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Evaluation of Shear Bond Strength of Two Glass Ceramic Veneers Fabricated by CAD/CAM Technology (In Vitro Study)

Zakaria Jamal[1*], Bassam Amin[2]

[1]Erbil Directorate of Health, Erbil, Iraq

[2]Department of Conservative Dentistry, College of Dentistry, HawlerMedical University, Erbil, Iraq

*Corresponding author:Zakaria Jamal, Erbil Directorate of Health, Erbil, Iraq

E-mail: Doctor.zakarya@yahoo.com

ABSTRACT

Background and objectives: The purpose of the study was to evaluate and compare shear bond strength of lithium disilicate and zirconia reinforced lithium silicate glass ceramics for fabrication of veneer restoration by CAD/CAM technology.

Materials and methods: Thirty sound human maxillary first premolars with comparable dimensions were used. The teeth were prepared in standardize way for bonding to laminate veneer. Prepared teeth were divided into two groups (n=15/group) according to fabrication of veneer restoration by two different glass ceramics block, group (1); Lithium disilicate glass ceramic, and group (2); Zirconia reinforced lithium silicate glass ceramic. Ceramic veneers of (1) mm in thickness and (5×4) mm in diameter were luted to the tooth surface by using light-curing (RelyX Veneer) resin cement. After cementation samples were subjected to thermal cycling then shear bond strength test was performed in a universal testing machine at 0.5 mm/min until bonding failure.

Results: (G2) Zirconia reinforced lithium silicate showed significantly higher bond strength than (G1) Lithium disilicate glass ceramics (P= 0.02).

Conclusions: The bond strength of restorations depends on the chemical composition and micro structure of the glass ceramics.

Key words: Lithiumdisilicate, Zirconia reinforced lithium silicate, shear bond strength.

INTRODUCTION

In the aesthetic dentistry, the porcelain veneers present the first class clinical conservative modalities. The current literature recognizes them as the state of the art of each auspicious dental practice (Obradović-Đuričić et al, 2014). Dental ceramics are good restorative option attending precepts of smile's function and esthetics (Marques et al, 2010). Among the existing restorative esthetical materials, ceramics has been detached because is the material most similar to the natural appearance of teeth (Aquino et al, 2009). The use of all ceramic prosthesis in restorative treatments has become popular and many of these restorations can be fabricated by both traditional laboratory methods and CAD/CAM machination. The traditional methods of ceramic fabrication have been described to be time consuming, technique sensitive and unpredictable due to the many variables and CAD/CAM may be a good alternative for both the dentists and

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laboratories (Miyazaki et al, 2013).Furthermore, industrially fabricated blocks are more homogenous with minimal flaws and CAD/CAM restorations have been found to compare favourably with other restorative options (Manhart et al, 2004). IPS e.max CAD is a lithium disilicate glass ceramic designed to be used in CAD/CAM technology, it was introduced in 2006 as a material with a flexural strength of 360 to 400 MPa the blocks are blue in the partially crystallized state but it achieves the final shade after it is submitted to the firing process in a porcelain oven for 20 to 25 minutes to complete the crystallization; the final result is a glass-ceramic with a fine grain size of approximately 1.5 µm and 70% crystal volume incorporated in a glass matrix (Culp & McLaren, 2010).

Research focuses on the development of materials that offer a combination of adequate translucency,improved mechanical strength, and optimized timesaving machining (Denry&Kelly, 2014). Among others, a new group of machinable ceramics has recently been introduced for CAD/CAM techniques: zirconia-reinforced lithium silicate (ZLS) ceramics (Suprinity blocks). According to the manufacturers, these materials offer mechanical properties ranging from 370 to 420 MPa. Thus, they are comparable with the clinically well-proven lithium disilicate (LS_2) glass ceramics (Pieger et al, 2014).After crystallization, the presence of zirconia causes a homogeneous texture to form with a mean grit size of approximately 0.5 to 0.7 μm. The formed crystals are 4 to 8 times smaller than lithium disilicate crystallites (Denry&Kelly, 2014).

