

EVALUATION OF SHEAR BOND OF TWO PRESSABLE GLASS CERAMICS TO THEIR VENEERING MATERIALS (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: The bond between the veneering ceramic and the substructure is important for the long-term survival of the restorations. However, the shear bond strength (SBS) of heat-pressed ceramic substructures to veneering ceramic materials remains unclear.

AIM OF STUDY: This study aimed to evaluate the SBS and mode of failure of two heat-pressed glass ceramic substructures (lithium disilicate (LDS) and zirconia-reinforced lithium silicate (ZLS)) with their corresponding veneering ceramics.

MATERIAL AND METHODS. Thirty glass ceramic disk-shaped specimens were fabricated from heat-pressed LDS and ZLS (n = 15) with a diameter of 10mm and a thickness of 3mm. LDS and ZLS specimens were veneered with fluorapatite glass ceramic (FLGC) and leucite-reinforced feldspathic porcelain (LFP), respectively. The veneering material was condensed in a mold and fired on the glass ceramic materials to form a disk with a diameter of 3mm and a thickness of 2mm. Specimens were subjected to shear force in a universal testing machine at a crosshead speed of 0.5 mm/minute until failure of the specimens. The failed specimens were examined under an optical microscope and a scanning electron microscope to analyze the mode of failure. Data were analyzed using independent t-test.

RESULTS. LDS (29.75 MPa) showed a statistically significant higher shear bond strength than that ZLS (21.96 MPa) (P value<.05). LDS group showed predominantly cohesive failure, while ZLS group showed mixed adhesive/cohesive failure.

CONCLUSIONS. Zirconia-reinforced lithium silicate complex failed at lower load levels compared to the lithium disilicate complex. The predominantly cohesive failure mode in LDS specimens reflects the higher bond strength that surpassed the cohesive strength of the heat-pressed ceramic and the veneering material.

KEYWORDS: shear bond strength, bilayered ceramics, heat-pressed ceramics.

RUNNING TITLE: SBS of ZLS and LDS with veneering ceramics.

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INTRODUCTION

The field of restorative dentistry has been continually shaped by advances in ceramic materials due to their good esthetics and strength. Ceramic restorations can be used in monolithic form without veneering ceramic to maintain high strength during function. However, veneering materials applied by powder condensation over high-strength core materials offer a wide range of shades, translucencies, and effects that improve the esthetics and closely replicate the natural dentition (1).

Lithium disilicate (LDS) glass ceramic material is widely used as a monolithic structure or as a substructure material in bilayered restorations as it exhibits a combination of high aesthetic, mechanical properties, and chemical stability (2-4). Layering of LDS can be performed in different cutback forms, either similar to ceramometal restorations or with minimal cutback at the labial/ incisal areas of anterior restorations. A minimal cutback is now gaining

popularity, as it minimizes the manual effort yet gaining the maximum esthetics (5). However, the durability and longevity of bilayered restorations in general or minimal cutback methods in particular hinge upon the integrity of the bond between the veneering ceramic material and the underlying glass ceramic substructure (6,7).

Few evidence concerning the bond strength of LDS to its corresponding veneering ceramic are found in the literature. Dundar et al., (8) investigated the shear bond strength (SBS) of veneered lithium disilicate-based ceramic systems compared to zirconia-based ceramics and found that the mean SBS of lithium disilicate was significantly higher. Additionally, the failure mode was found to be predominantly cohesive in the LDS specimens, pointing out that the adhesive strength of the components of bilayered structures surpassed their cohesive strength.

Recent advances in glass ceramics were directed toward the optimization of the starting powders to create higher-strength materials combined with better esthetics than conventional LDS. Among the modifications is the incorporation of zirconia particles into the starting powder of the glass to form a different glass ceramic, zirconia-reinforced lithium silicate (9,10). The resultant glass ceramic has a homogeneous glassy matrix microstructure that contains two types of crystalline components: lithium orthophosphates and lithium metasilicates, which are formed of round and submicrometric elongated grains. In addition, 10% wt. of tetragonal zirconium oxide fillers (ZrO_2) are dissolved completely in the glass phase, aiming at enhancing the overall material strength. However, to date, this assumption is still controversial (9).

