



RESEARCH ARTICLE - MEDICAL TECHNIQUES

Evaluation of the Effect of Different Glazing Brands on Surface Roughness of Monolithic Zirconia

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| Article Info. | Abstract |
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| <p><i>Article history:</i></p> <p>Received 12 September 2022</p> <p>Accepted 23 October 2022</p> <p>Publishing 30 June 2023</p> | <p>The effect of glazing on the mechanical properties of monolithic high translucent zirconia is widely used to fabricate highly aesthetic and strong dental restorations using CAD-CAM technology. The purpose of this study was to evaluate the surface roughness of different glazing brands' materials on monolithic Zirconia. 40 specimens from Zirconia block (VITA YZ®XT Color, Diameter 98.4x14mm height) were prepared by computer-aided design/computer-aided manufacturing machined (Imes-Icore, 5 axis, COR TEC 250i dry, Germany). The samples dimension for the surface roughness test (diameter 10 mm and thickness 2 mm) by using a surface roughness testing machine profilometer (TR200, Germany), divided into 3 groups depending on types of glazing brands materials (VITA, VITA AKZENT® Plus, glaze LT, Germany), the second group with (Ivoclar Vivadent, IPS e.max Ceram glaze and stain liquid, Liechtenstein), and the third group with (GC Initial spectrum glaze liquid, Austria). The data were analyzed statistically using the package for social science, (ANOVA) test with the Bonferroni test to accept or reject the statistical hypothesis. For the roughness readings, the GC group had the greatest mean value of surface roughness in zirconia (0.721±0.014), followed Ivoclar group (0.663 ± 0.030), and then the VITA group (0.641±0.021). There was a statistically significant difference between (VITA&GC) and (Ivoclar & GC) with a p-value < 0.05, except between VITA with Ivoclar, there was no statistically significant association with a p-value > 0.05 for both. Zirconia glazed with GC paste (powder, fluid) has higher surface roughness than samples glazed with Ivoclar paste (powder, fluid) followed by the VITA group which has lower surface roughness. The results concluded that the monolithic zirconia glazed with GC glaze material displays a higher surface roughness than Ivoclar and VITA glaze.</p> |

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1. Introduction

The titles of the Stone Age and the Bronze Age were derived from the predominant materials throughout those eras. Therefore, the modern era is referred to as the era of ceramics due to the growing variety of ceramic materials that are now accessible for industrial or biomedical applications, ceramics are used in the medical and dentistry industries as "bio-ceramics." Zirconia technology has sped the creation of metal-free dental minerals over time, leading to materials with a high degree of dynamic compatibility, more attractive teeth, and increased robustness for many years [1]. Full crown and bridge restorations have been used successfully to maintain the appearance and functionality of damaged natural teeth, dental ceramics are components used to create a dental prosthesis that replaces lost or damaged teeth [2]. Monolithic zirconia restorations only need to so be stained, polished, and glazed because they are exposed to the oral environment directly [3]. The efficiency and accuracy of manufactured restorations have increased due to the ongoing advancements in digital dentistry, particularly the use of computer-aided design and computer-aided manufacturing technology in dental materials. Additionally, it has reduced handling errors associated with the conventional workflow as a result of potential human and technical errors occurring at various working steps, saving time and effort [4]. For ceramic dental restorations, the glazing process is used to provide aesthetics and smooth out rough surfaces. Many important characteristics exist in thin glaze layers. Glazed surfaces on ceramic materials may strengthen their surfaces. Additionally, it reduces the buildup of bacterial plaque and stops teeth on the opposite side from wearing down excessively. Glazed ceramic can replicate the appearance and gloss of real teeth. With glazed ceramic materials, the ceramic restoration is less exposed to the oral environment and is smoother than unglazed ceramic [5]. Rough repair surfaces are linked to periodontal, caries, or cosmetic issues. Increased wear on the opposing teeth can result from ceramic restorations with roughened occlusal surfaces, therefore that plaque buildup and bacterial retention are decreased with smooth surfaces [6]. Consequently, this *in vitro* study intended to investigate the influence of three different glazing brands (VITA, Ivoclar, GC) examines the surface roughness, the glazing materials have an effect on monolithic zirconia's surface roughness, therefore that appear GC glaze have higher result than Ivoclar and GC in the surface roughness.

