# Effect of two sintering protocols on translucency and flexural strength of different monolithic zirconia materials: An *In vitro* study

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## Abstract

**Background:** Dental ceramics and zirconia are increasingly being used with outstanding outcomes for various restorations such as fixed dental prosthesis, resin bonded FDPs, and implant restorations. Zirconia is a polymorphic ceramic that can be found in three various crystalline forms depending on temperature: monoclinic, tetragonal, and cubic. The monoclinic phase is stable at room temperature; unfortunately, its mechanical and optical properties are insufficient for clinical application; nonetheless, the tetragonal and cubic phases can be rendered stable at room temperature by applying stabilizing oxides. The multi-layered technology has shown an improvement in color of zirconia to mimic the natural teeth without affecting its mechanical properties.

**Aim of the Study:** The aim of this *In vitro* study is to evaluate the effect of two sintering protocols: Conventional firing cycle and Speed firing cycle on translucency and Flexural strength of the novel color gradient zirconia and compare it to different monolithic zirconia material.

**Materials and Methods:** 54 discs were constructed to be divided into 3 different groups each group sub divided to speed cycle group and conventional cycle group for materials: IPS e.max® ZirCAD® Prime, Katana ultra-translucent zirconia and BruxZir anterior, To compensate for sintering shrinkage, the zirconia samples were milled with dimensions bigger than the required final dimension. The discs were then sintered in a sintering furnace group conventional sintering and group speed sintering for each material.

**Results:** Translucency for conventional firing, there was a significant difference between different groups the highest value was found in Katana UTML, followed by Zircad prime, while the lowest value was found at BruxZir and for speed firing there was a significant difference between different groups. The highest value was found in Katana UTML, followed by Zircad prime, while the lowest value was found at BruxZir. Flexural strength for conventional firing, there was a significant difference between different groups. The highest value was found in Zircad prime, followed by BruxZir, while the lowest value was found at Katana UTML; and for speed firing, there was a significant difference between different groups. The highest value was found in Zircad prime, followed by BruxZir, while the lowest value was found at Katana UTML.

**Conclusion:** For all tested zirconia, zirconia samples sintered with the conventional sintering cycle showed a significantly higher translucency value than those sintered with the speed cycle. Katana UTML zirconia showed the highest translucency values while BruxZir zirconia exhibited the lowest values in both firing methods.

**Keywords:** Two sintering protocols, translucency and flexural strength, monolithic zirconia materials

## Introduction

Dental ceramics and zirconia are increasingly being used with outstanding outcomes for various restorations such as fixed dental prosthesis, resin bonded FDPs, and implant restorations. Zirconia is a polymorphic ceramic that can be found in three various crystalline forms depending on temperature: monoclinic, tetragonal, and cubic. The monoclinic phase is stable at room temperature; unfortunately, its mechanical and optical properties are insufficient for clinical application; nonetheless, the tetragonal and cubic phases can be rendered stable at room temperature by applying stabilizing oxides.

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The most commonly used stabiliser is yttrium oxide [1, 2]. According to reports, yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) exhibits the strongest phase transformation toughening. Mechanical and optical characteristics of zirconia are directly influenced by its yttria concentration. Zirconia's optical characteristics are often improved while its mechanical properties are decreased as the amount of yttria in the material increases [3, 4]. The first yttria-stabilized tetragonal zirconia polycrystalline material was zirconia stabilised with 3 mol% [5, 6] that has excellent mechanical properties [6] exceptional biocompatibility [7].

Due to its great opacity and white colour, the optical properties of 3 mol% are one of its disadvantages. Because of this, it was only utilized as a core on top of which high-translucent ceramics were veneered. However, there is still a persistent issue with the ceramic veneering chipping [8, 9]. Due to their resistance to chipping and preservation of tooth structure after reduction, monolithic zirconia restorations have drawn a lot of attention [2, 10].

Zirconia has undergone a number of changes in recent years that make it possible to utilize it as a monolithic restoration with sufficient aesthetics [11]. This entails adding poly-chromatic (multi-layered) zirconia as well as raising the yttria concentration from 3 mol% (3Y-TZP) to 4 mol% (4Y-TZP) and 5 mol% (5Y-TZP) to achieve enhanced translucency.

This multi-layered technology has improved the colour of zirconia to mimic natural teeth without affecting its mechanical properties, using pigmentations only to provide a shade gradient as natural teeth, while using the same generation of zirconia in each blank, with no difference in the flexural strength of the enamel and dentine layers [12, 13].

Another multi-layered technology was recently introduced; this technology combines two separate zirconia generations in one blank to gain the benefits of both generations. This fusionccurs between 3Y-TZP in the dentin/body area for higher mechanical qualities and 5Y-TZP in the incisal area for better translucency.

In various investigations, Monolithic 3Y-TZP shown wear behavior comparable to or slightly greater than natural teeth, but less than metal ceramics [14, 15].

In terms of mechanical properties, while the 5Y-TZP has the lowest flexural strength among zirconia generations, it has better mechanical properties than lithium disilicate ceramics [16, 17].

The lengthy sintering process of conventional zirconia is a downside; it became a concern with the development of ceramics and the rise in chairside restorations done in a single visit. The Y-TZP sintering procedure takes a long time [18, 19] and it typically requires several hours. As a result, applying a single visit restoration using the traditional sintering procedure is not viable because the restoration must be delivered over the course of at least two appointments. Recently, high-speed sintering has been employed to solve this issue by employing specialized furnaces that reduce the total sintering time to under 30 minutes, making zirconia an appropriate material for single visit restorations [20].

It has been stated that altering the sintering parameters has a variety of effects on the structure of zirconia and consequently its physical properties like as translucency and flexural strength [21, 22]. As a result, the changes in the properties of various types of zirconia during speed sintering must be thoroughly examined.

Furthermore, different generations of zirconia are recommended for different therapeutic conditions. The newest zirconia generation, which combines 3Y-TZP and 5Y-TZP in a single blank, is being marketed as a universal zirconia for all clinical indications ranging from anterior single crowns to full-arch restorations.

