedical Materials*. 2019;99:198-205.
25. Park C, Vang M-S, Park S-W, Lim H-P. Effect of various polishing systems on the surface roughness and phase transformation of zirconia and the durability of the polishing systems. *The journal of prosthetic dentistry*. 2017;117(3):430-7.