| Nomenclature & Symbols | | | |
|------------------------|----------------------------------|-----|------------------------------|
| CAD | Computer-Aided Design | 3D | Three-Dimensional |
| CAM | Computer Aided Manufacturing | CNC | Computer Numerical Control |
| STL | Standard Transformation Language | SEM | Scanning Electron Microscopy |
| mm | Millimeter | | |

2. Materials and Methods

2.1. Grouping of samples

A total of thirty disc-shaped specimens were created entirely from monolithic Zirconia (VITA Zahnfabric YZ@XT Color Extra Translucent Zirconia, Germany) samples, which were separated into three groups according to the various brands of glazing materials utilized. Each group had ten samples. the first group was coated with (VITA, VITA AKZENT® Plus, glaze LT, Germany), the second group with (Ivoclar Vivadent, IPS e.max Ceram glaze and stain liquid, Liechtenstein), and the third group with (GC Initial spectrum glaze liquid, Austria) [7].

2.2. Specimen description

As shown in Fig. 1, a disc-shaped specimen was created to measure surface roughness. The specimen was created using a computer-aided design /computer-aided manufacturing milling machine (Imes-Icore, 5 axis, COR TEC 250i dry, Germany) and was built of pure monolithic zirconia with dimensions of (10 mm in diameter and 2 mm in thickness), according to the previous research, the specimens' dimensions were created [8].

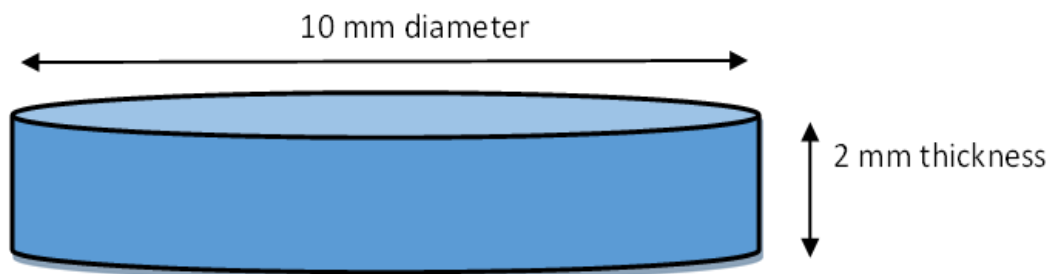


Fig. 1. Shape and dimensions of zirconia sample

2.3. Designing of specimens

Monolithic zirconia disc-shaped specimens with a 10 mm diameter and 2 mm thickness were created using specialist 3D modeling software (Mesh mixer 3D design program) [9]. The specimen's drawings were converted into a 3D template that could be milled by a computer-aided design/ computer-aided manufacturing, and the model was prepared as a standard transformation language (STL) file that the system could comprehend [10].

2.4. Installing standard transformation language (STL) files into a Computer- Aided Design (CAD) system

Computer Numerical Control (CNC) is a software program that enters and confirms the data of a scanned model or software model before storing it in a special file called the STL. This program contains all the material options that are compatible with the CAM machine. The type of element (Zirconium Oxide) was determined before the zirconia blank detail, including dimension (diameter, height) and serial number were entered. This data was entered into the program's library database, which includes all the previously entered workpieces. After that, the software was used to import the specimens generated by the STL files Fig. 2, this image was taken by a screenshot from CAD software. The type of object to be milled can be selected using this program [11].



Fig. 2. Software of CAD unit

After that, arrange the specimen's model in the appropriate locations on the zirconia blank until it fits and fills the blank's dimensions Fig. 3, this image was taken by a screenshot from CAD software. The specimens were kept inside the blank during the milling process by placing bars or supporting connections on all specimen borders in the next stage see Fig. 4 [9], this image was taken by a screenshot from CAD software.