The material is already commercially accessible and being used in medical applications, but more information regarding its mechanical and optical properties is needed, according to the author.

Therefore, the purpose of this investigation is to test the biaxial flexural strength and translucency of the color gradient zirconia using conventional and high-speed sintering and compare it to other 2 types of monolithic zirconia material.

## Statement of Problem

Monolithic zirconia as a recently introduced restorative material is characterized by improved esthetics and mechanical properties, however, to satisfy the requirements of chair side clinical techniques, zirconia ceramics are required to be sintered in duration less than that consumed by conventional firing protocols to reduce treatment times, allowing production of single visit restoration. Although speed sintered dental zirconia are already being used in dental clinics, further investigations are needed to study the effect of varying the sintering protocols on the mechanical and optical properties of zirconia restorations.

## Aim of the study

The aim of this *In vitro* study is to evaluate the effect of two sintering protocols: Conventional firing cycle, speed firing cycle on translucency, flexural strength of different monolithic zirconia material: Katana ultra- translucent UTML (5Y-TZP), IPS E.max Zir CAD Prime (3Y-TZP) and (5Y-TZP), Bruxzir anterior (4Y-TZP).

## Hypothesis

There is no difference in the flexure strength and translucency of different tested zirconia materials sintered by conventional or speed sintering.

## Materials and Methods

### Materials

The materials used in the study are shown in table (1):

**Table 1:** Materials used in the study

| Material | Brand name | Manufacturer | Serial number |
|---|---|---|---|
| Cubic Zirconia Blanks | Katana ultra- translucent A3-UT | Kuraray Noritake Dental Inc | EFJNH |
| Cubic Zirconia Blanks | IPS E.max ZirCAD Prime A3 | Ivoclar, Vivadent USA | Z03bh9 |
| Cubic Zirconia Blanks | Bruxzir anterior A3 | Prismatic dentalcraft, inc. | Z0797321 |

### Katana Ultra-translucent Monolithic Zirconia (color gradient multilayered zirconia)

This multilayered technique includes 5Y-TZP for effective restoration of the anterior teeth's aesthetics, and it has a four-layer structure. (35%) Enamel Layer (1) Transitional Layer Layer 2 of Transitions (15%) (Dentin) Body Layer (35%). Katana UTML blank, with shade A3 was used to construct zirconia samples:

**Fig 1:** Katana UTML Blank shade A3

Chemical composition physical and mechanical properties of Katana UTML are shown in table 2 & 3 respectively:

**Table 2:** Composition of Katana:

| Zirconium Oxide | ZrO2 | <89% |
|---|---|---|
| Yttrium Oxide | Y2O3 | >8% |
| Hafnium Oxide | HfO2 | >4% |

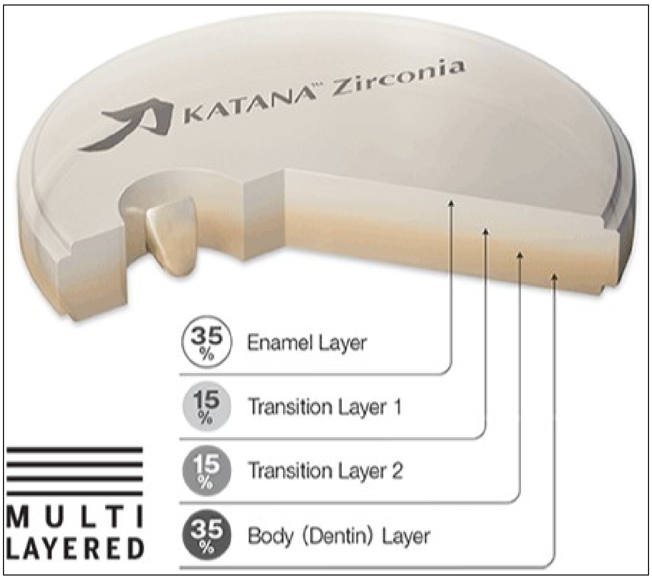

**Fig 2:** Composition of katana UTML

**Table 3:** Physical and mechanical properties of Katana:

| Physical & mechanical properties | Katana |
|---|---|
| Coefficient of thermal expansion (25-500 °C) | 10-6 K-1 |
| Shade stability | Excellent, ΔE < 2 |
| Translucency | 43% |
| Density | 6.05 gm/cm3 |
| Flexural strength | 550 Mpa |

**IPS e.max ZirCAD Prime (strength gradient multilayered zirconia)**

By combining two raw zirconium oxide materials—3Y-TZP in the dentine zone (9 mm) and 5Y-TZP in the incisal zone (3 mm)—into a single blank with a transition layer (4 mm), this gradient technique enables the strength of 3Y-TZP and the aesthetics of 5Y-TZP. IPS e.max ZirCAD Prime with shade A3 was used to construct zirconia samples:

**Fig 3:** IPS e.max ZirCAD Prime blank shade A3

**Table 4:** Composition of IPS e.max ZirCAD Prime:

| Zirconium oxide ($ZrO^2$) | 88.0 - 95.5% |
|---|---|
| Yttrium oxide ($Y^2O^2$) | >4.5% - ≤ 7.0% |
| Hafnium oxide ($HfO^2$) | ≤ 5.0% |
| Aluminum oxide ($Al^2O^3$) | ≤ 1.0% |
| Other oxides | ≤ 1.5% |

**Fig 4:** Composition of IPS e.max ZirCAD Prime blank

**Table 5:** Physical and mechanical properties IPS e.max ZirCAD Prime

| **Coefficient of thermal expansion (25-500 °C)** | **10-6K 10.4±0.5** |
|---|---|
| Flexural strength | 1200 mpa |
| Fracture toughness | >5.0 Mpa. m ½ |

