Influence of Immediate and Delayed Dentin Sealing on Bonding Strength of Lithium Disilicate Glass Ceramic: An in vitro Study

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Abstract

Objective: To investigate the influence of immediate and delayed dentin sealing technique on shear bonding strength (SBS) of the lithium disilicate glass-ceramic on tooth structure with different depths.

Methods: The buccal surfaces of 40 maxillary first premolars were prepared with two different depths (1 mm and 1.5 mm) and two different timings for bonding (immediate and delayed dentin sealing). G1 (1 mm preparation) and G2 (1.5 mm preparation) were treated with bonding (Tetric N-Bond Universal, Ivoclar.2021, Schaan/Liechtenstein) two weeks after preparation, before cementation to the ceramic block with delayed dentin sealing (DDS), while G3 (1 mm preparation) and G4 (1.5 mm preparation) were treated immediately after preparation with bonding and immediate dentin sealing (IDS). All specimens were stored in artificial saliva (Biotene dry mouth, GSK group, Canada) for two weeks at 24°C. Forty lithium disilicate glass-ceramic rectangular blocks (Rosetta SM) (HASSBIO, Korea) with dimensions of (2 mm height, 2 mm width and 3 mm thickness) were prepared. After preparation of the tooth surfaces, all prepared blocks were cemented to the prepared teeth in groups G1 and G2 with phosphoric acid 37% for 15 seconds, and all ceramic fitting surfaces were treated with 10% hydrofluoric acid for 20 seconds and coupling agent monobond, then aging was performed for 5000 cycles in artificial saliva from 5-55 °C for all specimens. A universal test machine was used to test the shear bond strength (SBS). The statistical analysis was done using a one-way ANOVA test followed by Tukey's post hoc test (p<0.05).

Results: The result revealed that IDS and minimum preparation depth had significantly higher bonding strength than DDS. Bonding strength in sequence was 15.50 ± 3.873 MPa in G3 and G4 8.25 ± 3.344 MPa, while for delayed dentin sealing the bonding strength was 7.75 ± 2.993 in G1 and 6.25 ± 2.125 MPa in G2.

Conclusions: Teeth treated with IDS immediately after preparation showed significantly higher bonding strength than those treated with DDS for indirect ceramic restoration. Also, increase in the depth of the preparation toward the dentin led to a decrease in the bonding strength of the restoration.

Keywords: Bonding, Cementation, Ceramic, Immediate Dentin Sealing.

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Introduction

The principles of adhesive dentistry date back to 1955, when Buonocore proposed that acids could be used as a surface treatment before applying resins using industrial bonding techniques. The author subsequently found that etching enamel with phosphoric acid extended the duration of adhesion of restoration under water. The ability of restorative materials to bond reliably to enamel is now widely accepted, but as Buonocore suggested in 1963, the adhesion of our restorative materials to dentin has proven more elusive. The aids of the adhesive system help the dentist shift from conventional restoration to minimal invasive restoration to maintain the patient's natural tooth structures while providing optimal bonding, strength, and retention. Till now, there have been eight generations of adhesive systems, all of which aim to provide better strength of bonding to tooth structure.

IDS and DDS are two techniques used to apply bonding agents for prepared teeth for indirect restoration. IDS involves applying adhesive resin coating to the freshly cut dentin after preparation and before taking the impression, while for delayed dentin sealing, the adhesive resin coating is not applied to the freshly cut dentin. The impression will be taken directly after the preparation, without surface treatments. There are several advantages to IDS, such as patient satisfaction during the temporary stage, less necessity for anesthesia at the cementation date, and decreased post-cementation sensitivity. It also offers enhanced bond strength and retention, mainly for tapered teeth with short crowns, and least removal of tooth mass.

Dental ceramic is a widely used material for indirect restoration that improves both function and esthetics. Ceramic restorative materials are divided into three groups based on the presence of particular properties in their formulation (Glass-matrix ceramics, Polycrystalline ceramics and Resin-matrix ceramics). Ceramic restorations are made using a variety of techniques. These methods range from a simple traditional method, in which a ceramic slurry is applied to platinum foil or a refractory die, to a relatively new method, in which computer software (e.g., CAD/CAM) is used to design and manufacture the restoration, and hot press technique. Dental ceramics with high fracture resistance, such as lithium-disilicate, now provide the option of replacing unnecessary loss of tooth material with minimally invasive procedures.

