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Evaluation of Shear Bond Strength of Resin Cement to 5 mol% Yttrium-Stabilized Zirconia

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Abstract

Purpose: The purpose of this study is to compare the shear bond strengths of four different zirconias at the dentally relevant esthetic zirconia-resin interface, using a standardized recommended bonding regimen.

Materials and Methods: Twenty samples each of four different 5Y-TZP containing zirconia cylinders (n=20) were bonded to a Luxacore Z-Dual core build-up material. The specimens were tested for shear bond strength using the Instron 5943 machine at a speed of 0.5 mm/min.

Results: Cercon xt ML samples had the highest shear bond strength (29.94 MPa, SD = 11.58) and samples using Lava Esthetic Full-Contour Zirconia recorded the lowest shear bond strength (24.98 MPa, SD = 9.90). However, a one-way ANOVA failed to show any statistical difference in shear bond strength between the groups, P = 0.79.

Conclusion: This study failed to show that one esthetic zirconia has a higher bond strength than the others. Esthetic zirconia may have similar shear bond strength to resin-based cement compared with other indirect ceramic materials.

Introduction

Zirconia is a popular dental material used as an alternative to metal or metal-ceramic for the treatment of a tooth with a full coverage crown. The growing increase in use of zirconia by dental clinicians is mainly driven by the esthetic demand of their patients. Clinicians have found that zirconia has proven to be a great material for use as a dental prosthesis due to its high compressive strength, esthetic capabilities, low consumer cost, and minimal tooth preparation requirements.[1,2] Zirconia used as a dental prosthesis is typically stabilized with yttrium. The yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) is most commonly used with 3 mol% (3Y-TZP), 4 mol% (4Y-TZP), and 5 mol% (5Y-TZP) yttrium.[3] As the yttrium in the zirconia material increases, esthetics of the prosthesis is usually more favorable due to the increase in translucency which mimics a more natural tooth appearance. With higher percent of yttrium, the zirconia material compressive strength decreases.[3] 5Y-TZP zirconia esthetics can be comparable with the esthetics of other highly translucent dental materials, while providing the advantage of using a stronger material. All zirconia materials in this study contain 5 mol% yttria.

Core Build-Up Material

When restoring a tooth that has a large part missing due to caries, fracture, developmental defects, or another reason, a type of core build-up material is usually required for adequate retention and resistance form for the final crown. Luxacore Z-Dual is a dual cure composite core build-up material that contains barium glass, pyrogenic silicic acid, nanofiller and zirconium dioxide in a Bis-GMA based matrix from dental resins.[4, 5] Luxacore Z-Dual was used as an interface to test the bond strength of a dual-cure resin cement and four different 5Y-TZP zirconias.

Bonding Zirconia

For most teeth with adequate retention and resistance form, luting is a viable option for permanent cementation of zirconia crowns. However, there has been an increase in studies into defining a consistent and reliable protocol for pretreating zirconia to aid in chemical and micro-mechanical bonding to other structures such as enamel, dentin and various core build-up materials.[6, 7, 8, 9, 10, 11] Although there is no agreement on the minimum strength necessary to provide successful bonding, 20MPa or higher has been proposed as a reasonable goal.[16] The bonding protocol that is recommended for ideal zirconia adhesive strength includes airborne-particle abrasion (APA) with silica-coated aluminum oxide, thorough cleaning of the intaglio surface using ultrasonic bath, treatment of intaglio with 10-methacryloyloxydecyl dihydrogen phosphate primer (10-MDP), and bonding with 10-MDP containing cement.[6, 7, 8, 10, 11, 12, 13] A standardized adhesive protocol has not yet been established, but pretreated zirconia is still favorable to untreated zirconia when bonding to core material or tooth structure. APA of zirconia using aluminum oxide coated with silica can improve the flexural strength of conventional zirconia via transformation toughening.[14] APA can also improve bond strength by creating micromechanical retention and embedding silica particles in the zirconia to aid in forming a chemical bond with a resin cement.[15] When using a cement containing 10-MDP, pretreatment of the zirconia with a ceramic primer containing 10-MDP has shown an interaction between 10-MDP and the hydroxyl groups in the oxide layer of zirconia (and embedded silica particles) which also increase adhesion. Any 10-MDP containing primer and cement creates an increased bond strength when bonding to zirconia.[16] The cement system chosen for the present study was MDP-containing Panavia V5. It is well documented and has shown higher bond strength to oxide ceramics compared with other adhesive cements.[17, 18, 19, 20]

Relevance for This Study

With more knowledge on the bond strength of different zirconia materials to a resin cement, it is possible that less retentive and more conservative tooth preparations may be performed with considering a bonded zirconia restoration. Future studies may include observing the cement failure being either cohesive or adhesive.