### Bruxzir anterior

Cubic zirconia –(4Y) containing zirconia, BruxZir anterior Milling Blanks are uniquely formulated to satisfy the functional and esthetic requirements of anterior and premolar restorations. Bruxzir anterior with shade A3 was used to construct zirconia samples:

**Fig 5:** Bruxzir anterior blank shade A3

**Table 6:** Composition of Bruxzir anterior:

| **Zirconium oxide** | **>99.9** |
|---|---|
| Yttrium oxide | <5.15 |
| Hafnium oxide | <3 |
| Aluminum oxide | <0.5 |
| Silicon oxide | <0.02 |
| Iron oxide | <0.01 |
| Sodium oxide | <0.04 |

**Table 7:** Physical and mechanical properties of Bruxzir anterior:

| **Flexural strength** | **≥ 870 MPa** |
|---|---|

## Methods

### (A)–Samples Grouping

A power analysis was designed to have adequate power to apply a 2-sided statistical test of the research hypothesis that there is no difference in the flexural strength and translucency of different tested materials with different firing protocols. According to the results of Lawson, Nathaniel C., and Anvita Maharishi. Effect size (f) was found to be (0.515). By adopting an alpha (α) level of 0.05 (5%), and a beta (β) level of 0.20 (20%) i.e. power=80%; the predicted sample size (n) was found to be a total of (54) samples i.e. (18) samples per group, (9) for each subgroup. Sample size calculation was performed using G*Power version 3.1.9.4.

**Table 8:** Sample grouping

| **Firing cycle** | **Conventional firing (C)** | **Speed firing (S)** | **Total** |
|---|---|---|---|
| **Material** | | | |
| Zircad prime (Z) | ZC n=9 | ZS n=9 | 18 |
| Katana UTML (K) | KC n=9 | KS n=9 | 18 |
| Bruxzir (B) | BC n=9 | BS n=9 | 18 |
| | 27 | 27 | 54 |

### (B)-Sample preparation

Dimensions of 1mm thickness and 15 mm length side

### 1. Katana ultra-translucent zirconia samples preparation:

Zirconia blocks with a 15 mm length side were precisely designed using a digital 3D builder software system as follows: (insert object tool) was used to select the desired shape (cube). The 15 mm length side cube dimension is ready in design. The Planned cube was saved as an STL file, which was then imported into software [1].

Using a free form tool, editing software [2] for fine (smoothing or adding any attachment). Accurate confirmation, saving, and export of the cube shape to the software [3] to be milled.

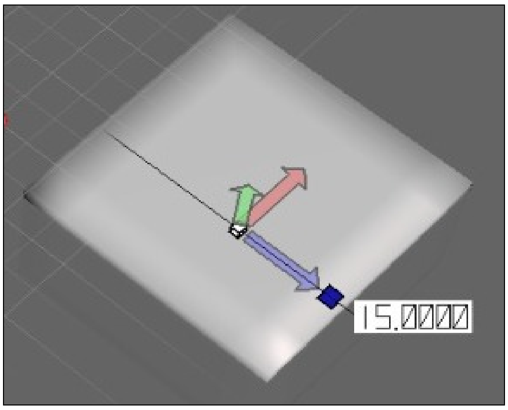

**Fig 6:** Designing square on in Lab CAM SW 18.5

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[1] MillBox, dental Cam software for milling any kind of material and objects

[2] DGSHAPE editing software

[3] CAM, Computer aided manufacturing

The blank was put into a milling machine[4], and it was milled in accordance with the imported design. The blank had a 20%-25% oversize when it was machined into a square. Each blank is identified by a barcode and a unique enlargement factor, which are used to determine the precise oversize required during milling to account for sintering shrinkage. The milling machine automatically scanned the barcode before machining each blank.

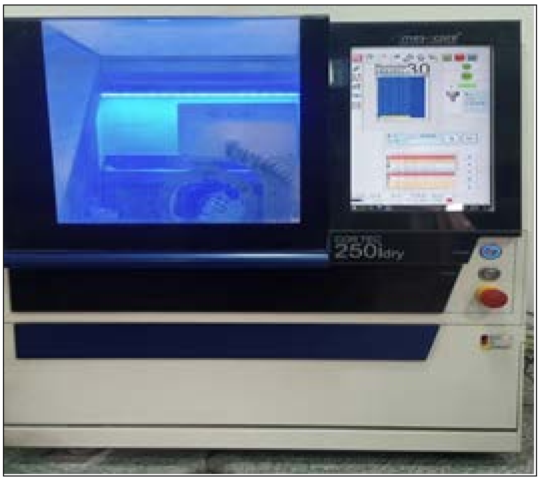

**Fig 7:** German-made Core Tec type 250idry milling machine

9 Katana UTML Zirconia samples were machined from their respective cubes with low-speed diamond saw [5], to about 20%-25% oversize in thickness (1.2 mm) to compensate for sintering shrinkage and achieve uniform standard thicknesses of (1mm). The thickness was measured with a digitalized caliper.

