

# EVALUATION OF THE TRANSLUCENCY AND THE EFFECT OF TRIBOCHEMICAL SILICA COATING ON THE BOND STRENGTH OF ULTRA TRANSLUCENT ZIRCONIA (IN VITRO STUDY)

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## ABSTRACT

**INTRODUCTION:** Zirconia restorations present long-term clinical survival. Their low translucency makes them esthetically less than lithium disilicate (e.max CAD). The newly introduced ultra-translucent (UT) zirconia blocks improved the aesthetic problems of esthetic restorations.

**OBJECTIVES:** To evaluate the translucency of UT zirconia restorations and to assess the effect of tribochemical silica coating (TSC) on its bond strength (BS) to the resin cement, using lithium disilicate as control.

**MATERIALS AND METHODS:** Forty four disc-shaped specimens were fabricated and subjected to two main tests which were translucency test and shear bond strength test. Translucency groups: the specimens (10×0.5mm (n=20)) were divided into UTZT (ultra translucent zirconia) and LDT (lithium disilicate). Shear bond strength groups (SBST), specimens (5mm x 4mm (n=24)) were divided into UTZAA (ultra translucent zirconia treated by air abrasion), UTZSC (ultra translucent zirconia treated by TSC) and LDS (lithium disilicate that was etched and silanated).

**RESULTS:** Translucency results showed p value <0.001 which indicated higher translucency for the lithium disilicate than UT Zirconia. For SBST the results showed that, (UTZSC) provided the highest mean BS (22.73 ± 3.91) followed by (LDS) (18.18 ± 1.56) and finally (UTZAA) provided the least BS (13.39 ± 4.31).

**CONCLUSIONS:** Within the constraints of this study, UT zirconia showed less translucency than lithium disilicate. The use of silica coating improved the BS of zirconia.

**KEY WORDS:** Ultra-translucent Zirconia, e.max CAD, Tribochemical Silica Coating, Shear Bond strength.

**RUNNING TITLE:** Evaluation of silica coating on zirconia bond.

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## INTRODUCTION

The need for highly esthetic and strengthened dental materials have expanded in dentistry recently. There has been a great focus on the refinement of esthetic needs and mechanical behavior of all-ceramic materials (1, 2). One of the main drawbacks of Zirconia-based component is having a clinical problem which is opaqueness and lack of translucency. So, new products were launched to overcome the opaque nature of zirconia. Ultra Translucent Zirconia (UT) has overturned the conventional image of zirconia with its translucency (3), due to the high crystalline formation of Zirconia, their mechanical properties have been proven to offer good long-term strength in the stress-bearing areas (3, 4). Another drawback of zirconia is, its difficulty in achieving suitable adhesion (4, 5). For this reason, different surface conditioning techniques, such as

airborne-particle abrasion, tribochemical silica coating TSC (Rocatec 3M), selective infiltration and different types of lasers have been suggested in order to improve its bonding to the resin-based cements (6-8).

Available evidence indicates the effectiveness of many all-ceramic systems for numerous clinical applications. Bonding and cementation have been shown to increase clinical success (9).

The objective of this study is to evaluate the translucency of UT zirconia laminates and to assess the effect of TSC on its BS to the resin cement, using lithium disilicate as control.

## MATERIALS AND METHODS

Specimen preparation for Translucency Test ten disc specimens of UT Katana Zirconia (Kuraray Noritake Dental Inc., Japan) (UTZT) and ten discs of e.max

CAD (Ivoclar Vivadent AG, Schaan / Liechtenstein) (LDT) (10mm diameter×0.5mm thickness) were fabricated for spectrophotometric analysis (Cary5000 uv-vis-NIR, aligent, USA) (10).

The specimens of UT zirconia (katana) and e.max CAD were designed by exocad software and saved on STL file then sent to CAD/CAM machine (Sirona, Germany) for milling of all the specimens according to the desired dimensions for standardization (Figure 1).

Milling the zirconia specimens was done using CAD/CAM system (in Lab MCX5 milling machine) (Sirona, Germany) in the presintering stage. Zirconia Blank was clamped to the CAD/CAM milling unit and milled successively. Before milling started; a laser scanning of the bar code present on the blank was done to determine the amount of shrinkage which will occur in zirconia after sintering. Accordingly, the software calculated the size compensating the shrinkage. After the milling process and prior to sintering, a diamond cutting bur on low speed was used to separate the restoration.