According to in vitro investigations (11-13), Zirconia-reinforced lithium silicate (ZLS) exhibited higher mechanical performances than LDS. Additionally, Mavriqi et al., (14) investigated the fracture toughness and Vickers hardness of LDS and ZLS and found that ZLS has a higher fracture toughness and Vickers hardness than LDS, confirming the possible efficiency of the zirconia additional phase in increasing material mechanical properties, making it a promising material for achieving both functional and cosmetic success in dental restorations. However, a pivotal knowledge gap persists concerning the shear bond strength of ZLS glass ceramic substructure with its veneering ceramic.

The present study aims to evaluate the shear bond strength and mode of failure of two heat-pressed LDS and ZLS glass ceramic substructures with their corresponding veneering ceramics. The null hypothesis of this study was that there is no statistically significant difference in the shear bond strength (SBS) between the two ceramic systems.

MATERIAL AND METHODS.

Two types of core-veneer ceramic complexes were used to test the shear bond strength between the ceramic substructure and its veneering porcelain: LDS veneered with fluoroapatite glass ceramic powder (FLGC) (IPS-e.max Press and IPS-e.max Ceram; Ivoclar Vivadent) and ZLS veneered with leucite-reinforced feldspathic porcelain (LFP) (Celtra Press and Celtra Ceram; Dentsply Sirona). The composition of the materials is shown in (Table 1) (15).

Preparation of heat-pressed specimens

Thirty-disc shaped specimens were manufactured by (CAD-CAM) technology from milling wax blocks. Wax blocks were milled to form discs of a diameter =10mm and thickness= 3mm. Discs were sprued and invested using phosphate-bonded investment (Bellavest® SH, Bego). For burnout, the ring was placed in a preheating furnace (MIDITHERM 100 MP, Bego) and heated from

200 °C to 900 °C; the temperature was maintained at 900 °C for 30 minutes. LDS and ZLS ingots of shade LT A2 were heat pressed according to the manufacturer's instructions using a pneumatic furnace (Programat® EP 3010 - Ivoclar Vivadent). Pressing program temperatures are shown in Table 2.

After bench cooling, the ring was divested using air-borne particle abrasion with aluminum oxide particles (Blasting Compound, Ivoclar Vivadent) at 110 µm at 2 bar (15–30 psi) pressure (16). Sprues were removed using diamond discs (FLEX Diamond Disc, Edenta, Ivoclar Vivadent). LDS discs (n = 15) were immersed in hydrofluoric acid and sulphuric acid in water (Invex Liquid, Ivoclar Vivadent) for 20–30 minutes to soften the surface reaction layer (17). ZLS discs (n = 15) were exposed to power firing program to increase the flexural strength to more than 500 MPa (18). Silicon carbide abrasive paper grits (220–1200) (Wetordry, 3M) were used to finish the surface of the ceramic discs. Specimens were cleaned with distilled water at 55 °C for 10 minutes using an ultrasonic cleaner.

Veneering

Ceramic dentin powder was mixed with Build Up Liquid and condensed on the center of the glass ceramic discs using a specially designed mold (Fig. 1) before firing according to manufacturer's instructions. A second layer was condensed using the same mold to compensate for firing shrinkage. The final shape is a disc of veneering ceramic with a diameter of 3mm and a thickness of 2mm (16). The dimensions of the completed specimens were verified using a digital caliper device (Digital vernier caliper, SOMET) (Fig. 2). All samples were stored at 37 °C in water for 24 hours.

Shear bond test

The specimens were mounted in a special jig that was attached to the lower member of the universal testing machine (Model 5ST-Tinius Olsen) (Fig. 3). The specimens were oriented so that the stainless-steel blade of the universal testing machine was parallel to the interface between the substructure and the veneering material (19) Shear force was applied at a crosshead speed of 0.5 mm/min until failure (16,20). The load at which failure occurred was recorded for each specimen.