Objective

The purpose of this study is to compare the shear bond strengths of four different zirconias at the dentally relevant esthetic zirconia-resin interface, using a standardized recommended bonding regiment.

Materials and Methods

Overview

The shear bond strength of the four different 5Y-TZP cylinders to LuxaCore Z-Dual discs will be evaluated using the Instron 5943 Single Column Tabletop Testing System.

Materials

Four different 5Y-TZP zirconia ceramics were analyzed (A2 shade):

IPS e.max® ZirCAD® MT Multi (Ivoclar Vivadent)

Katana™ Zirconia UTML (Kuraray Noritake)

Cercon® xt ML (Dentsply Sirona)

Lava™ Esthetic Full-Contour Zirconia (3M)

IPS e.max® ZirCAD® MT Multi (Ivoclar Vivadent)

ZirCAD® MT-Multi has an increase in yttria content to 6.5 – 10.0 wt%. ZirCAD® MT-Multi has a combination of 5Y-TZP in the incisal 20%, 4Y-TZP and 5Y-TZP in the transitioning 20%, and 4Y-TZP in the cervical 60%. The flexural strength of ZirCAD® MT-Multi is 850 MPa.[21]

Katana™ Zirconia UTML (Kuraray Noritake)

Katana™ Zirconia UTML is the most translucent zirconia that Kuraray offers. According to the Katana™ UTML technical guide, in order to achieve the high level of translucency "They do not contain glass ceramics. Their high translucency has been achieved through a new type of zirconia powder which we developed using our own unique technology." Katana™ UTML chemical composition consists of 87-92% zirconia oxide and hafnium, 8-11% yttria content, 0-2% and other oxides. Flexural strength is 557 MPa and translucency is 43%, compared to IPS e.max® ZirCAD® MT Multi 44% translucency at 1mm.[22]

Cercon® xt ML

Cercon® xt ML is an extra translucent multilayer zirconia offered by Dentsply Sirona Lab. It is composed of zirconium oxide, 9 wt% yttrium oxide, 3% hafnium oxide, and 2% other oxides. The flexural strength is 750 MPa with translucency of 49% at 1mm measured on a white disc with haze meter.[23]

Lava^{TM} Esthetic Full-Contour Zirconia

The exact composition of Lava^{TM} Esthetic is not published by the company as it is proprietary information. The 3M technical product profile states their product contains 5mol% yttria. Translucency is 40% at 1mm. The flexural strength of Lava^{TM} Esthetic is 800 MPa.[24]

Core build-up material: Luxacore Z-Dual Natural (A3 shade) (DMG)

Zirconia Primer: Clearfil Ceramic Primer (Kuraray)

Bonding Agent: Panavia V5 Tooth Primer (Kuraray)

Cement: Panavia V5 (Kuraray)

Air-Particle Abrasion: Ney Aluminum Oxide 60 µm

Fabrication of specimens

Twenty cylindrical specimens were obtained from each IPS e.max® ZirCAD® MT-Multi, Katana^{TM} Zirconia UTML, Cercon® xt ML, and Lava^{TM} Esthetic Full-Contour Zirconia. The specimens were milled using inLab MC X5 to ensure post-sintering cylinder size remained 5 mm in diameter. The core build-up portions were fabricated using silicone cylinder molds with central well measuring 12.7 mm in diameter. Luxacore-Z Dual was mixed using the automix syringe tips, dispensed into the molds, light cured from the top of the well for 20 seconds, and allowed to fully cure at room temperature for 5 minutes.

Zirconia Surface Conditioning

Surface conditioning was performed on all specimens. The specimens were treated with air-particle abrasion using Ney Aluminum Oxide 60 µm at 2 bar (30 psi) pressure for 15 seconds, at 10 mm distance, and 90º angle. The samples were soaked in denatured ethanol 200 proof alcohol and cleaned in an ultrasonic bath. Clearfil Ceramic Primer was applied to the treated zirconia surface using manufacturer's instructions by applying and scrubbing with a applicator brush and thoroughly drying with oil-free air.

Bonding Protocol

Panavia V5 Tooth Primer was applied to the Luxacore Z-Dual samples. The zirconia cylinders and Luxacore Z-Dual cylinders were bonded using Panavia V5 cement using a standard 5 lb. weight (22.24 Newtons) on a surveyor table which applied a constant pressure and light-polymerized (Elipar S10, 1200 mW/cm^2; 3M ESPE) on four sides for 20 seconds each side.