The milled discs were placed in a sintering furnace (MV MIHM-Vogt HT sintering furnace) (Company – MIHM-VOGT GmbH & Co. KG.)

As regarding to e.max CAD glass-ceramic, specimens were milled using the same design mentioned earlier. After milling the specimens, they were separated from the e.max CAD blocks, cleaned for 3 minutes with ultrasound waves in a water bath (Digital Ultrasonic Cleaner CD-4820, Codyson, China) ; to eliminate any remaining residues on the surface after milling. Finally, crystallization and glaze firing were performed following the manufacturer's instructions in Ivoclar Vivadent ceramic furnace (Programat P300) at 840 °C for 25 minutes using the program specified for this purpose (Ivoclar Vivadent Inc. USA). A digital caliper was used to check the thickness of the specimens. Translucency was recorded using translucency parameter (TP) by a spectrophotometer (10).

Each Specimen was placed over white ( $L^* = 96.3$ ,  $a^* = 0.1$ ,  $b^* = 1.9$ ) and black ( $L^* = 8.9$ ,  $a^* = -0.7$ ,  $b^* = 1.2$ ) tiles and "tooth single" mode was selected.  $L^*$  is for perceptual lightness,  $a^*$  and  $b^*$  is for the four unique colors of human vision: red, green, blue and yellow.

Measurements were repeated and the means CIE  $L^*a^*b^*$  values were recorded. TP was obtained by calculating the color difference between the average values:

$$TP = [ (L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2 ]^{1/2}$$

B is the color coordinates over the black background while W is to those over the white background.

If the material is opaque, TP value is zero; if the material is transparent, TP value is 100.

Specimen preparation for Shear bond strength test (SBST): sixteen disc specimens of (UT) zirconia (UTZAA, UTZSC) and eight discs of e.max CAD

(LDS) with dimensions (5 mm diameter x 4 mm height) for SBST (11).

The specimens were designed and saved on STL file then sent to CAD/CAM machine of the same system according to the desired dimensions and milled using the same milling machine as described before for each type of ceramic material (Figure 2). Then a digital caliper was used to check the thickness of the specimens.

UTZAA group: The fitting surface of UT zirconia discs were treated with  $Al_2O_3$  particles approximately 110  $\mu m$  in size at a pressure of 2.8 bar for 15 seconds. For standardization, samples were held at a distance of 10 mm from the end of the air abrasion unit (Renfert GmbH, Hilzengen, Germany), this fixed distance was adjusted by using a customized wire of 10mm length fixed from the end of the air abrasion unit, the time of air abrasion was controlled by using a stop watch (12).

UTZSC group: The fitting surface of zirconia discs were cleaned and treated with 110  $\mu m$   $Al_2O_3$  particles, using the same protocol, then TSC (30  $\mu m$ ) was applied perpendicularly on the blast surface for 20s, (coated with rocatec soft) under pressure of 2.8 bar the fixed distance was 10 mm from using a customized wire from nozzle of thee provjit tip (Bio-Art Equipamentos Odontologicos Ltda, Sao Carlos-Brazil). The distance and time were adjusted as described before (12).

LDS group: the disc specimens were prepared, cleaned and air dried then the fitting surface was Etched with 9.5% hydrofluoric acid for 20 s, cleaned by water and air spray, followed by silanation coupling agent (Bisco, Shaumborg, USA) for 1 minutes then drying with oil free air spray was performed (13).

Fabrication of composite resin discs

Teflon mold was customized in two pieces that joined together using screws containing two holes of 6 mm diameter x 6 mm height to prepare twenty four composite discs by condensation of composite resin into the holes and curing them using light cure device. After complete polymerization, the surface to be bonded was made absolutely flat by used sand paper sheet mounted on a glass slab.

A copper mold with a circular hole 10mm internal diameter and 10mm depth was made assembled by interlocking male and female parts. This mold was designed for fixing the composite resin discs into self-curing acrylic cylinders.

Each ceramic disc was bonded to a composite disc using RelyX Unicem, dual cure self-adhesive resin cement (3M-ESPE Deutschland GmbH).

All zirconia and e.max CAD specimens were cemented to the composite resin discs following manufacture instructions using dual cure resin cement (Rely X) both discs with the cement in between. Light cured for 2 minutes more to ensure complete setting of the cement, the load was applied to keep the specimen in place until the cement was fully set. Excess resin was removed using a scaler to be ready for testing.