For the longevity of the porcelain laminate veneers, a vital importance is attributed to the strength and durability of the adhesion complex formed between the three different components: the tooth surface, the resin cement, and the porcelain surface (Peumans et al, 2000). Although clinical trials are the most suitable tools to evaluate the efficacy of the adhesive systems, long term clinical trials are difficult to perform because of the time and rapid developments and changes in the adhesive systems. Therefore, laboratory studies are still largely used to predict the clinical behaviour of dental materials (Perdigao, 2002). The laboratory tests most widely used to examine the bond strengths of the adhesive systems to dental hard tissues are shear and tensile bond strength tests (Pekkan&Hekimoglu, 2009).

MATERIALS AND METHODS

Thirty sound human maxillary first premolars extracted for orthodontic treatment in patients age ranges between (15-20) years were selected for this in vitro study with comparable dimensions by measuring the occluso-cervical and mesio-distal dimensions. After removing the debris with scaler, the teeth were stored in distilled water at room temperature that changed every two days (ISO/TS 11405, 2003). The exclusion criteria was teeth with the caries, restorations, hypo plastic defects and crack as described byLambade et al (2015).

Sample preparation design

All the teeth were mounted individually in manikin during the preparation, the long axis of tooth was parallel in the socket area with the aid of dental surveyor, then the layer of wax was added at the mesial and distal of the tooth in a manikin for fixation of the tooth during the preparation. Prior to tooth preparation a silicone index was reconstructed over the each sample by using condensation polysiloxane impression material to ensure even tooth reduction as described by Guess et al (2013). The preparation of the teeth was carried out using high-speed handpiece attached to a dental surveyor, which allowed standardized preparation. The dental manikin was adapted on the movable table of the surveyor to hold each sample during cutting procedure (Fig1).

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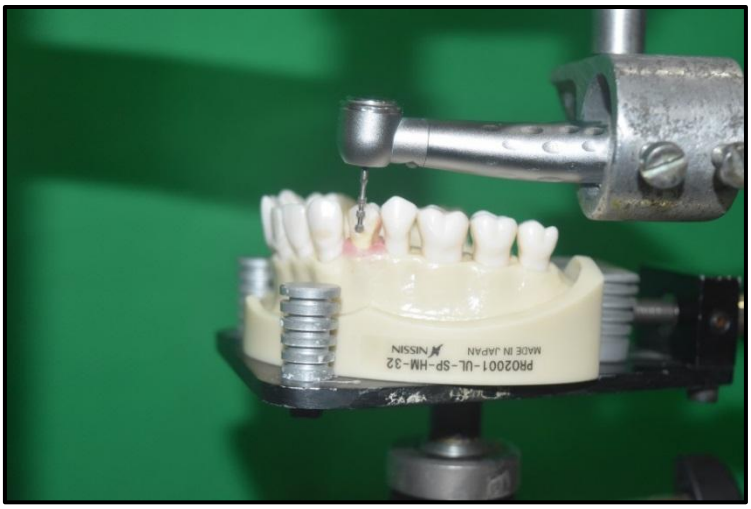

Fig 1: The tooth during preparation

The preparation design for all samples was a window type; the buccal reduction was feathered occlusally to terminate just short of occlusal edge (Matoses& Ruiz, 2014), before preparation the design was drawn on the each sample. Facial surfaces of the teeth were initially prepared by placing depth-orientation groove (0.5 mm in depth) with a self-limiting depth-cutting bur with continues irrigation (Shetty et al, 2010).

The preparation surfaces were painted with a pen, which was insoluble in water. Then the specimens were prepared without exceeding the depth-orientation groove by using round end diamond tapered fissure bur to reduce the remaining buccal tooth structure between the depth cut to provide flat enamel surface area. Preparations were continued until the color was disappeared from the middle third of the painted facial surface as described by Ozturk et al (2013).

The final preparation margin was (5mm length × 4 mm width) in dimension with a chamfer finish line; the finishing line of the preparation was (1mm) occlusal to cemento enamel junction (CEJ) (Fig 2.).

