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COMPARISON OF THE SHEAR BOND STRENGTH OF TRANSLUCENT ZIRCONIA AND LITHIUM DISILICATE CERAMIC FOLLOWING IMMEDIATE DENTIN SEALING

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ABSTRACT

Aim: The purpose of this study was to evaluate and compare the effect of immediate dentin sealing after tooth preparation on the shear bond strength of both Super translucent and Top translucent monolithic zirconia to monolithic lithium disilicate glass-ceramics.

Materials and Methods: Forty-two sound molars were prepared to obtain flat occlusal dentin surfaces and embedded in resin blocks. The specimens were divided into three main groups (N=14) according to type of ceramic material used; 1) Lithium disilicate LD (E.max CAD), 2) Super-translucent zirconia ST (UPCERA), 3) Top-translucent zirconia TT (UPCERA). Each group was subdivided into two subgroups (n=7); (a), no immediate dentin sealing (IDS), (b) IDS after tooth preparation. LD blocks were cut into 14 discs and crystallized according to the manufacturer's instructions. ST and TT zirconia blanks were milled with larger sizes to compensate for shrinkage after sintering. LD Discs were surface treated with 9% hydrofluoric acid (Ultradent Porcelain Etch), followed by a silane coupling agent (Ultradent). The fitting surfaces of TT and ST zirconia samples were treated by airborne-particle abrasion, followed by the application of ceramic primer (iTENA C-RAM BOOSTER). All samples were cemented to teeth specimens with self-adhesive universal resin cement (RelyX Unicem). Thermal cycling was performed at the 5 °C and 55 °C for 5000 cycles. The samples were subjected to a shear bond strength test. Data were recorded and statistically analyzed.

Results: Sub-groups (a); which were bonded without IDS, E-Max CAD group recorded the highest shear bond strength mean value (6.64 MPa) followed by ST Zirconia (6.31 MPa), then TT Zirconia (4.28 MPa). Tukey's post-hoc showed a non-significant difference ($p>0.05$) between E-Max CAD and ST Zirconia, and a significant difference between both E-max CAD and ST Zirconia to TT Zirconia. Sub-groups (b); which were bonded after IDS, E-Max CAD group recorded the highest significant ($P<0.05$) shear bond strength mean value (13.36 MPa) followed by ST Zirconia (10.42 MPa), then TT Zirconia (6.81 MPa). Bonding after IDS recorded a statistically significant ($P<0.05$) higher shear bond strength value than bonding without IDS.

Conclusions: Surface treatment of translucent zirconia by sandblasting and MDP primer showed a reliable bond with resin cement but lower than lithium disilicate ceramic using hydrofluoric acid and silane. The protocol of IDS is recommended before ceramic bonding.

KEYWORDS: Immediate dentin sealing, translucent zirconia, lithium disilicate ceramic, MDP primer, air-borne particle abrasion.

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INTRODUCTION

All ceramics have become the most popular materials required for restoring the lost dental tissues due to their high esthetic quality. The success of any ceramic restoration depends mainly on its esthetic value, strength, and adhesion to tooth structure [1, 2].

Recently, zirconium oxide ceramics have been widely used due to their high flexural strength and high fracture toughness [3]. Unfortunately, zirconia is an opaque in color which limits their use when highly aesthetic restorations are needed [4]. However, many changes in composition and structure were done to zirconia to improve its esthetic properties, by increasing translucency, without altering the mechanical properties. Consequently, being an esthetic material, translucent zirconia offers many clinical indications in manufacturing crowns, veneers, and anterior and posterior monolithic fixed partial denture [5]. Super translucent and Top translucent zirconia have been developed as monolithic esthetic veneer zirconia by increasing yttria up to 9 wt.% and become more cubic in form more than the tetragonal form [6].

Bond strength is an essential factor affecting the clinical performance of ceramic restorations[7], specially with resin cement and through ceramic surface treatment either by mechanical and/or chemical methods such as etching with hydrofluoric acid and sandblasting[8,9]. Lithium disilicate glass ceramics meet both functional and aesthetic demands. They are silica-based ceramics which have high physical and chemical bonding ability to resin cements through conditioning with hydrofluoric acid followed by application of silane coupling agent [8]. On the other hand, zirconia ceramics do not contain a silicon dioxide and so, they cannot be etched or roughened by hydrofluoric acid. Also, application of silane was shown to be unsuccessful in the absence of silica [9].