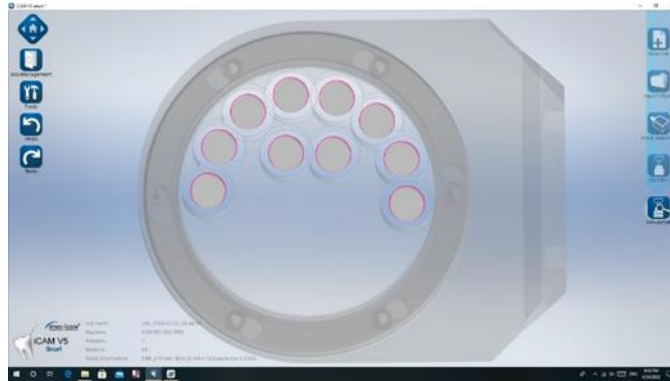


Fig. 3. Arranging the discs models on the blank

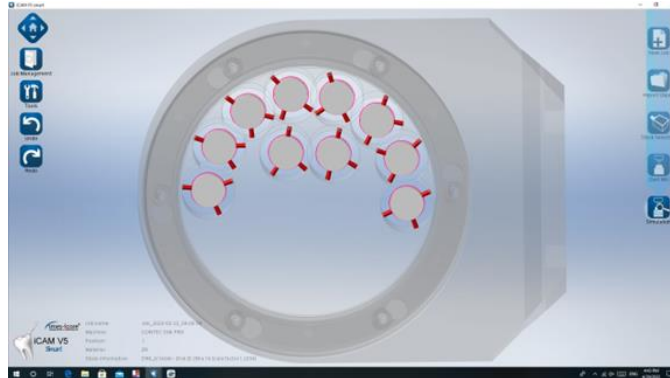


Fig. 4. Adding supporting connectors to the specimens

Because the computer-aided design/computer-aided manufacturing 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 [9]. Sending the workpiece order to the computer-aided manufacturing system is the last step before the milling process. The computer-aided manufacturing 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 [11].

2.5. Specimen fabrication

The creation of the specimens, for pre-sintered zirconia (VITA YZ®XT Color Extra Translucent Zirconia, Germany), Fig. 5, was utilized, which was supplied by the manufacturer in huge disc-shaped blocks. The zirconia block had a diameter of 98.4 mm, a height of 14 mm, and a shade (A1) with great translucency.



Fig. 5. Monolithic zirconia disc as provided by the manufacturer

2.6. Milling process of Zirconia specimens

To begin the milling process by the manufacturer's instructions, the zirconia block (VITA YZ®XT Color, diameter 98.4 x 14mm height) was attached to the blank holder in the milling device. Then the request for the digital model of the disc was submitted to the computer-aided manufacturing machine. The computer-aided manufacturing 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. to start the 5-axis milling unit's dry milling operation on the disc [9].

Utilizing two diamond burs, each of which changed automatically during the milling process, the pre-sintered zirconia blocks were milled from 2.50 mm in diameter for cutting the outlines to 1.00 mm in diameter for fine finishing. Following the milling operation for specimens with a thickness of approximately 2 mm. With the use of a screwdriver, the milled block was removed from the holder so that the specimens could be separated from it [9].

2.7. 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 according to the manufacturer's recommendations. Each specimen was cleaned with a brush to remove any remaining milling dust and debris after the sprues were removed using a carbide bur. The foregoing method was carried out by the manufacturer's guidelines to prepare the specimen for the sintering process [9].

2.8. Sintering process

After milling, the zirconia discs had a chalky-white appearance and had grown by 20–25 percent in size. They thus required an intensive sintering technique, which was applied in the sintering furnace seen in Fig. 6.

All disc-shaped specimens were sintered for eight hours at (1450 °C) in a high-temperature ceramic furnace by the manufacturer's instructions. The temperature continued to rise until it reached 200 °C. The temperature was increased to 1000 °C after that by adding 4 degrees each minute according to manufacturer instructions. The temperature of the furnace will progressively increase until it reaches its maximum setting of 1450 °C and is maintained there for 120 minutes. After this time, the temperature is lowered for cooling until it reaches 200 °C, at which point the furnace is slowly opened. The zirconia specimens spontaneously reduced in size by 20% to 25% after sintering. The final diameter and thicknesses were examined using manual dental calliper equipment [12].



Fig. 6. Sintering furnace of Zirconia

2.9. Acrylic holder construction

A specially made acrylic holder [13] 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 in Fig. 7, this holder was employed to permit the specimens' insertion and removal as they were being changed throughout the polishing technique.



Fig. 7. Acrylic holder for easier holding

2.10. Polishing of specimens

To achieve a consistent beginning roughness and surface uniformity, all specimens were polished to a flat, mirror finish. Each sample was placed in a custom-made holder for uniformity to make handling easier when polishing [9]. With the diamond pink rubber polishers (VITA SUPRINITY_Polishing) the samples surfaces are pre-polished. The technical steps are set at (7,000–12,000) revolutions per minute; everything is done by the manufacturer's instructions.