**Fig 8:** IsoMetM 4000 precision sawing machine

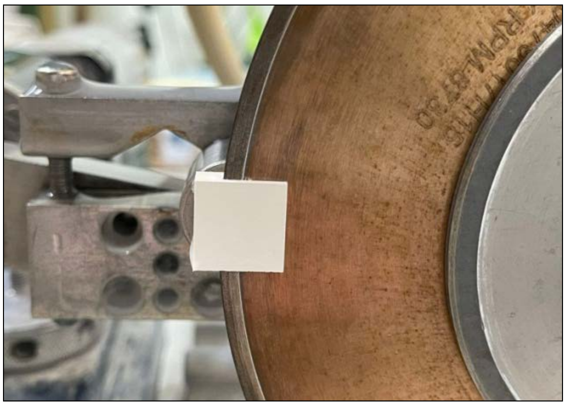

**Fig 9:** IsoMetM blade cutting katana UTML zirconia samples

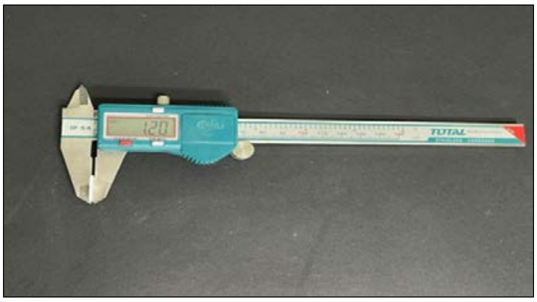

**Fig 10:** Digital caliper checking thickness

### Conventional Sintering of Katana UTML discs

9 samples were placed in a pure alumina sintering boat, and a single layer of 2mm zirconia sintering beads was placed underneath the samples. The samples were subsequently sintered in a sintering furnace [6] according to the prescribed sintering temperatures and timings. The usual sintering cycle for Katana UTML is 7 hours, including 1550 °C and holding at this temperature for 2 hours, with a temperature increase rate of 10 °C/min.

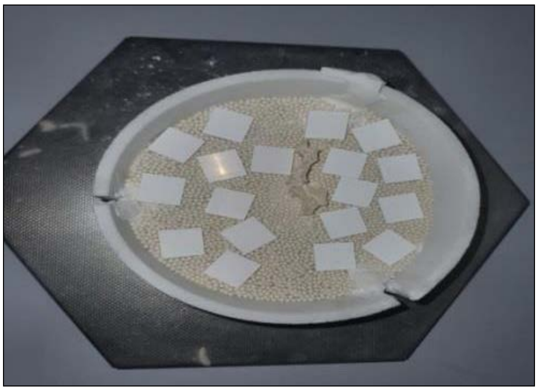

**Fig 11:** Sintering boat

**Fig 12:** Dentsplys sirona inlab profile

### Speed sintering cycle of Katana UTML

Using sintering furnace [7], 9 discs were sintered in accordance with the specified speed sintering cycle of 90 minutes, including 1560 °C, holding period of 30 min, and

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[4] German-made Core Tec type 250idry

[5] IsoMetTM 4000

[6] Dentsply sirona inlab profire

[7] Dentsply's sirona inlab profire

rate of temperature increase of 35 °C/min. The rate of heating differs between speed sintering cycles and traditional.

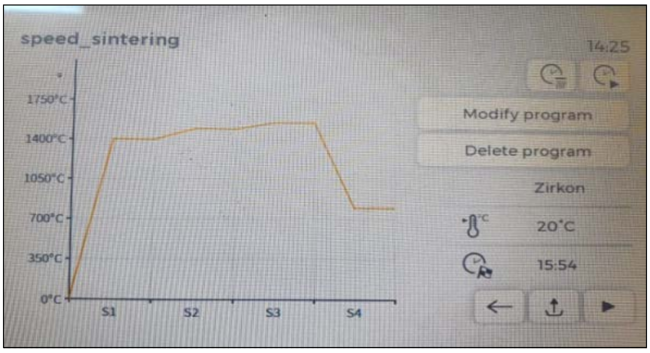

**Fig 13:** Dentsply's sirona inlab profire speed settings

### IPS e.max ZirCAD Prime

Digital 3D builder software system which was used in order to accurately design zirconia blocks of 15 mm side length and 1mm thickness as follows

The (insert object tool) was used to choose the necessary shape (cube). The 15 mm length side square dimension was modified. A STL file was used to save the designed cube. Then using a free form tool, exported to programme[8] for further modification (smoothing or adding any attachment). Accurate confirmation of the square shape was made before it was stored and exported to the software system [9].

The blank was put into a milling machine [10], and it was milled in accordance with the imported design. The blank had a 20%-25% oversize when it was machined into a square. Each blank is identified by a barcode and a unique enlargement factor, which are used to determine the precise oversize required during milling to account for sintering shrinkage. The milling machine automatically scanned the barcode before machining each blank.

**Fig 14:** German-made Core Tec type 250idry milling machine

The samples were cut horizontally in each layer of the gradient zirconia by using a low-speed diamond saw [11] to approximate 20%-25% oversize in thickness (1.2 mm) to compensate for sintering shrinkage to achieve uniform standard thicknesses of (1mm). The thicknesses were checked with a digital caliper.

**Fig 15:** IsoMetM 4000 precision sawing machine

**Fig 16:** Isomet blade cutting IPS e.max zircad prime

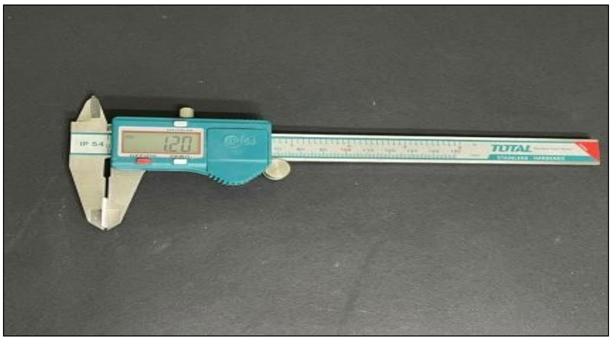

**Fig 17:** Digital caliper

### Conventional sintering cycle

9 samples were inserted into a sintering vessel made of pure alumina, and a single layer of 2 mm zirconia sintering beads was placed underneath the samples. Following that, the samples were put into Sintering Furnace [12] and sintered in accordance with the predetermined sintering temperatures and timings. For IPS e.max ZirCAD Prime, a typical sintering cycle of 9 hours and 50 minutes is advised, with temperatures rising at a rate of 10 degrees Celsius per minute for the first two hours, holding for 2.5 hours, and then cooling at a rate of -10 degrees Celsius per hour.

### Speed sintering cycle

9 samples were arranged in a pure alumina sintering boat form, and a single layer of 2 mm zirconia sintering beads was positioned beneath the samples. Following that, the samples were put into Sintering Furnace and sintered in accordance with the predetermined sintering temperatures and timings. The recommended sintering cycle is 2 hours and 26 minutes, with a temperature of 1530 °C for a 1-hour heating rate of 60 °C per minute and a cooling rate of -6 °C per minute.