Consequently, various surface treatment methods were investigated to improve the bond strength between zirconia and resin-based luting agent [10]. airborne-particle abrasion using aluminum oxide (AL_2O_3) particles of different sizes at a high air pressure is a mechanical method which has been reported to provide surface roughening of zirconia[11]. For chemical bonding, a primer containing 10 methacryloyloxydecyl dihydrogen phosphate (10-MDP) monomer has been used as the phosphate ester group of the MDP can bond directly to metal oxide [12].

As dentine adhesion is not applicable in temporary materials, the dentin is exposed to saliva, impression material, and bacteria which results in weak bond strength and pulpal sensitivity[13,14]. However, the application of a resin coating on a freshly cut dentin has been reported in several literatures known as immediate dentin sealing (IDS)[15-17].

Immediate dentin sealing (IDS) includes the application of dentin bonding agent in three steps; etch, rinse and bonding immediately after the preparation of the dentin. The IDS seals the dentinal tubules, reduces bacterial leakage and dentin sensitivity. Furthermore, it seems to achieve less gap formations and improved bond strength [16, 18].

Shear bond strength is one of the commonly test method used in dental materials studies because most of in-vivo bonding failures of restorative materials were due to shear stresses [19, 20]. This study was aimed to assess shear bond strength following immediate dentin sealing of Super translucent and Top translucent zirconia to dentine, compared to lithium disilicate glass ceramic using their corresponding surface treatments and bonding protocol.

MATERIALS AND METHODS

Ceramic materials used in this study were super translucent zirconia (UPCERA), Top translucent zirconia (UPCERA), and lithium disilicate ceramic (IPSs e-max CAD), are shown in Table (1).

TABLE (1): The ceramic materials used in the study

Material	Manufacturer	Composition
Super translucent Zirconia (ST)	UPCERA, Shenzehn, Guangdong, China	ZrO_2+ HfO_2+Y_2O_3 (≥ 99%), yttrium oxide Y_2O_3 (5%), Al2 O_3 (0.5%), other oxides (0.5%)
Top translucent Zirconia anterior (TT)	UPCERA, Shenzehn, Guangdong, China	ZrO_2+ HfO_2 (90%), yttrium oxide Y2 O3 (5.8-9.7%), Al_2O_3 (0.5%), other oxides (2.5%)
IPS e.max CAD Lithium disilicate glass ceramic (LD)	Ivoclar Vivadent Inc., New York, USA	40% Partially crystallized lithium metasilicate crystals embedded in a glassy phase. 70% approximately fully crystallized fine-grain lithium disilicate crystals embedded in a glassy matrix.

Forty-two caries free human mandibular molars were selected with approximate size and stored in saline solution for one week. All teeth were prepared occlusally by using a round diamond bur to create grooves with 2.5 mm depth in the center of buccal, lingual, and proximal grooves. Then, a wheel diamond stone was used perpendicular to the long axis of each tooth to prepare a flat occlusal dentin surface. Preparation of all teeth was performed by the same operator.

Each prepared tooth was placed at its flattened occlusal surface on a glass slab and was surrounded with a 2.5 cm length custom made cube tube holder. An auto polymerizing acrylic resin was mixed and poured into the tube holder with the tooth in its place until curing. A low-speed diamond disc with a water coolant was used to ensure flushing of flat occlusal dentin surface with the acrylic resin mold.

The teeth specimens embedded in the resin blocks were randomly divided into three main groups (N=14) according to the type of ceramic material used in the study; 1) lithium disilicate IPS e.max CAD blocks (ivoclar vivadent AG) (LD) as a control, 2) Super translucent zirconia blocks (Upcera ST), 3) Top translucent zirconia blocks (Upcera TT). Each group was subdivided into two subgroups (n=7). In subgroup (a), no immediate dentin sealing (IDS) protocol was applied. While IDS protocol was applied on the surface of flattened dentin in subgroup (b).