Failure mode and surface analysis

Following shear testing, all specimens were examined under a stereomicroscope (model Bx45; Olympus Corp.) (using x1.8 magnification) to identify the failure mode (17). Four representative samples from each group were examined under scanning electron microscope (JEOL JSM-5300, JEOL Ltd.) using two levels of magnification (x16 and x80).

Sample specimens were meticulously prepared by sputter-coating with a thin layer of gold to enhance surface conductivity using (Ion sputter

evaporator JFC-1100E-JEOL Ltd.). Imaging was conducted at an accelerating voltage of 20 kV, with a working distance of 28.4 mm and a beam current of 100 pA.

Statistical analysis

Normality was checked using the Shapiro Wilk test and Q-Q plots. Comparison between the two groups was done using independent t-test. Data were analyzed using IBM SPSS, version 23, Armonk.



Figure (1): Plastic mold used for condensation of veneering porcelain powder over the ceramic disks. 1. Plastic mold. 2. Veneering porcelain. 3. Plastic wing to increase mold stabilization and easier handling. 4. Ceramic disk.

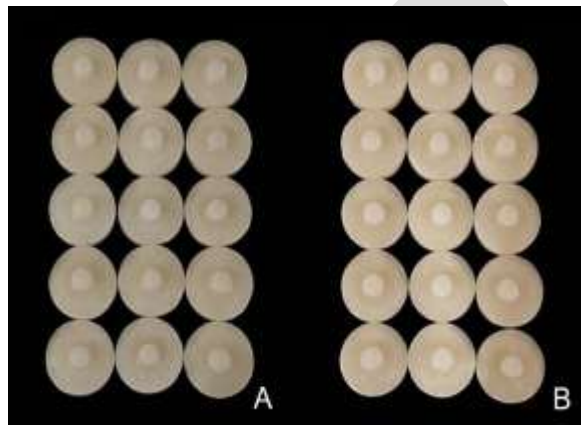


Figure (2): Completed samples of A. E-max press and B. Celtra press.

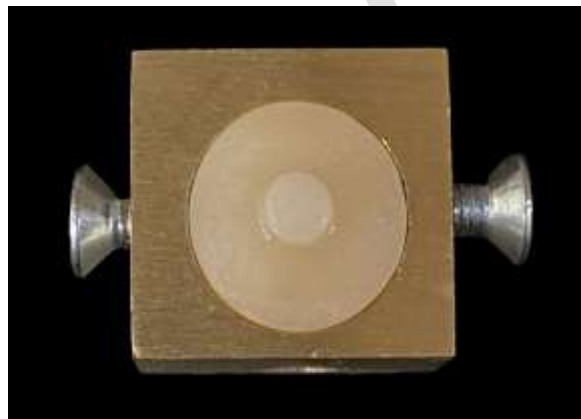


Figure (3): Specimen placed in the mounting jig.

Table 1. Material composition.

Brand name	Ceramic type	Composition	Manufacturer
IPS e.max® press	Lithium disilicate (LDS)	Lithium disilicate crystals (approx. 70%), Li ₂ Si ₂ O ₅ , Embedded in glassy matrix.	Ivoclar Vivadent
IPS e.max® Ceram	Nano-fluorapatite glass-ceramic	low-fusing nano-fluorapatite glass-ceramic	Ivoclar Vivadent
Celtra® press	Zirconia reinforced Lithium silicate (ZLS)	Glass with completely liquified zirconia, Lithium phosphate and lithium disilicate	Dentsply Sirona
Celtra® Ceram	Leucite-reinforced feldspathic ceramic	low-fusing, leucite-reinforced feldspathic ceramic	Dentsply Sirona

Table 2. Pressing parameters.

	start	Heating rate	Final temperature	Holdin g time	pressu re
ZL S	700° C	40°C/m in	870°C	30 min	4.5 bar
LD S	700° C	60°C/m in	920°C	25 min	5 bar

RESULTS

Values were normally distributed; thus data were presented using mean, 95% Confidence Interval, and standard deviation in addition to minimum and maximum As shown in Table 3. Statistically significant difference between the two-glass ceramic core-veneer bond strength ($p < .001$). Stereoscopic microscope.