After tooth preparation all (30) teeth were randomly divided into two groups of (15) teeth for each glass ceramics (IPS e. max CAD or suprinity).

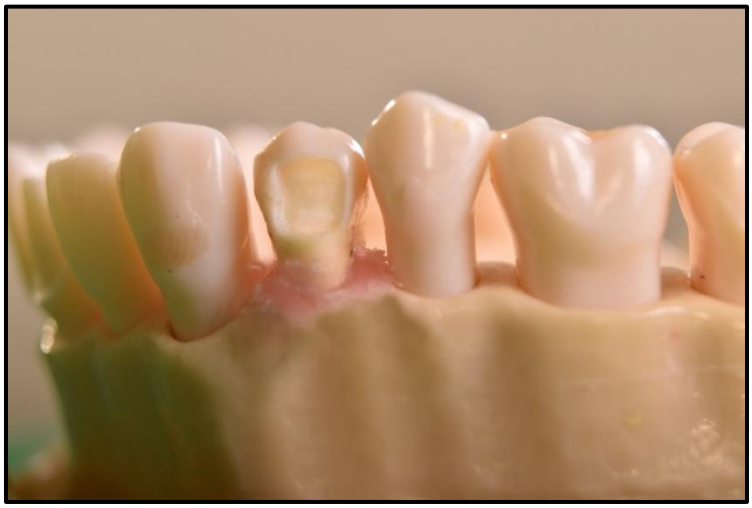

Fig 2: Final preparation design

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2.2.4 Fabrication of ceramic veneer on specimens

The design of the restoration was performed using the software (Zirkonzahn.Scan V3.0.3377) and the milling of restoration was performed by using (Zirkonzahn Milling unit M1).The prepared tooth was placed in the dental manikin that allow accurate placement in the premolar region and fixed with a sticky wax, then the veneers were completed in four phases: firstly, in in "administration" phase, veneer was selected as restoration type from single restoration options. Maxillary first premolar tooth was selected as abutment tooth, the type of materials and manufacture (IPS e. max CAD or suprinity) was defined. Secondly in the "scan" phase; 3D images were obtained by scanning the models by (Zirkonzahn Scanner S6oo ARTI), after coating the prepared tooth with contrast spray.The designing of veneer was then started in "model" phase which the margin of preparation was automatically detected by the system after that, other veneer parameter was defined in "design" phase such as minimum veneer thickness (1 mm) and spacer (50 μm) according to the standard manufacturer's parameters, then it was sent to the CAM nesting software for the milling process in a wet grinding process.

The milling process of the samples started as follows:

A) The selected ceramic block (IPS e.max CAD, A1, high translucent/HT or suprinity A1, high translucent/HT) was inserted in the spindle of the milling chamber of the machine and fastened with the set screw.

B) The milling process was fully automated without any interference with diamond cutting instrument (bur 2.5 mm, 1.25 mm, 0.6 mm) in the shaping process with copious water cooling sprayed from direction of cutting.

Prior to crystallization, the restoration was cleaned thoroughly under running water and dried, then they were placed on the honeycomb tray to be crystallized by Artis (UginDentalre) furnace at (850) ^{o}C for (seven) minutes (dwelling time) for IPS e.max and at (840) ^{o}C for (eight) minutes (dwelling time) for Suprinity, which was full automatically programed by manufacturer specialized for each materials.

Finally all restorations were checked by digital caliper before cementation to guarantee all samples have comparable thicknesses and dimensions as described by Runnacles (2014), then all received veneer restoration was inspected and checked for fitness and adaptation, after that light cure resin cement was used for cementation of all samples according to manufacturer's instruction.All cemented specimens were stored in distilled water at 37°C in incubator for 24 hours before subjected to thermocycling process (ISO/TS 11405, 2003).

Thermocycling

From each groups (15 samples) were subjected to automatic thermocycling device in a de-ionized water for 500 cycles between (5±1°C) and (55±1°C) with a dwell time of (30) seconds in each bath and a transfer time two min per a cycle (ISO/TR 11405, 1994), Then 24 hours after thermocycling, a load test was performed by using a universal testing machine according to Turkaslan et al (2009).