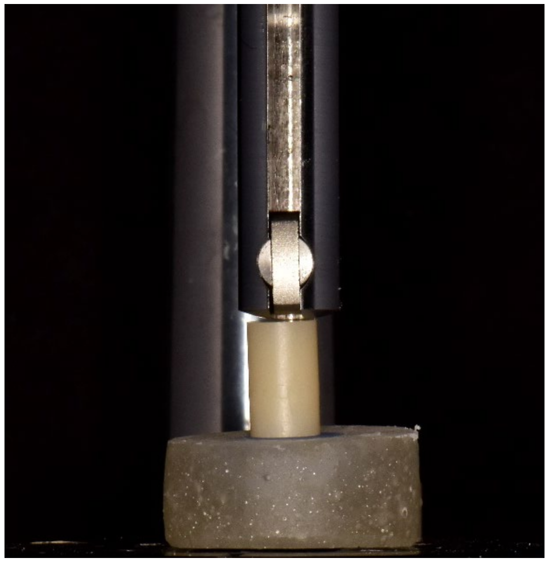

Figure 1. Zirconia sample on surveyor table setup for bonding

Testing Protocol

The samples were shear tested using the Instron 5943 machine at a speed of 0.5 mm/min. Data was evaluated on the shear bond strength at the zirconia/cement interface. The sample size (20 specimens from each group) was chosen based on a power analysis of a two-sample test with a significance level of 5% with true differences of means set at 3 MPa and with a power of 90%.

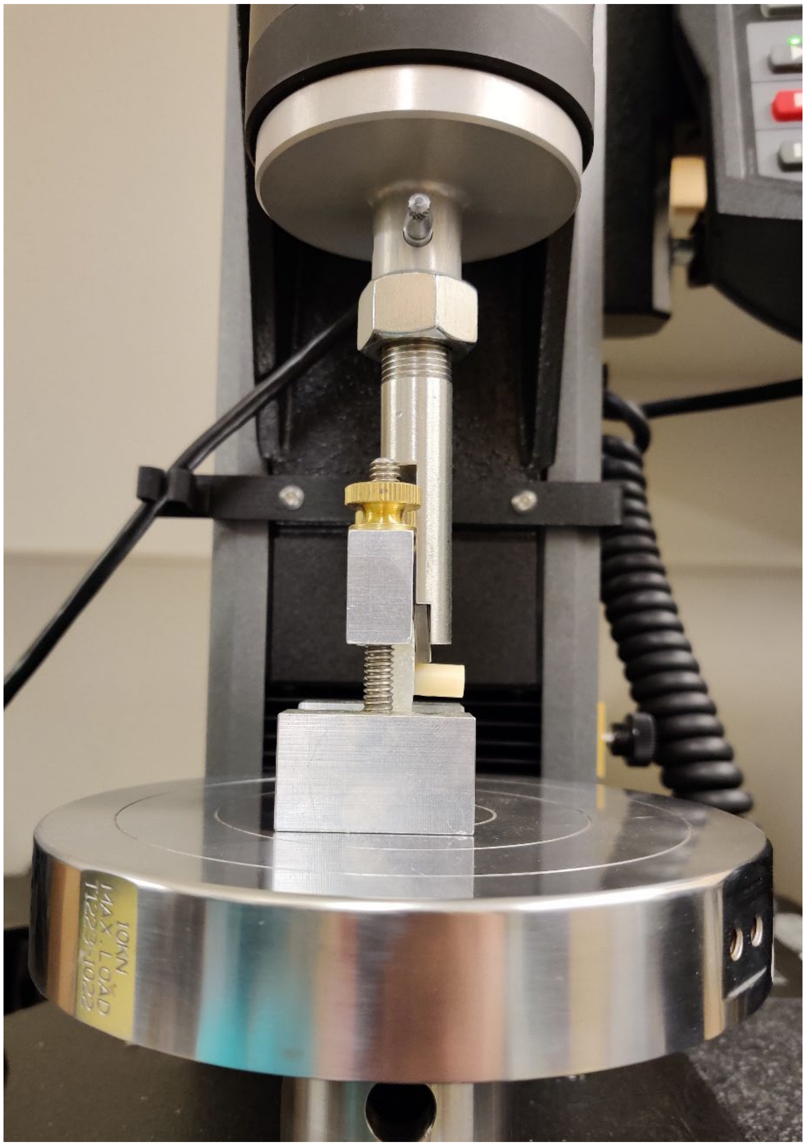

Figure 2. Sample setup on Instron machine for shear bond strength test

Results

Shear bond strength characteristics are presented in Table 1 by zirconia material. Numerically, Cercon samples had the highest shear strength (29.94 MPa, SD = 11.58) and samples using Lava recorded the lowest shear strength (24.98 MPa, SD = 9.90). However, a one-way ANOVA failed to show any statistical difference in shear bond strength between the groups, P = 0.79.