Images of lithium disilicate specimens showed predominantly cohesive failure, involving both the substrate and the veneering porcelain. While images of zirconia-reinforced lithium silicate specimens showed mixed adhesive/cohesive failure modes. (Fig. 4)

Scanning electron microscope

Images of ZLS specimens from scanning electron microscope showed mixed failures, mainly cohesive failure within the veneering porcelain. While images of LDS specimens showed predominantly cohesive failures within both the substructure and the veneering material. (Fig. 5) (21).

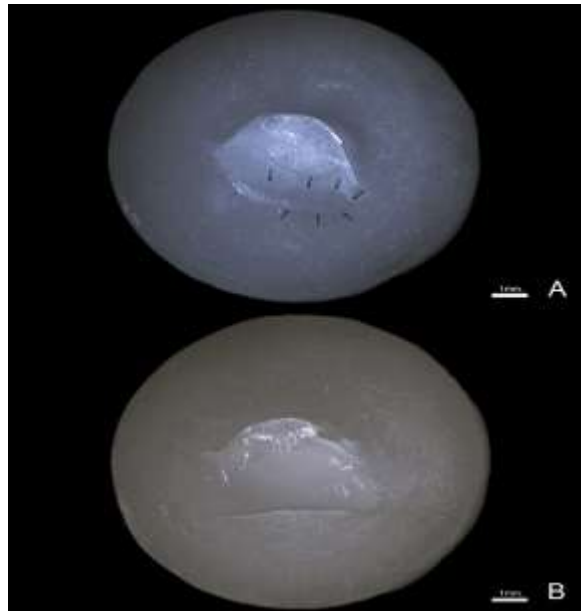


Figure (4): Stereomicroscope image of A. Celtra press sample at x1.8 magnification, showing mixed failures mainly cohesive failure within the veneering porcelain with some sites of interfacial failures at the core-veneer interface. Area of adhesive failure (arrows). B. E-max sample at x1.8 magnification, showing cohesive failure within the veneering porcelain and LDS substructure.

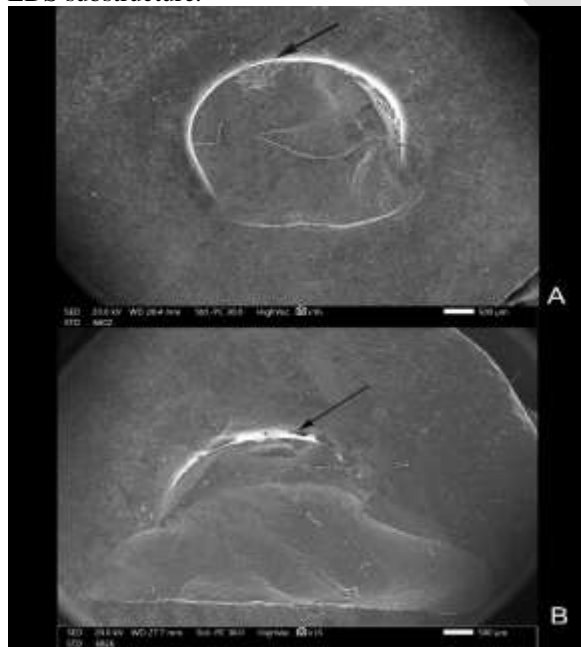


Figure (5): Scanning electron micrographs at x16 magnification of A. Celtra press specimen showing mainly cohesive failure mode within the veneering porcelain, with some sites of interfacial failures at the core/veneer interface. B. E-max press specimen showing cohesive failure within the veneering

porcelain and the LDS substructure, origin of fracture. (arrows)

Table 3. Comparison of shear bond strength (SBS) in MPa between E-max and Celtra.