Then, at a slower speed of (4,000 to 8,000) revolutions per minute, high-gloss polishing is done with grey rubber polishers that have been diamond-coated. Consequently, the antagonist is protected against unintentional abrasion by the high polish; the polishing burs were replaced for every 5 specimens [14].

2.11. Glazing procedure

Following polishing, the 30 samples will be sorted into 3 groups, with 10 samples for each group, each group glazed with different brand material:

2.11.1. Group I

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 specially 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 instructions).

2.11.2. Group 2

IVO- CLAR glaze: Consist of powder and fluid: IPS e.max Ceram Glaze 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-around Liquid), a consistency suitable for conventional processing and drying is achieved. Powders mixed with the all-around Liquid demonstrate a shorter processing time (from manufacturer instructions).

2.11.3. Group 3

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 allows a fine application (from manufacturer instructions).

Each group was glazed using two coats of glazing materials (VITA, Ivoclar, GC) and each layer will be fired at the same temperature according to the parameter of each company. The powder was combined with the liquid until it had a uniform, creamy consistency according to the manufacturer's instructions. Then holding the specimen with a tweezer and the mixture was painted evenly on one side of the entire surface of the specimens with a fine brush and fired in the furnace as per the manufacturer's instructions on the firing program for each one [7].

2.12. Energy-Dispersive X-Ray Analysis

Energy-dispersive X-ray analysis (EDX) is a technique used for the measurement of nanoparticles by SEM. In this technique, the nanoparticles are analysed 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 with the characterization of nanoparticles. This method has found some limitations regarding accurate dimensional and elemental characterization [15], the elemental composition of the glaze powder was qualitatively evaluated, and the weight % of each element was calculated as displayed in Table 1.

Table 5. EDX results for glazing materials (powder) for all groups in weight %

| Element Group | Vita Weight % | Ivoclar Weight % | GC 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 |
| Aluminium (Al) | 2.84 | 3.42 | 4.28 |
| Carbon (C) | 2.29 | 1.68 | 0.00 |

2.13. Surface roughness measurement

For each specimen, a mean roughness profile was looked at to determine the overall roughness of the surface. The acrylic holder that had been used earlier in the first polishing process was utilized to stabilize the specimens. For all specimens, a contact stylus profilometer was used to assess the surface roughness in micrometers. On the center of each disc specimen, three parallel measurements were taken, and the mean surface roughness was computed to determine the specimens' overall surface properties [16].

2.14. Statistical analysis

The data were analysed statistically using the software computer program statistical package of social science to perform the descriptive statistics and inferential statistics including analysis of variations (ANOVA) test with the Bonferroni test to accept or reject the statistical hypothesis.

3. Result

3.1. Surface roughness test of Zirconia

The surface roughness test for entire specimens was measured in μm . The study's findings were statistically examined as shown in Tables 1 and Fig 8 present descriptive statistics for the values of surface roughness, including means, standard deviations ($\pm\text{SD}$), standard errors (SE), and ranges (maximum, minimum) for each group. In Table 2 and Fig. 8, the GC group had the greatest mean value of surface roughness in zirconia (0.721 ± 0.014), whereas Ivoclar had the lower mean value (0.663 ± 0.030), and VITA had the lowest mean value (0.641 ± 0.021).

Table 2. Descriptive statistic of the surface roughness (μm) for different glazing materials of Zirconia

| Groups | N. | Mean | Std. Deviation | Std. Error | Range | |
|---------------|----|-------|----------------|------------|-------|-------|
| | | | | | Min. | Max. |
| Vita glaze | 10 | 0.641 | ± 0.021 | 0.007 | 0.621 | 0.679 |
| IVOCLAR glaze | 10 | 0.663 | ± 0.030 | 0.009 | 0.602 | 0.692 |
| Gc glaze | 10 | 0.721 | ± 0.014 | 0.004 | 0.701 | 0.744 |
| Total | 30 | 0.675 | ± 0.041 | 0.007 | 0.602 | 0.744 |