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[8] MillBox DGSHAPE programme

[9] CAM, Computer-aided manufacturing

[10] German-made Core Tec type 250idry milling machine

[11] Buehler-Isomet LakeBulff, IL, USA

[12] Dentsply's Siona Inlab Profire Sintering Furnace

**Fig 18:** Dentsply's sirona inlab profire

### Bruxzir anterior

Digital 3D builder software system which was used in order to accurately design zirconia blocks of 15 mm side length and 1mm thickness as follows:

The (insert object tool) was used to choose the necessary shape (cube). The 15 mm side length square dimension was modified. A STL file was used to save the designed square. Then using a free form tool, exported to programme [13] for further modification (smoothing or adding any attachment). Accurate confirmation of the square shape was made before it was stored and exported to the CAM software system.

The blank was put into a milling machine, and it was milled in accordance with the imported design. The blank had a 20%-25% oversize when it was machined into a square. Each blank is identified by a barcode and a unique enlargement factor, which are used to determine the precise oversize required during milling to account for sintering shrinkage. The milling machine [14] automatically scanned the barcode before machining each blank.

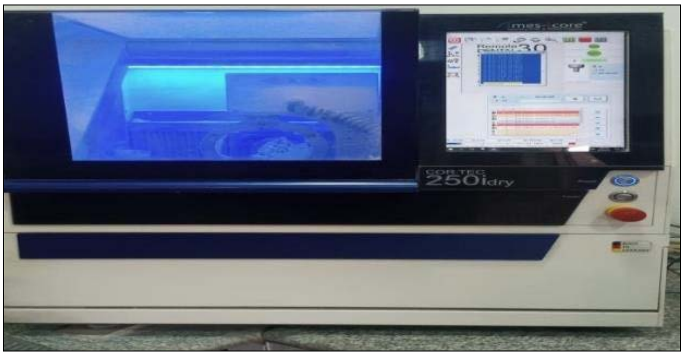

**Fig 19:** German-made Core Tec type 2 milling machine [15]

The samples were cut horizontally in each layer of the zirconia by using a low-speed diamond saw[16] to approximate 20%-25% oversize in thickness (1.2 mm) to compensate for sintering shrinkage to achieve uniform standard thicknesses of (1mm). The thicknesses were checked with a digital caliper.

**Fig 20:** IsoMetM 4000 precision sawing machine

**Fig 21:** Isomet blade cutting bruxzir anterior blank

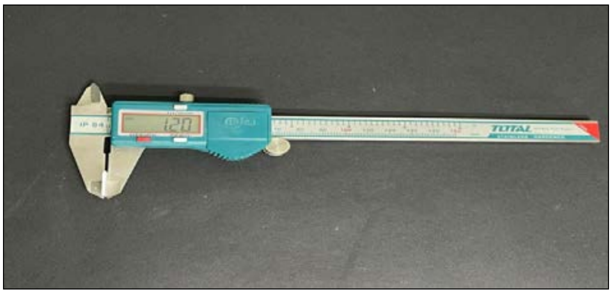

**Fig 22:** Digital caliper

### Conventional sintering cycle

9 samples were inserted into a sintering vessel made of pure alumina, and a single layer of 2 mm zirconia sintering beads was placed underneath the samples. Following that, the samples were put into Sintering Furnace [17] and sintered in accordance with the predetermined sintering temperatures and timings. For Bruxzir anterior, a typical sintering cycle of 9 hours and 50 minutes is advised, with temperatures rising at a rate of 10 degrees Celsius per minute for the first two hours, holding for 2.5 hours, and then cooling at a rate of - 10 degrees Celsius per hour.

### Speed sintering cycle

9 samples were arranged in a pure alumina sintering boat form, and a single layer of 2 mm zirconia sintering beads was positioned beneath the samples. Following that, the samples were put into Sintering Furnace [18] and sintered in accordance with the predetermined sintering temperatures and timings. The recommended sintering cycle is 2 hours and 26 minutes, with a temperature of 1530 °C for a 1-hour heating rate of 60 °C per minute and a cooling rate of -6 °C per minute.

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[13] MillBox DGSHAPE

[14] German-made Core Tec type 250idry

[15] German-made Core Tec type 250idry milling machine

[16] Buehler-Isomet LakeBulff, IL, USA

[17] Dentsply sirona inlab profire

[18] Dentsply sirona inlab profire

**Table 9:** Comparing conventional and speed cycles

| | Katana UTML | IPS Zircad prime | Bruxzir anterior |
|---|---|---|---|
| Conventional cycle | **Time:** 7 hours | **Time:** 9 hours and 50 min | **Time:** 9 hours and 50 min |
| | **Temperature:** 1550 °C | **Temperature:** 10 °C | **Temperature:** 10 °C |
| | **Holding time:** 2 hours | **Holding time:** 2.5 hours | **Holding time:** 2.5 hours |
| | **Temperature increase:** 10 °C/min | **Temperature cooling:** -10 °C/min | **Temperature cooling:**-10 °C/min |
| Speed cycle | **Time:** 90 min | **Time:** 2 hours and 26 min | **Time:** 2 hours and 26 min |
| | **Temperature:** 1560 °C | **Temperature:** 1530 °C | **Temperature:** 1530 °C |
| | **Holding time:** 30 min | **Holding time:** 1 hour | **Holding time:** 1 hour |
| | **Temperature increase:** 35 °C/min | **Temperature cooling:** -6 °C/min | **Temperature cooling:** -6 °C/min |

## Translucency measurements

Using a spectrophotometer [19] and Black and White backdrops, a quantitative measurement of relative translucency was made. By comparing the color differences between readings on a white background and readings on a black background using the following equation, the translucency parameter (TP) values have been discovered: TB= (L1-L2)2+(a1-a2)2+(b1-b2)2 Measurements of translucency is measured using spectrophotometer device.