Preparation of ceramic samples:

A total of 42 cuboidal disk-shaped specimens (N=14 for each group) were prepared for this study. For IPS e.max CAD specimens, CAD-CAM blocks (LT, A2, C14) were shaped into cuboids discs (6×6mm length and 2mm thickness) using a precision saw (IsoMet 4000; Buehler, Lake Bluff, USA) under constant water irrigation, then polished with silicon carbide abrasive papers (400, 600, 1200-grit papers; 3M) in a polisher (Metaserv 2000; Buehler). IPS e.max CAD disks were finally crystallized in calibrated porcelain furnace (Programat P310; Ivoclar Vivadent AG) according to manufacturer instructions.

For zirconia specimens, Specimens (3D cuboids 6×6mm length and 2mm thickness were drawn using AUTOCAD (Autodesk, mac, 2017), and exported as STL. file to CAD/CAM software (Sirona inLab CAM SW 18.0), which will be sent to the milling machine. Both 14 super translucent and 14 ultra-translucent zirconia discs were prepared by milling their blanks and cut into discs with 20% larger sizes to compensate for shrinkage after sintering.

The zirconia samples were placed in special sintering furnace (InFire HTC speed; Dentsply Sirona) according to manufacturer instructions. The overall thickness of all specimens was checked and verified to a precision of 0.1 mm with digital calipers (Dial Caliper D; Aura-Dental, Aura an der Saale, Germany). All ceramic specimens were ultrasonically cleaned, in a distilled water for 5 minutes, and air dried to be ready for bonding to their corresponding tooth.

Immediate dentin sealing:

For subgroup (a), No IDS was performed for randomly selected 21 teeth samples. While IDS was applied on 21 freshly cut flattened teeth specimens of subgroup (b) by using a three-step adhesive system (Etch, Rinse, and bond) according to the manufacturer's instructions.

Etching was performed with phosphoric acid gel 37% (Ivoclar Vivadent AG, Liechtenstein) which was applied for 15 seconds on dentin surface, followed by rinsing with copious amount of water spray. Then, each tooth surface was dried by air spray and bonding agent (ADHESE Universal, Ivoclar Vivadent AG, Liechtenstein) was applied by a micro brush, thinned and light cured for 20 seconds.

Bonding of ceramic samples:

For IPS e-max CAD group, the fitting surfaces were etched using 9% hydrofluoric acid (Ultradent Porcelain Etch, Ultradent Products, Inc USA) for 60 seconds, then rinsed and air dried. A silane coupling agent (Ultradent Products, Inc USA) was applied to each disc surface for 60 seconds and allowed to evaporate completely.

For all zirconia samples, the fitting surfaces were treated by sandblasting using AL_2O_3 particles of 50µm size and 2.5 bar pressure at a 10 mm distance for 15 seconds. The samples were cleaned for 30 minutes and left to dry [10]. Then, a ceramic primer (iTENA C-RAM BOOSTER, France) was applied for 30 seconds.

All disc samples of each group were cemented to teeth specimen subgroups using self-adhesive universal resin cement (RelyX Unicem, 3M ESPE, St. Paul, MN, USA). Cementation protocol was performed according to the manufacturer's instructions. All specimens were loaded with 5 kg weight and light cured for 40 seconds.

Thermal cycling:

All samples were subjected to thermal circulation in water baths at the 5 °C and 55 °C for 5000 cycles with dwell time 30 seconds and transfer time 20 seconds [21].

Shear bond strength test:

Shear bond strength was measured by a universal testing machine. Each specimen was mounted, and the load was vertically applied by the chisel head at ceramic-substrate interface with a constant cross-head speed of 0.5mm/minute. The maximum load result in debonding was recorded in Newton (N) using computer software (NEXYGEN-MT; Lloyd Instrument). The shear bond strength was expressed in Megapascal (MPa) by dividing the load (N) on the bonding surface area (mm^2).