The specimens were mounted in a specially designed copper attachment with a central hole of 14 mm diameter to hold and fix the specimens during SBST.

The SBST was done using a Universal Testing Machine (Comten industries Inc., Florida, USA) (11). Each specimen was screwed in a metal mold in the lower platform of the universal testing machine. The specimen was oriented so that the stainless steel chisel shaped blade fixed to of the upper arm of the universal testing machine, applied a load at a cross head speed of 0.5 mm/min at the interphase between the two discs. The specimens were loaded continuously until debonding occurred, then it was recorded for each specimen in each group.

The SBS was calculated by dividing the failure load over the surface area of the specimen.

Calculation of the BS:

$$SBS = \frac{\text{Failure load (P)} = \text{Kg} / \text{cm}^2}{\text{Surface area (A)}}$$

Where (P) is the failure load recorded from the screen in k.g.

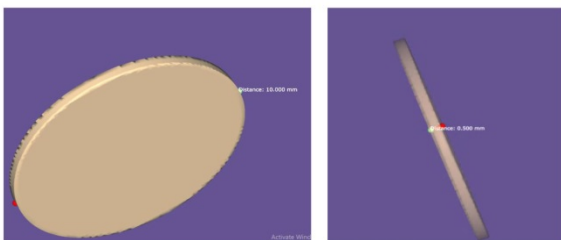
And (A) is the surface area of the bonded disc =  $\pi r^2$ .

Where  $\pi = 3.14$  and r = the radius of bonded area.

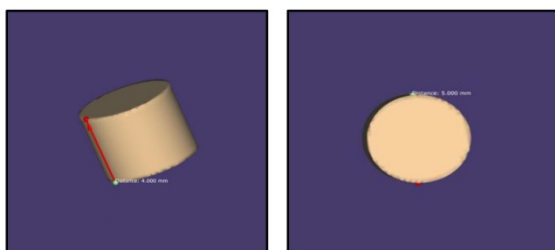
Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median.

For normally distributed quantitative variables, student t-test was used to compare between two studied groups and ANOVA test was used to compare between three studied groups. Pairwise comparison bet, each 2 groups was done using Post Hoc Test (Tukey). Significance of the obtained results was judged at the 5% level. A p-value of less than 0.05 was considered statistically significant.



**Figure (1):** Designing the specimens on the software for the Translucency evaluation



**Figure (2):** Designing the specimens on the software for the Shear bond strength testing

## RESULTS

This study was designed for evaluation of the translucency of ultra-translucent zirconia discs with thickness resembling laminate veneers and to assess the outcome of TSC on the BS of ultra translucent zirconia to the cement using lithium disilicate as control.

The data was collected from each group then tabulated and the average values for each group were statistically surveyed using student t test and ANOVA test.

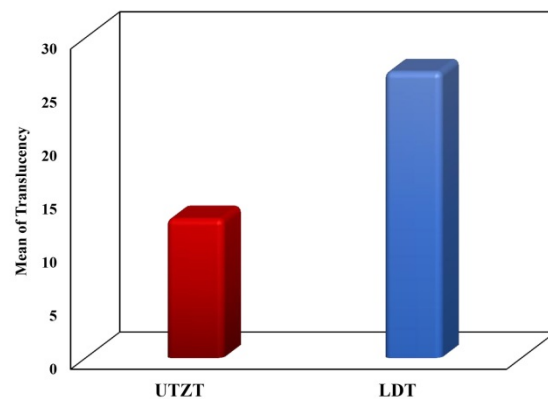
Translucency testing

Table (1) shows the difference between lithium disilicate and Ultra-translucent Zirconia as regards to  $\Delta E$ . The mean  $\Delta E$  was  $26.8099 \pm 0.57949$  and  $13.06376 \pm 0.36378$  for respectively between lithium disilicate and Ultra-translucent Zirconia. With p value  $< 0.001$  which mean that the differences were statistically significant, indicating higher translucency for the lithium disilicate (Figure 3).