Consequently, a post-hoc power analysis was performed to determine the observed power and whether the lack of significant results could be due to the limited sample size (n = 80). Results indicate based on the mean, the between-groups effect size observed in the data (f = 0.11) indicates that a total sample size of 832 would be required to obtain statistical power at the standard .80 level while maintaining significance at the 0.05 level. Thus, while the current data cannot definitively show a true lack of difference between the groups with respect to shear bond strength, any difference may be small and thus unlikely to be of any clinical relevance.

Material	N	Mean MPa	Std. Deviation	Min - Max MPa
Cercon	20	29.94	11.58	9.88 - 49.25
Katana	20	28.28	9.66	13.34 - 46.68
Lava	20	24.98	9.90	10.13-44.31
ZirCAD	20	26.98	10.33	5.58 - 46.51

Table 1. Shear Bond Strength Characteristics by Group

Discussion

The application for all-ceramic restorations has become increasingly popular for use as indirect dental crowns, overlays, onlays, and inlays. One reason for the shift to all ceramic restorations is the ability to bond to dentin and enamel. With the ability to reliably bond, the ability to conserve tooth structure has increased as well. This is the direction that the future of dentistry is headed, and more research is necessary to continue progressing in this direction. The ability to use a zirconia restoration in a non-retentive situation can have benefits over other materials. One such benefit could be the compressive and flexural strength of the material.

Lithium Disilicate Shear Bond Strength to Resin Cement

Lithium disilicate material is a popular all-ceramic material choice because of its esthetics, strength, and ability to achieve a high bond strength specifically to enamel. Shear bond strength of lithium disilicate to resin cements has been shown to be in the 40 MPa range.[25] This is comparable to the high end of the results obtained with zirconia shear bond strength to a resin cement. One limitation of zirconia compared to a material such as lithium disilicate is the long sintering time necessary for zirconia. With a much shorter crystallization time, lithium disilicate is the most common all-ceramic same-day restoration material of choice.

Zirconia Bond Strength to Dentin and Enamel

The shear bond strength of zirconia to dentin has been found to be between 3.70 MPa – 8.66 MPa. This lower value is consistent with using other materials due to the organic collagen make-up of dentin.[26] Enamel is a more reliable hard tooth substrate to bond because of the majority composition of inorganic hydroxyapatite. Shear bond strength of zirconia to enamel has been shown to be around 21 MPa.[27]

Zirconia Bond Strength to Resin Cement

Invitro studies of zirconia to resin cement bonding have shown promising results of cohesive failure and high bond strength. Similar high shear bond strength studies of 3 mol% zirconia has shown between 46.2 MPa – 55.7 MPa.[28]

Is There a Need for Resistance and Retention Form Tooth Preparations?

Inadequate resistance and retention form of a crown preparation is one of the top three reasons for replacement.[29] There are many clinical scenarios where a full coverage crown preparation may not be the ideal treatment for a tooth. Preservation of tooth structure is a common goal that most dental professionals strive for with restorative dentistry. One of the benefits of a bonded restoration is the ability to prepare a tooth with a defect, fracture, or carious lesion in a more conservative manner rather than preparing a tooth to gain ideal properties of the restorative material. Although there is no agreement on the minimum strength necessary to provide successful bonding, 20 MPa or higher has been proposed as a reasonable goal for shear bond strength.[30]

Currently there are no studies comparing the bond strength of similar esthetic zirconia materials. The composition of the zirconia materials used in this study had different oxides, yttria, zirconia, and hafnium content. In this study there was not enough data to show a correlation between the esthetic zirconias and shear bond strength. However, Cercon had the highest average shear bond strength of the zirconia to resin cement. One reason may be the make-up of the zirconia material. Cercon states their zirconia contains 9 wt% yttrium oxide, 3% hafnium oxide, and 2% other oxides. The difference in materials may be contributing to the higher shear bond strength. Lava had the lowest average shear bond strength. Its exact composition is not stated in its technical manual. The high standard deviations and range of bond strength could be a result of inconsistency with specimen preparation. Although all specimens were prepared in the same fashion, error may have been introduced in one of the multiple preparation steps.

Conclusion

Within the limitations of this study, it can be concluded that 5Y-TZP zirconia may have similar shear bond strength to resin-based cement compared with other indirect ceramic materials. Future studies of zirconia bonding should include similar materials used in this research with a larger sample size. Additional testing of the bond strength to dentin/enamel would be beneficial as well.

Acknowledgements

CPT Luke Sandersfeld developed the study concept, collected the data, and wrote the manuscript. Mr. Thomas Beltran completed the statistical analysis.

Disclaimer

The views expressed herein are those of the author and do not necessarily reflect the official policy of the Department of the Army, Department of Defense, or the US Government.

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