	E max (n=15)	Celtra (n=15)	Mean Difference
Mean (SD)	29.75 (3.09)	21.96 (2.74)	7.79
95% CI	28.04, 31.46	20.45, 23.48	5.61, 9.97
Min - Max	25.58 – 35.71	18.92 – 28.21	-
Test value (p value)	7.307 ($<.001^*$)		

*Statistically significant difference at $p \text{ value} \leq 0.05$,
CI: Confidence Interval

DISCUSSION

The research aimed to evaluate the shear bond strength (SBS) and mode of failure of two different heat-pressed glass ceramic substructures, namely lithium disilicate (LDS) and zirconia-reinforced lithium silicate (ZLS), when veneered with their corresponding veneering ceramics, fluorapatite glass ceramic (FGC) and leucite-reinforced feldspathic porcelain (LFP), respectively. The results of the study demonstrated that there is a statistically significant difference in the in vitro shear bond strength between the two ceramic systems. Therefore, the null hypothesis, stating no significant difference in shear bond strength between the two materials, was rejected. The shear bond strength (SBS) is a critical mechanical property that directly influences the overall structural integrity of veneered ceramic restorations. The SBS serves as a reliable indicator of the adhesive forces holding together the veneering ceramic and the underlying substructure. Enhancing this bond strength is a fundamental consideration in optimizing the longevity and functionality of veneered ceramic restorations. LDS complex exhibited a higher mean shear bond strength (29.75 MPa) compared to the ZLS complex (21.96 MPa). This finding suggests that lithium disilicate restorations veneered with its corresponding porcelain ceramic may be more resistant to clinical failure and less likely to fail by delamination of the veneering ceramic.

Moreover, the current study found that LDS group showed predominantly cohesive failures, as fracture occurred within both the substrate and the veneering porcelain. This suggests that the core-veneer bond strength exceeded the cohesive strength of both veneer and core materials, which makes it a proper bond according to cohesive plateau theory (22). While ZLS group showed mixed adhesive/cohesive failure mode.

The cohesive failure occurred within the veneering ceramic extending through the core-veneer interface explains the lower load levels recorded in ZLS group. These results agreed with those of Ereifej et al., (23) as in their study, cohesive failure was predominant, involving both the veneering porcelain and the substructure ceramic. Al-Dohan et al., (24) investigated the average shear strength of the core-veneer interface in bilayered all-ceramic systems compared to metal-ceramic systems. The authors found that the highest mean shear strength was recorded for lithium disilicate system. The superior shear bond strength observed in LDS ceramic system can be attributed to the high compatibility of coefficient of thermal expansion (CTE) of the core and veneer materials (25), the careful surface treatment prior to veneering, and the well-formulated firing program of the veneering materials that reduces stresses during cooling.

The study's findings have several clinical implications. Dental practitioners can take advantage of the superior shear bond strength observed in the LDS complex making the material a potentially favorable choice for veneered ceramic restorations. Additionally, the predominant cohesive failure observed in LDS group indicates that the bond between the substructure and veneering porcelain is reliable and robust, providing increased confidence in the long-term success of these restorations.

Given these results, it can be inferred that LDS can be used safely in veneering of anterior teeth with minimal cutback design at the incisal and labial surfaces without the need for extending around the incisal edge as performed earlier in ceramometal restorations. This finding simplifies the cutback design process and reduces concerns about potential delamination.

This strength might not be sufficient in regions subjected to higher occlusal forces, as cohesive failures are more likely to occur within the veneering ceramic. Therefore, monolithic design should be considered to offer high mechanical strength in load-bearing regions to ensure adequate durability and longevity.

However, it is essential to acknowledge certain limitations of this research. The study was unable to investigate the distribution of stress during SBS testing (26). As forces were concentrated at the point of contact between the metal blade and the ceramic disc (27). The study focused solely on in vitro evaluations, and the clinical setting might present different challenges that could influence the bond strength and failure mode.

CONCLUSIONS

The following conclusions were drawn based on the findings of this in vitro study:

The lithium disilicate glass ceramic veneered with its corresponding ceramic showed statistically significant higher bond strength compared to the zirconia-reinforced lithium silicate (ZLS) complex (p value < 0.05).

The mode of failure observed in LDS complex was predominantly cohesive failure. While in ZLS ceramic complex was mixed adhesive/cohesive failure, this indicates a higher bond strength in LDS system that surpassed the cohesive strength of both the heat pressed LDS ceramic and the veneering material.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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