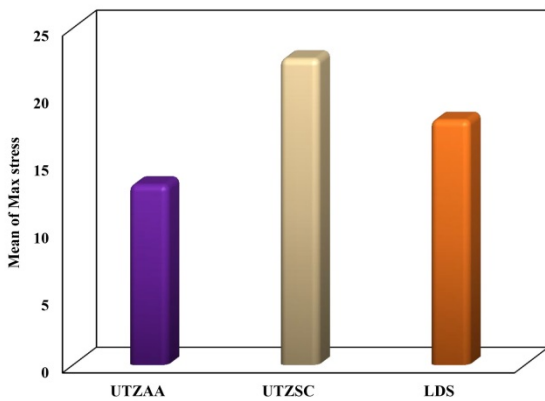
Shear bond strength testing (SBST)

Table (2) shows the outcomes of testing the SBS for zirconia surface treated by airborne abrasion (UTZAA), zirconia surface treated by airborne abrasion with silica coating (UTZSC) and lithium disilicate surface treated with hydrofluoric acid (LDS). The results showed that, (UTZSC) provided the heighest mean BS ( $22.73 \pm 3.91$ ) followed by (LDS) ( $18.18 \pm 1.56$ ) and finally (UTZAA) provided the least BS ( $13.39 \pm 4.31$ ).

The average of SBS for (UTZSC) was ( $22.73 \pm 3.91$ ) which is much higher than that for (UTZAA) with a mean strength of ( $13.39 \pm 4.31$ ). The difference is statistically significant, indicated by a  $p < 0.001$ . Also, the (LDS) CAD showed a significant higher bonding strength with a  $P_2 = 0.031$  compared to (UTZAA). In addition comparing the mean strength value for (UTZSC) ( $22.73 \pm 3.9$ ) to that of (LDS), there was a statistical significance in favor for (UTZSC).  $P_3$  was 0.041. Finally, A p value less than 0.001 document comparing the three groups of study, indicating (UTZSC) to getting the largest average of SBS outcomes (Figure 4).



**Figure (3):** Comparison between the two studied groups (UTZT, LDT) according to translucency.



**Figure (4):** Comparison between the three studied groups (UTZAA, UTZSC, LDS) according to Max stress.

**Table (1):** Comparison between the two studied groups according to translucency

Translucency	UTZT 0.5mm (n = 10)	LDT 0.5mm (n=10)	t	p
Min. – Max.	12.61 – 13.65	25.97 – 27.99		
Mean ± SD.	13.06 ± 0.36	26.81 ± 0.58	63.467	<0.001*
Median (IQR)	12.97 (12.78 – 13.30)	26.82 (26.51 – 27.01)		

**t: Student t-test**

p: p value for comparing between the studied groups

\*: Statistically significant at  $p \leq 0.05$

**Table (2):** Comparison between the three studied groups according to Max stress

Max stress	UTZAA (n = 8)	UTZSC (n = 8)	LDS (n = 8)	F	p
Min. – Max.	4.54 – 18.35	18.14 – 28.61	16.32 – 21.45		
Mean ± SD.	13.39 ± 4.31	22.73 ± 3.91	18.18 ± 1.56	14.40 2*	<0.001*
Media n (IQR)	13.94 (11.89 – 16.29)	22.56 (19.29 – 25.71)	18.17 (17.08 – 18.60)		
Sig. bet. grps.	p <sub>1</sub> <0.001*, p <sub>2</sub> =0.031*, p <sub>3</sub> =0.041*				

F: F for ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)

p: p value for comparing between the studied groups

p<sub>1</sub>: p value for comparing between UTZAA and UTZSC

p<sub>2</sub>: p value for comparing between UTZAA and LDS

p<sub>3</sub>: p value for comparing between UTZSC and LDS

\*: Statistically significant at  $p \leq 0.05$

**DISCUSSION**

Recently, high translucent, and ultra translucent zirconia (14,15) have been introduced to the dental field to overcome the opacious nature of zirconia restorations and develop close match colors of human teeth especially when it is used to restore esthetic region. The flexural strength of this material is 900-1400 MPa. These conveniences have gained zirconia more popularity and more for fixed restorations (16). For excellent esthetics, it is important to reproduce the natural translucent appearance of the tooth structures.

The study was to evaluate the translucency of ultra translucent zirconia discs resembling laminate veneers in clinical situations and to measure the outcome of TSC on its BS to the resin cement, using lithium disilicate as control.

Ultra translucent zirconia was selected in this research, due to its persistence to high fracture loads and good optical properties (17). Moreover, straight forward and fast fabrication by CAD/CAM technology might increase the use of monolithic reconstructions (18).

Concerning translucency, in this study two different materials was indicated for laminated veneers have been represented to evaluate their translucency, UT zirconia was used to be compared with lithium disilicate for the well known aesthetic properties & acceptable strength of lithium disilicate (19).