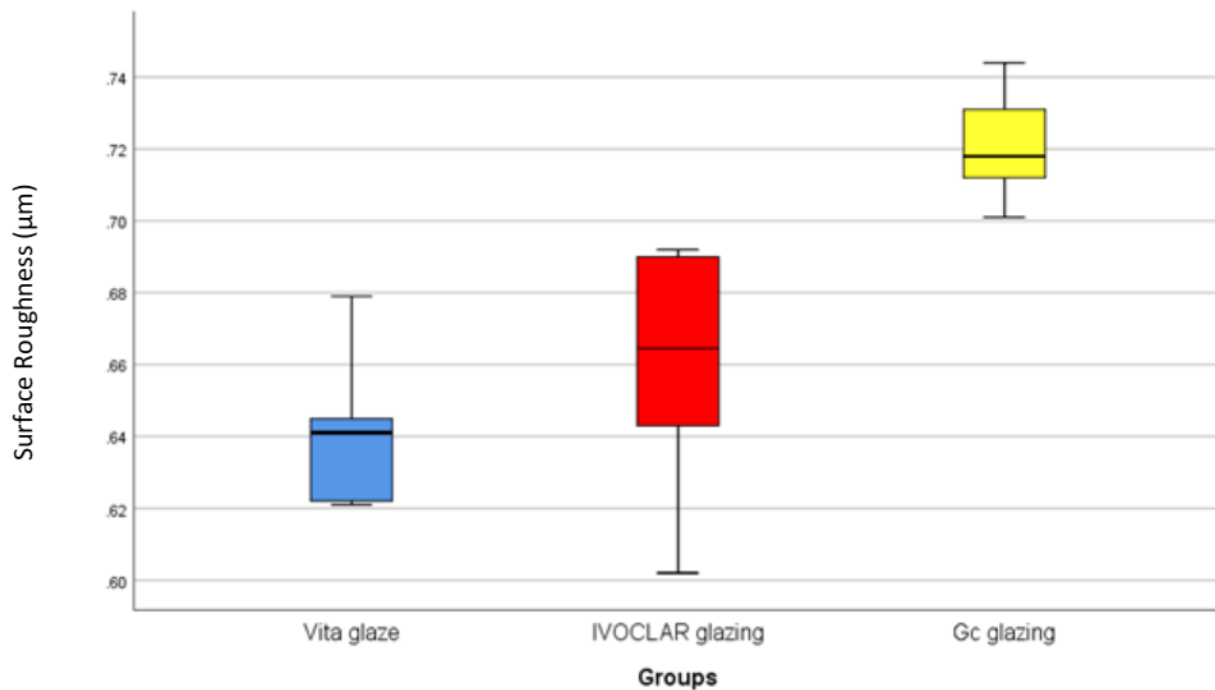


Fig. 8. Bar chart showing the mean distribution and standard deviations of surface roughness (μm) values of the studied zirconia groups (VITA, Ivoclar, GC)

3.2. Test of homogeneity of variances

According to the result of the homogeneity of Levene's test for the quality of variance data as shown in Table 3, which was indicated no statistically significant difference between groups of variances for roughness with a P-value > 0.05 .

Table 3. Test of homogeneity of variances across groups

| | Levene's statistic | Df1 | Df2 | P-value | Sig |
|--|--------------------|-----|--------|---------|-----|
| Based on mean | 2.006 | 2 | 27 | 0.154 | NS |
| Based on median | 1.959 | 2 | 27 | 0.161 | NS |
| Based on the median and with adjusted df | 1.959 | 2 | 21.012 | 0.166 | NS |
| Based on trimmed mean | 2.009 | 2 | 27 | 0.154 | NS |

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

* DF: Degree of freedom

According to Table 4 one-way ANOVA findings, there was a highly statistically significant difference in roughness across the three groups.

Table 4. One-way ANOVA test for roughness among all groups

| Groups | Sum of Squares | df | Mean Square | F | P- value | Sig |
|----------------|----------------|----|-------------|--------|----------|-----|
| Between Groups | 0.035 | 2 | 0.017 | | | |
| Within Groups | 0.013 | 27 | 0.000 | 34.748 | 0.000 | HS |
| Total | 0.048 | 29 | | | | |

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

3.3. Bonferroni post hoc test

The source of statistical difference was further investigated by analysis of data using the Bonferroni test as shown in Table 5. For the roughness readings, there was a statistically significant difference between (VITA & GC) and (Ivoclar & GC) with a p-value < 0.05, but there non-statistically significant association between (VITA & Ivoclar) with a p-value > 0.05.