**Fig 23:** Agilent Cary 5000 spectrophotometer

A black disc with a tiny aperture was attached and centred to the front port of the sphere because the samples were smaller than what the device is intended to measure. To reduce the front port aperture and underfill the sample area, a 2 mm diameter aperture area is ideal.

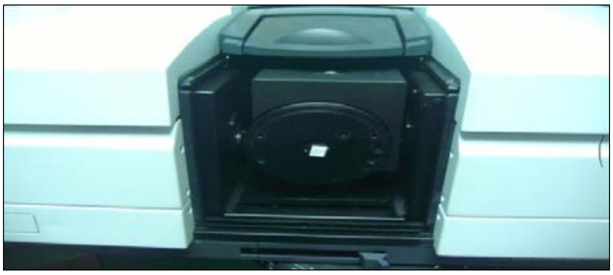

**Fig 24:** Placement of the sample in the device

Each sample was inserted into the tiny aperture, and it was set on a white background.

According to the manufacturer's instructions, the following procedures were used to measure each sample on the apparatus: the reflectance port's standard white PTFE (Polytetrafluoroethylene) disc reference was used to record a baseline. The sample was then placed over the port, where the sphere captured the reflection of the sample's surface, a baseline correction was made for the 380-780 nm wavelength range, by pressing the bottom SCAN, the samples were measured. The generated curve showed a link between diffuse reflectance and wavelength for 1 nm intervals.

## Biaxial Flexural Strength

The following samples were used to determine the biaxial flexural strength (BFS) of all samples: After translucency testing, 9 discs from each group (n=9) were examined for flexural strength. The piston-on-three ball technique was used in an Instron testing [20] in accordance with the ISO 6872 specifications for evaluating ceramic materials, and data was recorded using computer software [21].

**Fig 25:** Instron testing machine model 3345 England

A 12mm diameter metallic platform was built, and three 3mm diameter steel balls were spaced equidistantly above it.

**Fig 26:** Metallic Platform with steel balls

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[19] Agilent Cary 5000 spectrophotometer

[20] Instron testing machine model 3345 England

[21] BlueHill Universal Instron England version 3.3

Each disc was put on the steel balls, and the load was provided by a piston with a 1.5mm diameter and a crosshead speed of 0.5mm/min.

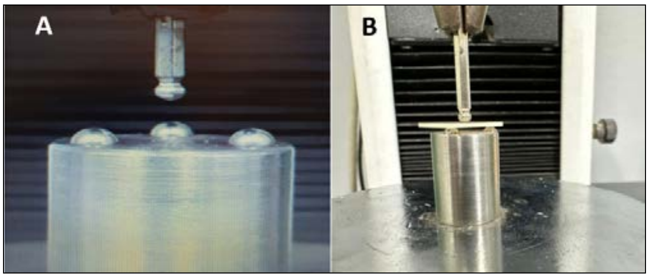

**Fig 27:** (A) Close-up view of metallic platform, (B) Disc and piston with the sample

### Fractured discs then calculations

**Fig 28:** Fractured discs

### Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparison of simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test and the pooled error term of the two-way model. P- values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at *p*<0.05. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows1.

## Results

### I- Translucency parameter (TP)

Intergroup comparisons, mean and standard deviation (SD) values of translucency parameter (TP) for different materials and firing cycles are presented in table (10).

### A- Effect of material

- **Conventional firing**
  There was a significant difference between different tested groups (*p*<0.001). The highest value was found in Katana UTML (14.71±0.34), followed by Zircad prime (13.89±0.27), while the lowest value was found at BruxZir (11.28±0.20). All post hoc pairwise comparisons were statistically significant (*p*<0.001).
- **Speed firing**
  There was a significant difference between different groups (*p*<0.001). The highest value was found in Katana UTML (13.84±0.11), followed by Zircad prime (12.20±0.15), while the lowest value was found at BruxZir (9.17±0.31). All post hoc pairwise comparisons were statistically significant (*p*<0.001).

### B- Effect of firing cycle

- **Katana UTML**
  Conventional firing (14.71±0.34) resulted in a significantly higher value of translucency than speed firing (13.84±0.11) (*p*<0.001).
- **Zircad prime**
  Conventional firing (13.89±0.27) had a significantly higher value than speed firing (12.20±0.15) (*p*<0.001).
- **BruxZir**
  Conventional firing (11.28±0.20) had a significantly higher value than speed firing (9.17±0.31) (*p*<0.001).

**Table 110:** Intergroup comparisons, mean and standard deviation values of translucency parameter (TP) for different materials and firing cycles

| Firing cycle | Translucency parameter (TP) (Mean ± SD) | | | p-value |
|---|---|---|---|---|
| | Katana UTML | Zircad prime | BruxZir | |
| Conventional firing | 14.71±0.34$^{A}$ | 13.89±0.27$^{B}$ | 11.28±0.20$^{C}$ | <0.001* |
| Speed firing | 13.84±0.11$^{A}$ | 12.20±0.15$^{B}$ | 9.17±0.31$^{C}$ | <0.001* |
| p-value | <0.001* | <0.001* | <0.001* | |

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant (*p*<0.05) ns; non-significant (p>0.05)

### II- Biaxial flexural strength

Intergroup comparisons, mean and standard deviation (SD) values of biaxial flexural strength for different materials and firing cycles are presented in table (11).

### A- Effect of material

- **Conventional firing**
  There was a significant difference between different groups (*p*<0.001). The highest value was found in Zircad prime (844.91±59.30), followed by BruxZir (717.54±79.55), while the lowest value was found at Katana UTML (690.63±46.29). Post hoc pairwise comparisons showed Zircad prime to have significantly higher value than other groups (*p*<0.001).
- **Speed firing**
  There was a significant difference between different groups (p=0.003). The highest value was found in Zircad prime (865.67±21.87), followed by BruxZir (744.23±13.49), while the lowest value was found at Katana UTML (704.26±64.87). Post hoc pairwise comparisons showed Zircad prime to have significantly higher value than other groups (p=0.003).