Sonza et al., (2015) (20) have reported methods to evaluate the translucency and opacity of restorative materials using a spectrophotometer. The TP is the color difference of the material on white and black backgrounds repeated 3 time for each specimens to assess the translucency (10).

The translucency measurements in this study revealed that the mean ΔE was 26.8099±0.57949 and 13.06376±0.36378 for respectively between lithium disilicate and Ultra-translucent Zirconia, with p value <0.001 which mean that the differences were statistically significant, indicating higher TP for lithium disilicate.

The results showed that, there were significant differences between lithium disilicate and Ultra-translucent Zirconia as regards to mean ΔE which was measured by the spectrophotometer as the mean value was 26.81±0.58 and 13.06±0.36 respectively and P value was <0.001.

Translucency results of the current study showed similarity to many studies that concluded that lithium disilicate showed more translucent than UT zirconia and scored the higher TP using spectrophotometer (15,21).

The results of the current study are in disagreement with a study conducted by Baldissara et al., (2018) (22). They concluded that UT zirconia was more translucency. This difference in results compared to the current study may be due to the different thickness in the zirconia (1.0 mm) used as crowns and device used for translucency measurements, as a photo radiometer was used by Baldissara et al., while in the current study spectrophotometer was used.

Another main aim of the current study was to study the outcome of TSC effect on the BS of ultra translucent zirconia to the resin cement and compare it to BS of lithium disilicate as a control.

Shear bond strength is one of the keys to evaluate the performances for dental ceramics to guarantee the long-term clinical efficacy.

Zirconia is widely used in dentistry due to its strength and biocompatibility. Unfortunately, debonding of zirconia restorations has been observed. Many studies were conducted to test the most appropriate zirconia surface treatment (23).

In this study the APA method used to enhance the retention to zirconia micromechanically. APA methods might create microcracks within the zirconia surfaces which promote the behavior and mechanical characteristics of zirconia (24). In this study the TSC of particle size 30  $\mu\text{m}$ , surface treatment was used to assess its effect on the SBS of ultra translucent zirconia as veneering material.

In this study, silica deposition by air-abrasion creates more surface roughness and micromechanical interlocking and chemical with resin cement (25). The silica is embedded into the surface up to a 15 $\mu\text{m}$  depth and fused to the surface in islands (26), enabled chemical interaction to resin cement and promotes bonding of resin to zirconia (27).

For lithium disilicate, surface treatment was done by 9.5% hydrofluoric acid (Porcelain Etchant, BISCO, USA) for 20 s, cleaned by water and air spray, followed by application of silane coupling agent (Bisco, USA) for 1 minutes then drying with oil free air spray was performed (13).

The results showed that, (UTZSC) provided the highest mean BS ( $22.73 \pm 3.91$ ) followed by (LDS) ( $18.18 \pm 1.56$ ) and finally (UTZAA) provided the least BS ( $13.39 \pm 4.31$ ).

The results of the current study showed that the (UTZSC) shows better BS than the other 2 groups. P3 value comparing (UTZSC) BS to (LDS) was 0.041, and P1 value comparing it to (UTZAA) was less than 0.001. That showed the use of TSC enhanced the BS with zirconia (28).

In the current study Rocatec soft was used that has APA of (30mm) particle size that make more rough surface than using (110mm) particle size. As in Hallmann et al., studied effect of APA size, grade and pressure, on morphological change and phase transformation of dental zirconia surface, their results showed that abrasion by APA of size 110  $\mu\text{m}$  for ceramic surface at pressures of 1.5 or 2.5 bar,

respectively, showed the best surface conditioning and give better BS results for zirconia (29).

The outcomes of the current study of SBST run with many studies that conducted, found that APA give better results in SBS. That mean that APA method has a great influence on increasing the bonding to zirconia by roughing the surface (30, 31). Also the current study results run with the results of many studies found that APA followed by silica coating has also been reported as an effective method to increase the BS (29-34).

Dérاند et al., (35) reported that APA had only minor influence on BS and didn't improve the results. Also de Oyague et al., (36) concluded that APA on the bonding surface of zirconia substrate did not produce higher BS, even though the substrate surface became rougher than the control group, probably because of different grain size, or different pressure used absence of silica.

## CONCLUSION

This study revealed that UT zirconia showed less translucency than lithium disilicate at thickness of 0.5mm. The bond strength of tribochemical Silica Coating zirconia surface shows significantly higher results than APA zirconia.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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