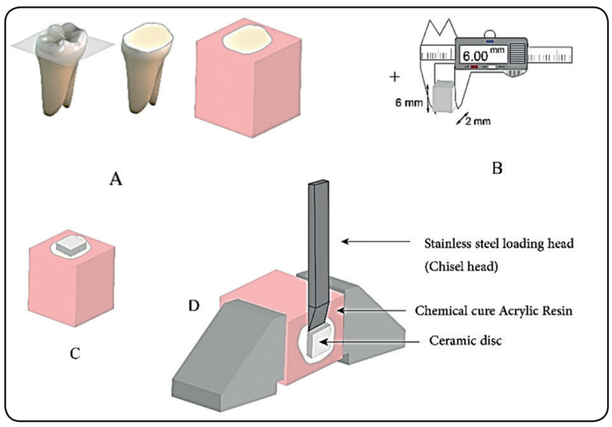

Fig. (1) Schematic presentation of prepared specimens and shear bond strength testing. A: Preparing a flat dentin surface in mandibular molar and acrylic resin block. B: Verifying measurement of ceramic disc. C: Cemented ceramic disc in the tooth specimen. D: Load application in universal testing machine.

Statistical analysis:

Data were analyzed using Statistical package for Social Science (SPSS) version 22.0., Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage. The shear bond strength values were analyzed with one-way analysis of variance (ANOVA) to compare between material groups with a 5% significance level, followed by post-hoc test for pairwise comparison of groups, when the ANOVA test is positive. Independent-samples t-test of significance was used when comparing between two subgroups. Differences were considered significant at P<0.05.

RESULTS

The mean values and standard deviation of shear bond strength of the tested groups in (MPa) with or without immediate dentin sealing (IDS) are summarized in table (2) and graphically drawn in figure (2). ANOVA showed a highly significant differences between the groups (P < 0.001), as shown in table (3).

TABLE (2): Shear bond strength results (Mean values ±SD) for the experimental material groups (MPa) With and without IDS

Material group	Mean± SD		t-test	P value
	Subgroup (a) No IDS	Subgroup (b) IDS		
E-Max CAD	6.64 ±0.83a	13.36±0.9 c	14.53	< 0.001
ST Zirconia	6.31 ±0.73a	10.42±1.27d	7.39	< 0.001
TT Zirconia	4.28±0.54b	6.81±0.85 e	6.63	< 0.001

Different letters indicating significant between groups (p<0.05). non-significant (p>0.05), significant (p<0.05)

TABLE (3): Results of analysis of variance (ANOVA)

ANOVA	F	P-Value
Between Groups with IDS	71.3	< 0.001
Between Groups with NO IDS	22.67	< 0.001

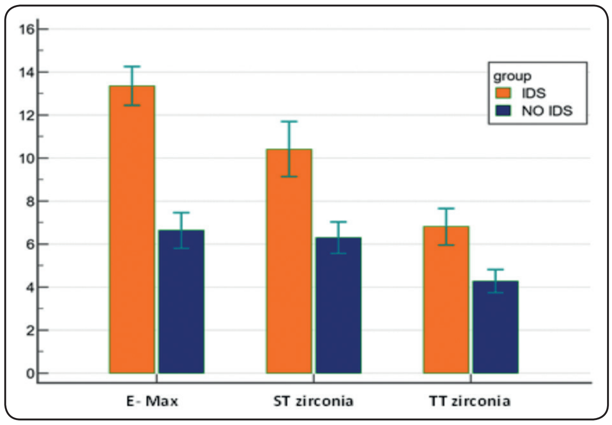

Fig. (2): Bar chart showing mean values of shear bond strength for experimental material groups With and without IDS

For all (a) sub-groups which were bonded without IDS, it was found that E-Max CAD group recorded the highest shear bond strength mean value (6.64 MPa) followed by ST Zirconia (6.31 MPa). While UT Zirconia recorded the lowest shear bond strength mean value (4.28 MPa). The difference between groups was statistically significant as indicated by ANOVA test (p< 0.001). Tukey's post-hoc showed non-significant (p>0.05) between E-Max CAD and ST Zirconia.

For all (b) sub-groups which were bonded after IDS, it was found that also, E-Max CAD group recorded the highest shear bond strength mean value (13.36 MPa) followed by ST Zirconia (10.42 MPa). While UT Zirconia recorded the lowest shear bond strength mean value (6.81 MPa). The difference between groups was statistically significant as indicated by ANOVA test (p< 0.001) followed by Tukey's post-hoc tests.

For comparison of each ceramic group, it was found that bonding after IDS (subgroup b) recorded statistically significant (P<0.05) higher shear bond strength value than bonding without IDS (subgroups a).