Shear bond strength test

All prepared teeth were mounted in plastic cube mold of (3×3×1.5 cm width, height and depth respectively) which is suitable for the universal testing machine with self-cure acrylic, only buccal surface of crown at level below cemento-enamel junction was exposed. A dental surveyor

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was used to align teeth in acrylic mold that buccal surface oriented perpendicular to its bottom, so it was parallel to force that exerted during debonding procedure.

From each group (15 samples) was selected for shear bond strength test and then the teeth were debonded by using the universal testing machine (TERCO, MT, 3037, Sweden), All embedded samples were placed in a custom made holder and mounted in a universal testing machine jig. The Chisel was fabricated for the force application on the specimen during the shear bond testing procedure. The dimensions of chisel were compatible with the universal testing machine and the chisel width was 0.5 mm used to apply a shearing force to the veneering restoration as close as to interface (ISO/ CD TR 11405, 1991).

The shear force was applied parallel to the adhesive surface of the laminate veneer occlusogingivally (Gresnight et al, 2011) at crosshead speed of 0.5mm/min (Akoğlu&Gemalmaz, 2011) until sample failure was registered (Fig 3). The maximum load at the deboning was recorded digitally by a load cell (20 kN) of machine that connected with a personal computer.

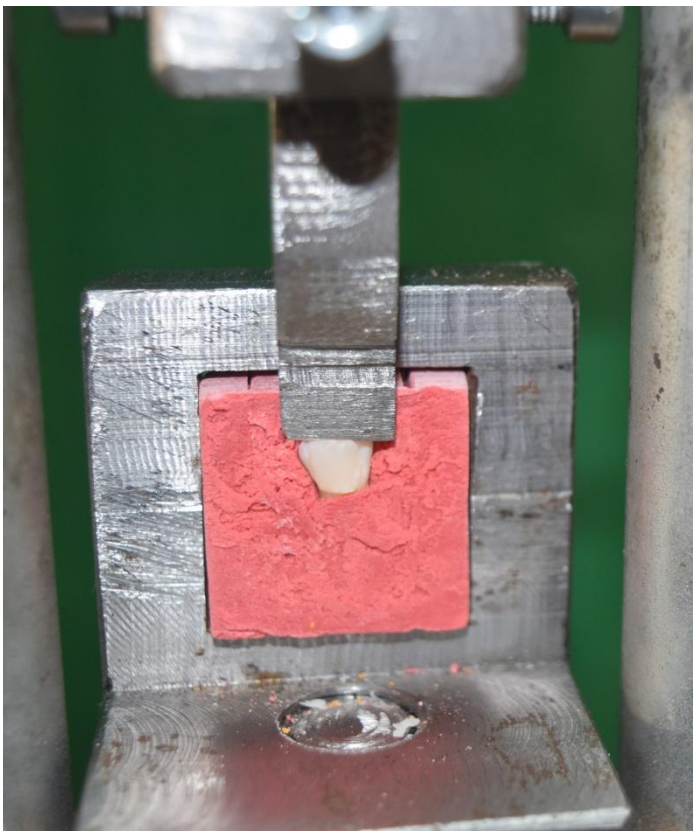

Fig 3: The specimen during testing

Shear bond strength, F/A (force per unit area), was calculated from the recorded failure loads. The force output from the machine was divided by the bonding surface area/adherence area and the results recorded in Megapascals (Mpa = N/mm^2) (ISO/TS 11405, 2003).

Adherence area was calculated for all specimens:

$$\text{Shear stress (MPa)} = \frac{load\ (N)}{Area\ (mm^2)}$$

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Where Area = exacted diameter of bonded surface

The debonded surfaces was visually analyzed by blind examiner under the stereomicroscope 40X (Motic ST-39 series, Japan) magnification to assess the mode of bond failure.The fracture mode was classified as follow based upon the remaining resin on the bonding surface of specimen according to (Lambadeet al, 2015):

- Adhesive failures between the ceramic and tooth surface within the bonding interface.
- Cohesive failures in resin cement and tooth structure.