### B- Effect of firing cycle

- **Zircad prime:** Speed firing (865.67±21.87); there was a statistically significant difference than conventional firing (844.91±59.30) yet the difference was not statistically significant (p=0.484).

- **BruxZir**
  Speed firing (744.23±13.49); there was a statistically significant difference than conventional firing (717.54±79.55) yet the difference was not statistically significant (p=0.481).

- **Katana UTML**
  Speed firing (704.26±64.87); there was a statistically significant difference than conventional firing (690.63±46.29) yet the difference was not statistically significant (p=0.712).

**Table 211:** Intergroup comparisons, mean and standard deviation values of biaxial flexural strength for different materials and firing cycles

| Firing cycle | Biaxial flexural strength (Mean ± SD) | | | p-value |
|---|---|---|---|---|
| | **Zircad prime** | **BruxZir** | **Katana UTML** | |
| Conventional firing | $844.91 \pm 59.30^{A}$ | $717.54 \pm 79.55^{B}$ | $690.63 \pm 46.29^{B}$ | <0.001* |
| Speed firing | $865.67 \pm 21.87^{A}$ | $744.23 \pm 13.49^{B}$ | $704.26 \pm 64.87^{B}$ | 0.003* |
| p-value | 0.484ns | 0.481ns | 0.712ns | |

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant ($p<0.05$) ns; non-significant ($p>0.05$)

## Discussion

All-ceramic restorations now offer great esthetics and biocompatibility for crowns and bridges. Ceramic materials, such as zirconia, have lately been created with improved physical and mechanical properties and have become commonly used in esthetic dentistry.

Aesthetic restorations should accurately reproduce color and translucency while simulating the shape, form, and contours of natural teeth. The form, contour, and type of ceramic material of the restoration are only a few of the variables that impact how well it matches the natural tooth [29].

Thanks to zirconia's superior mechanical properties, which allowed it to be employed in long-span restorations, zirconia restorations are now very useful. Zirconia's primary disadvantages were its opacity and the chipping of the porcelain veneer used to cover the opaque zirconia core. Monolithic and cubic zirconia are introduced to provide full-contour zirconia restorations in order to solve this problem without the need of veneering porcelain [23, 29].

The most recent generation of zirconia, which has superior optical properties to conventional and monolithic zirconia, is composed of a blend of tetragonal and cubic zirconia. Though its mechanical properties are not compared to those of the other forms of zirconia, cubic zirconia gives a translucency close to lithium disilicate [26].

Three different zirconia materials are used in this study which are Bruxzir anterior, Katana Ultra-translucent zirconia, and IPS e.max ZirCAD Prime. Since the final strength and translucency of the restoration are influenced by thickness, they have the advantage of being used in thin thicknesses. As a recommendation for a veneer material to evaluate for translucency and flextural strength, IPS e.max ZirCAD Prime, Bruxzir anterior, and Katana utml with a 1 mm thickness were used.

The true comparative values of translucency and biaxial flexural strength of the available cubic zirconia brands remain in question and more laboratory data are still needed for long term survival of new formulation zirconia based restoration.

Because of this, the primary goal of our research was to test how does sintering cycles, speed sintering and conventional sintering might affect the translucency and biaxial flexural strength of three different types of zirconia materials.

Three commercially accessible zirconia products-Kazana UTML, IPS e.max ZirCAD Prime, and Bruxzir anterior with the shade A3-were chosen for this *In vitro* study in order to examine the various properties of the available zirconia products.

Zirconia squares with a 15 mm length side were correctly created using a digital 3D building software system. In order to compensate for the shrinkage caused by sintering, the blank was machined into a square with a 20%-25% oversize to achieve the three uniform standard thicknesses of (1mm) used for our investigation. The thicknesses were checked using a digital calliper before and after sintering.

To examine how two sintering cycles affected zirconia's optical and mechanical properties, samples were divided into conventional and speed sintering cycles. Speed sintering cycle was proposed as a solution to the issue of the conventional sintering cycle's lengthy sintering time; the difference between the two cycles is the rate of heating using specialized furnaces, which enables zirconia to be used in a single visit restoration.

Finishing and polishing were done to simulate real laboratory conditions, however, it was kept to minimum so as not to adversely affect the microstructure of our specimens. It was important to avoid any rough surfaces that would facilitate water sorption and penetration into the material. A standardized sequential minimal finishing and polishing protocol using a dental surveyor was followed for standardization among all specimens as adopted by other authors

Ultrasonic cleaning using 99% isopropanol for 3 mins followed by dryness of samples was also done for cleaning purposes, and removal of any contamination to avoid any negative effect on our results.

The spectrophotometer is a standardised equipment that has been created to measure and match colours; it provides a numerical description of the apparent colour of an object. It was employed in our study to obtain the specimens' (translucency) [30]. When compared to human eyes or traditional procedures, spectrophotometers provide a 33% boost in accuracy and a more objective match in 93.3% of situations [24]. Spectrophotometers are superior to colorimeters because they have a longer useful life and are not impacted by object metamerism [25].

The Agilent Cary 5000 spectrophotometer was used. Controlled by the Cary WinUV programme, a modular Windows-based software, it is simple to perform extensive analysis and incorporate spheres for spectral and diffuse reflectance.

The translucency of dental ceramics is an important factor to consider when selecting an all-ceramic system. The ability of a material to transmit light is referred to as its translucency. [27].

Translucency in ceramic materials is more dependent on diffuse (multiple light scattering) than direct transmission [31]. The material will look opaque if the majority of light travelling through it is scattered and diffusely reflected. When only a little portion of the light is dispersed and the majority is diffusely transmitted, the material appears translucent [32].