Table 5. Bonferroni test for multiple comparisons of surface roughness among three groups

| Multiple Comparisons of Bonferroni for surface Roughness test | | | | | | | |
|---|------------|-----------------------|------------|----------|-----|-------------------------|-------------|
| (I) Groups | (J) Groups | Mean Difference (I-J) | Std. Error | P- value | Sig | 95% Confidence Interval | |
| | | | | | | Lower Bound | Upper Bound |
| Vita | Ivoclar | -0.022 | 0.011 | 0.114 | NS | -0.047 | 0.0037 |
| Vita | Gc | -0.081** | 0.011 | 0.000 | HS | -0.106 | -0.0550 |
| Ivoclar | Gc | -0.059** | 0.011 | 0.000 | HS | -0.084 | -0.0332 |

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

3.4. Energy-Dispersive X-Ray Analysis

The effect of the glazing materials on surface roughness will be related to one elemental composition Al weight % [5], Table 1 shows the EDX results in weight % for the glazing materials used in this study. While the glazing material (powder) had more Aluminium (Al) in the GC group than Ivoclar and VITA.

4. Discussion

The purpose of this investigation was to evaluate how the effect of different brands of glazing materials (VITA, Ivoclar, GC) affected the surface roughness, Zirconia is widely used in prosthetic dentistry due to its excellent biocompatibility, low cytotoxicity, chemical stability, high mechanical strength, superior fatigue resistance, high fracture resistance, and hardness, as well as to the extended development of digital technological equipment, Zirconia is used in the making of individual dental crowns, short fixed partial dentures, and implants, the development of new manufacturing techniques using computer-aided design/manufacturing (CAD/CAM) technologies, in this respect, zircon is processed by CAD-CAM milling, the method is based on the milling of pre-sintered zirconia blanks with this procedure, zirconia acts as a highly homogenous material that is easier to mill, thus reducing production times, machinery wear and surface flaws [17]. Glazing as a laboratory procedure is achieved by applying a blend of colourless glass powder and fluid layer that reduced the roughness, seals the pores, and smoothens the ceramic surface [18] in this study used the surface roughness test because smooth restoration surface is important in three terms: function, aesthetics, and biologic compatibility, that avoids dental complications such as plaque formation, gingivitis, periodontitis, and wear of the opposing dentition, which is important for patient comfort [19].

The results of the present study revealed in Table 2 and Fig. 8, the highest value of surface roughness in monolithic Zirconia was found in GC glaze followed by Ivoclar glaze while the lower value of surface roughness was found in the VITA group this related to increase the ratio of Aluminium in glaze materials according to the examination done by Energy-Dispersive X-Ray Analysis (EDX) test that found in Table 1 the percentage of Aluminium in GC glaze powder was (4.28) while the Ivoclar glaze powder (3.42) and VITA glaze powder (2.84). This result agrees with (Moosa et al). who reported the increase in the ratio of Aluminium in glaze materials leads to an increase in surface roughness due to crystalline phases that are formed by Alumina and hence it is expected that the wear of opposing teeth is increased because increasing the surface friction [5]. According to the result in Table 4 for the roughness readings, there was a highly statistically significant difference between VITA and Ivoclar with GC, except (Vita with Ivoclar) there was no statistically significant association. The surface of monolithic zirconia glazed with the VITA brand was much smoother than GC and Ivoclar brands related to a decrease in the ratio of Aluminium in VITA glaze powder in the other two brands (GC, and Ivoclar) and thus reduce the crystalline phase that led to have surface much smoother than other brands and this agreement with the study done by (Vasiliu et al). proved the same result in this study but used different glaze brands materials and different surface treatment [7].

This investigation was disproved by (Incesu and Yanikoglu) who reported that monolithic Zirconia that has been treated with the "VITA AKZENT® Plus" glaze (powder and fluid) has a rougher surface than alternative surface treatments [16]. Then group VITA with Ivoclar showed no difference between them this related to a close ratio of Aluminium, so this agreed with the result of (Kurt et al). that found powder/liquid application is the most effective way to reduce the surface roughness of lithium disilicate ceramics compared with other types of glazing materials/methods [20].

5. Conclusion

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

- GC glaze produced higher surface roughness and was followed by Ivoclar than VITA, due to an increase in the Aluminium ratio.
- In terms of surface roughness, there was no statistical difference between the VITA and Ivoclar groups but there were highly significantly different between VITA and Ivoclar with GC, due to the variation in the proportion of Aluminium between them.

6. Recommendations

- Evaluation of other mechanical properties of Zirconia, such as bend strength, and fracture toughness.
- Evaluation of different applied glazing materials (paste and spray).

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