RESULTS

Difference between different CAD/CAM blocks

The descriptive statistics for the mean and the standard deviations, standard error, 95% confident interval of mean, minimum, maximum values of the SBS between two groups were reported in (Table 1), it was clear that ZLS showed higher mean value which was (241.66 ±29.22 N) (= 12.08 MPa) than that of LS_2 which was (211.86±36.53 N) (=10.59 MPa).

Table 1: The descriptive statistics of SBS values between the groups in N.

Groups	N	Mean In N	Sd.	S.E.	Min.	Max.	95% C. I. M.	
							Lower Bound	Upper Bound
LS_2	15	211.866	36.535	9.433	160.00	265.00	191.634	232.099
ZLS	15	241.666	29.224	7.545	200.00	289.00	225.482	257.850

Consequently Independent Samples t-test showed that there are statistically significant difference between the two groups with respect to SBS (P= 0.020) as it is less than 0.05 (Table 2).

Table 2: Independent Samples t-test between the groups of tested for SBS study

Groups	N	T-Value	P-Value	95% C. I. D.	
				Lower Bound	Upper Bound
LS_2	15	-2.467	0.020	-54.545	-5.055
ZLS	15				

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Mode of failure

In the assessment of failure modes under a stereomicroscope, the results of failure patterns of each group were shown as the frequency distribution of sample in each type of failure mode. The explanation of failure modes after SBS testing of de-bonding are presented in (Table 3) and graphically illustrated at (Fig 4, 5). It was clear that the cohesive failure was in high percentage for both groups especially in ZLS group, while the adhesive failure was the predominant type in LS_2.

Table 3: Percentage of failure mode of experimental groups

Groups	Failure Mode	
	Adhesive Failure	Cohesive Failure
LS_2	40.0%	60.0 %
ZLS	20.0%	80 %