DISCUSSION

Fixed dental restorations should mimic the natural teeth in function and esthetics. Recently, newly developed translucent zirconia ceramics were introduced to meet both strength and esthetic for dental restorations. In this study, both Super translucent and Top translucent monolithic zirconia were selected and compared to monolithic lithium disilicate glass ceramics for shear bond strength without and after immediate dentin sealing. The natural teeth were used in order to simulate the clinical situations.

To improve the bond strength of zirconia to resin cement, a zirconia primer was applied after air abrasion surface treatment(22). Air abrasion was done for translucent zirconia by using AL_2O_3 particles of 50µm size which is adequate for micromechanical interlocking with resin cement (23). Özcan et al (24) Found that the highest roughness of zirconia using air particle abrasion was obtained by using 50µm AL_2O_3. A zirconia primer containing 10-methacryloyloxydecyl dihydrogen phosphate (MDP) was used in this study. As mentioned before, it was applied to air abraded zirconia to strengthen the bond with resin cement (25). Yoshida et al (26) confirmed that 10-MDP molecules develop chemical bonds with the remaining hydroxyapatite crystals, which is more resistant to biodegradation at the adhesive interface.

Thermocycling was applied using 5000 cycles before test, which was shown to simulate aging inside the patient mouth for six months (21). Furthermore, the bond strength after thermal cycling might be affected (8).

To obtain a proper bonding between ceramic and tooth, the luting agent should bond to both the two different substrates. The result of this study revealed that immediate dentin sealing before ceramic cementation provided significantly higher shear bond strength than that without IDS. The results were agreed with the finding of Choi Y-S et al (27) who stated that immediate dentin sealing provided an integrated sealing coat on the surface of dentin with better marginal adaptation between ceramic and dentin. The applied IDS generated a dentin-resin hybrid layer which developed the bond strength of dentin bonding agent. Also, Magne (16) recommended sealing the freshly cut dentin surfaces using dentin bonding agent immediately after tooth preparation and before taking impression. He confirmed that the bond strength of indirect ceramic restorations will be improved.

The results showed also higher shear bond strength values of lithium disilicate ceramic to resin cement than the other two translucent zirconia in the study. E-max CAD is silica-based glass-ceramic which can be bonded through micro-mechanical and chemical bonding. Acid etching with hydrofluoric acid creates micro retentive surface porosities in which the bonding agent can flow and engage. Also, it changes the surface energy and increases wettability for bonding of lithium disilicate ceramic (28). Moreover, the applied silane reacts with the contained silica producing chemical bonds that results in development of organic layer at the lithium disilicate surface. Consequently, the bond strength to resin cement will be increased at the resultant cross-linking interface (29).

The results were in accordance with Li et al (8) who found that the combination of micromechanical interlocking and chemical bonding is more effective to resist damage of the bond strength between luting agent and surface of lithium disilicate induced by expansion or contraction during thermal cycling. Furthermore, ST and TT zirconia are oxide ceramics which are not etchable, instead they are sandblasted producing surface roughness without small porosities that create micro retention (30). On the other hand, Kwon et al (31) in their in vitro study compared the bond strength of translucent zirconia and lithium disilicate. They found no statistically significant difference between them and confirmed that an efficient bond of translucent zirconia to resin cement was attained after alumina airborne-particle abrasion and MDP-containing primer application.

They explained that the bond strength of both materials was reduced due to water storage of samples.

The mean bond strength of super translucent zirconia was significantly higher than that of top translucent zirconia either with or without IDS. TT zirconia contained about 5.8-9.7% yttrium oxide and has more cubic structure than ST zirconia which is more tetragonal and less containing yttrium oxide (5%). The more tetragonal structure of ST zirconia contains more oxygen ions permits more reactivity to MDP primer than the cubic structure of TT zirconia [10].

CONCLUSION

Within the limitation of the current study:

- Type of ceramic restorative material and surface treatment affect shear bond strength.
- Surface treatment of translucent zirconia using sandblasting with 50-µm alumina particles followed by MDP primer showed a reliable bond with resin cement but lower than lithium disilicate ceramic using hydrofluoric acid and silane.
- The protocol of IDS is recommended before ceramic bonding.

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