Assessment of the translucency of materials can be achieved using the following parameters: translucency parameter (TP), contrast ratio (CR), and transmittance [33]. Johnston *et al.* were the first to use TP as a direct measure of translucency to compare the optical properties of dental materials [33, 34]. The ability of a dental material to hide changes in the background is described by TP, which is measured as a colour difference between a material and a black and white background [34]. CR, on the other hand, describes material opacity and is defined as the ratio of luminous reflectance (Y) of a material against a black background (Yb) vs a white background (Yw) [33]. As defined by CIE, luminous reflectance is the Y tristimulus value in reflectance (87). Both parameters are based on CIE colorimetry and correlate negatively [33, 35, 36].

To measure translucency a spectrophotometer (Agilent Cary 5000 spectrophotometer) was used to measure the CIELab coor- dinates (L*,a*,b*) and Ytristimulusvalues (Y) of the ceramic discs against a white (L*=96.9, a*=–0.93, b*=2.35, Y= 92.21) and black (L*= 37.43, a* = –0.51, b* = 0.59, Y = 9.79) background. All specimens were measured at four pre-determined sites, using 45°/0° geometry with CIE illuminant D65 and 2° observer function (ISO 28642) against the white and black background. The spectrophotometer was calibrated according to the manual.

Interpreting our results and starting with translucency, the null hypothesis was rejected about translucency our results revealed that there was a significant difference between different groups. The highest value was found in Katana Ultra translucent zircon, followed by IPS e.max ZirCad Prime while the lowest value was found in BruxZir anterior, in both conventional and speed cycles.

These findings were in agreement with the results of who studied compared and concluded Andrea Reyes *et al*., (2021) [37]. Ultra-translucent zirconia Katana were more translucent than high-strength zirconia IPS e.max ZirCad Prime and BruxZir anterior.

Among the tested translucent zirconia ceramics, katana utml was the most translucent as it contain the highest amount of yttria (9.32 w%) increasing the cubic phase content which could explain the higher TP values [38].

A possible reason for our results could be that IPS e.max ZirCAD prime is a multilayered zirconia that contains both tetragonal and cubic zirconia. The type of crystals present in tetragonal zirconia is birefringent, which means that the refraction of light in crystals occurs in different directions, whereas the cubic crystal structure present in highly translucent zirconia UTML is fully stabilized due to the increased yttria percentage [37].

In terms of the effect of zirconia sintering cycles on translucency, the conventional cycle was much higher than the speed cycle for all types of examined translucent zirconia. This could be explain by the fact that the structure will have more time to create the grains due to longer sintering durations, particularly the dwell time on final temperature, and hence a bigger area under the sinter curve. This can result in grain expansion, which increases translucency [2, 20].

Our results are in agreement with EL Galab *et al*. (2023) [42] who experimentally proved that the conventional cycle had significantly higher translucency values than speed cycle regarding the studied zirconia. Moreover, Lawson *et al*. (2020) [41] confirmed reduction in translucency after speed sintering of both 3Y-TZP and 4YTZP compared to conventional sintering, they explained the lower translucency after speed sintering by the fact that higher temperatures and shorter sintering time resulted in higher particle density which reduced pore spaces during phase transformation and grain growth. Regarding the results of Biaxial flexural strength the null hypothesis was accepted results revealed significant variations between the tested groups in the speed cycle and conventional cycle, with IPS e.max Zircad prime having the greatest value, with significant difference than BruxZir anterior, and Katana having the lowest value.

Mechanical behavior of zirconia is strongly dependent on its grain size, and hence its ability to undergo transformation, in case of BruxZir anterior and Katana ultra-translucent zirconia, they have high yttria percentage to stabilize the cubic phase, stabilized cubic zirconia does not transform at room temperature; therefore, cubic zirconia will not undergo transformation toughening. In other words, it is more susceptible to mechanical damage, while in IPS e.max ZIRCAD prime flexural strength values may be explained due to that it contains both 3Y-TZP and 5Y-TZP, this might be linked to the high-strength 3Y-TZP core and its increased content of tetragonal phase crystals that can undergo transformation toughening [39].

Our results came in accordance with a study done by EL Galab *et al.* (2023) [42]. Who reported higher biaxial flexural strength in IPS e.max ZIRCAD prime compared to other studied zirconia?

In terms of the influence of sintering cycles, on biaxial flexural strength there was no significant difference between Speed and conventional firing cycle.

Ebied *et al.* (2014) [28]. Came to the conclusion that the sintering settings applied had no noticeable effect on the material's biaxial flexural strength. Moreover, several studies emphasized similar mechanical values of zirconia obtained for conventional and speed sintering [43, 44, 45]. Monolithic zirconia crowns did not show any fracture load differences under conventional and speed sintering conditions [46].

Yong *et al.* (2020) [40]. studied the effect of conventional and speed sintering cycles on the optical properties and mechanical properties of different generations of zirconia it was concluded that speed sintering can produce uniform grains without phase transformation comparable to conventional sintering, thus mechanical properties was not affected.

Further studies with equal testing arrangements parameters and evaluation techniques should be conducted to allow the comparison of research results. Information derived from geometrical specimens need to be verified in anatomical reconstructions simulating the clinical situation. Also clinical studies are needed to support the use of high speed sintered zirconia for long term restorations.

## Conclusions

For all tested zirconia, zirconia samples sintered with the conventional sintering cycle showed a significantly higher translucency value than those sintered with the speed cycle. Katana UTML zirconia showed the highest translucency values while BruxZir zirconia exhibited the lowest values in both firing methods. The sintering speed did not affect the biaxial flexural strength of zirconia material there was no significant difference between conventional and speed firing regarding biaxial flexural strength of all tested zirconia materials. Zircad prime exhibited the highest flexural strength values while Katana UTML showed the lowest values in both sintering cycles.

## Recommendations

Clinically, this research has the following significance given the limitations of this study: speed sintering is a valid option to be used for delivering same day restorations with equal mechanical properties to those sintered conventionally however the effect of optical properties must be considered during case selection, chair side regiment can only be used for non-esthetic zone restorations however esthetic zirconia restorations must be sintered at slow speed.

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