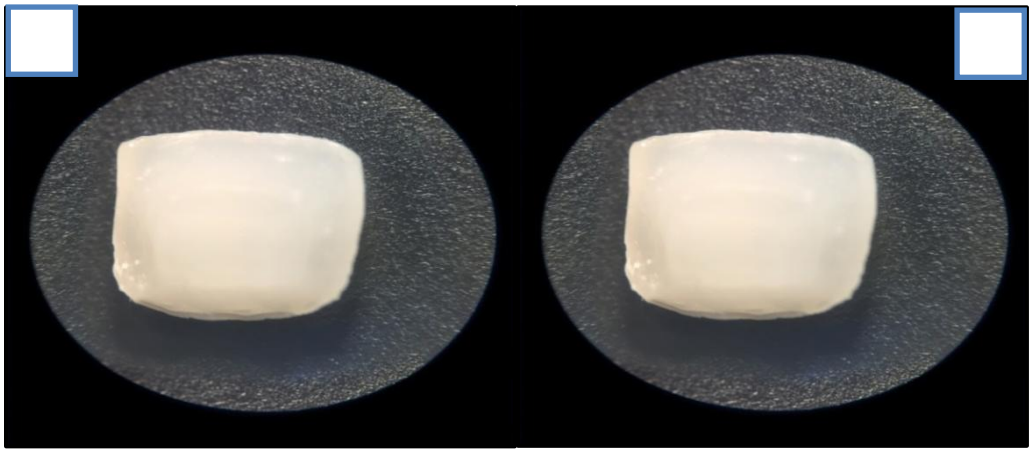

Fig 4 (A, B): Adhesive failure

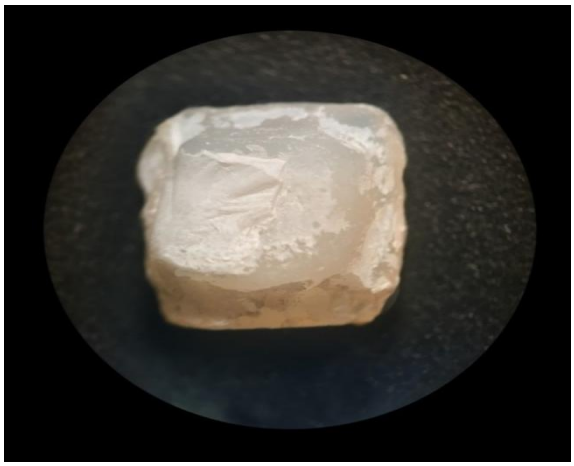

Fig 5: Cohesive failure

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DISCUSSION

Following the demand for tooth-colored, high strength restorations, ceramic systems have been developed with different proportions of glassy and crystalline phases to improve their mechanical properties while maintaining good esthetic properties (Liseet al, 2015). By modifying glass and crystalline content, dental ceramics can be produced with different esthetic and mechanical properties. When silicates concentration is above 15%, ceramics can be classified as "glass ceramic" (Kern, 2015). Within this category, feldspathic, leucite reinforced, lithium disilicate (LS_2) and zirconia reinforced lithium silicates (ZLS) are available for indirect restorations (Sedda et al, 2014; Kern, 2015).

Bonding ceramic restorations to tooth structure rely on a number of factors, including the type of ceramics, treatment of the ceramic surface, selection of a suitable resin luting agent, and appropriate treatment of prepared tooth structure (Bottino et al, 2015). Several factors are involved in the success of resin-bonded ceramic restorations, among which durability and stability of tooth-resin and resin-ceramic interfaces are particularly important. Bond strength at these interfaces should be optimized, as failures in this region can lead to failure of the restoration (Barattoet al, 2015). According to the present study findings, there was significant difference between two groups in regard to bond strength; ZLS has slightly higher bond strength than LS_2 glass ceramic, similar finding was reported by Fonzar (2015); where SUPRINITY showed significantly higher bond strength compared with IPS e.max CAD. According to another study, Aboushelib and Sleem (2014) found that the μ-TBS bond strength of Celtra Duo was higher than that of IPS e.max CAD. Farther more Frankenbergeret al (2015); in their study on evaluate the bonding performance of recently introduced tooth-colored CAD/CAM materials; they showed that significantly higher μ-TBS values for Celtra Duo comparing to IPS e.max CAD.

A possible explanation of this outcome might be found in the composition of both lithia silica-based glass ceramics (Hu et al, 2016). ZLS is a zirconia-reinforced lithium silicate glass ceramic with a mean crystals size of approximately 0.5 μm, whilst LS_2 is a lithium disilicate glass ceramic with a mean crystals size of 1.5 μm; the formed crystals of ZLS are 4 to 8 times smaller than LS_2. In addition, the phosphate monomer of Universal Adhesive can directly bond to zirconium oxides, creating chemical bonds between the resin cement and the ZrO_2- containing glass ceramic (Aboushelib&Sleem, 2014; Hu et al, 2016; Sato et al, 2016). Since ZLS (8.0-12.0) has more zirconia content than LS_2 (0.0-8.0) in the form of solution inside the glassy matrix (Rinkeet al, 2015), it is reasonable to expect different bond strengths between these two materials.

Thermocycling was used to simulate the in vivo aging of restorative materials by subjecting them to repeated cyclic exposures to hot and cold temperatures, in a water baths in a bid to reproduce thermal changes occurring in the oral cavity (ÖzelBektas et al, 2012).Classification of the failure modes in this study was similar to the classification of failure modes reported by Lambadeet al (2015). However, there is still no clear consensus in the literature regarding the classification of the failure modes and distinction between cohesive and mixed mode. Therefore, further researches are needed to distinct the failure modes correctly. In the present study there was difference in the fracture patterns observed between the groups G1 and G2. The percentage of adhesive failure was higher in G1 than in G2, moreover there is relation between high bond strengths and predominance of cohesive type failures within the cement, as higher bond strengths were measured in G2 than in G1.

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CONCLUSIONS

Based on the outcomes and within the limitation of this study, the following conclusions can be drawn:

1- VITA SUPRINITY (Zirconia reinforced lithium silicate glass ceramic) showed significantly higher bond strength compared to IPS e.max CAD (Lithiumdisilicate).
2- The bond strength of restorations depends on the chemical composition and micro structure of the glass ceramics.

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