The influence of preparation depth on bonding strength of the indirect resin bonded restoration, enamel and dentin matrices differs in terms of their construction and structure. As a result, these tissues’ adhesion mechanisms are also different. Dentin includes 12% water, 18% organic matrix, and only around 65-70% hydroxyapatite by weight, in contrast to enamel's 90–96% mineral content. Additionally, its composition changes with dentin depth. Even when the same bonding substance is employed, enamel's bonding efficacy is higher than that of dentin.

The adhesive ability of a restoration, which can be measured by bond strength testing, determines its longevity to some extent. A good bond strength test should be accurate, clinically reliable, and less technique dependent. It should necessarily involve the use of relatively simple and low-cost test protocols. Static tests are divided into macro-tests with bond areas greater than 3mm² and micro-tests with bond areas less than 3mm².

In this study, the author investigates the effect of immediate and delayed dentin sealing on the bonding strength of glass-ceramic restoration to tooth structure within different cutting depths. The null hypothesis of this study is that immediate dentin sealing and preparation depth do not affect the bonding strength.

Materials and methods

On 9/11/2021, the Ethics Committee of the Dentistry College, University of Suleimani accepted the current study, with no. 21/72. The power estimate revealed that the sample size for each group should be a minimum of 9 samples based on data from a previous study. In this investigation, ten teeth were chosen for each group.

Teeth collection and acrylic blocks

Forty sound human upper first premolar teeth were collected; all teeth were extracted for orthodontic treatment purposes. A hand scaler was used to remove soft tissue and the teeth were stored in distilled water at room temperature. The collected teeth were checked using a stereomicroscope 20x for any cracks or defects. Preapical x-rays were taken for all teeth to determine the thickness of enamel and to exclude the non-conforming teeth. It was concluded that the average location of the dentin-enamel junction was at (1.2 – 1.5 mm) in the middle third of the buccal surface. The specimens were fixed in cylinder acrylic blocks (Cold Cure – Dravlon,2021, India) of dimensions (30 mm length and 10 mm diameter) to be fitted into the universal test machine.

Teeth preparation and surface treatment

The buccal surfaces for the first 20 teeth were cut with a Tri-wheel depth cutter bur (1mm) (Lusterdent preparation set, Lusterdent, Italy) using a high-speed handpiece with water coolant, and the guide grooves were colored using a pencil. The buccal surface of the
teeth between the grooves was flattened using a straight flat-ended diamond bur at high speed (Lusterdent preparation set, Lusterdent, Italy), with each bur used only for preparation of 10 teeth. The other twenty teeth were cut at 1.5 mm toward the dentin area using a Tri-wheel depth cutter bur (1.5mm) and straight-flat-ended diamond bur at high speed with water coolant. Each twenty prepared teeth were divided into two groups: G1 (1mm prep.) and G2 (1.5 mm prep.). Preparation for these groups was done by installing a turbine onto the dental surveyor to provide preparation with a standardized parallel surface, and applying the bonding agent after two weeks (DDS), before cementation to the ceramic block. For the other two groups, G3 (1 mm prep.) and G4 (1.5 mm prep.), the teeth were treated with IDS as shown in Figure 1, by following the protocol of placing Phosphoric acid gel 37% (Ivoclar Vivadent AG, 2021,Schaan/Liechtenstein) onto the coated teeth’s surfaces for 15 seconds, then rinsing with water and drying. The bonding agent (Universal, Ivoclar Vivadent AG, 2021, Schaan/Liechtenstein) was applied to the tooth surface with a micro brush and light cured for 20 seconds (Woodpecker O Light Cure, China). All teeth were stored in artificial saliva for two weeks at 24 °C (Biotene, GSK group, Canada) in cylinder lab containers.

Ceramic block fabrication

Auto-Cad software (AutoCAD 2020, version 23.1) was used to prepare rectangular blocks with dimensions of 2mm length x 2mm width x 3mm thickness. The Auto-Cad design file was transformed to STL and sent to the CAM machine (Inesicore 150i pro, Ines-core GmbH, 2020, Hessen, Germany) for milling of the blocks using lithium disilicate glass-ceramic blocks (Rosetta SM - LT C14 / W2). Every six blocks were placed together in the CAM machine, as shown in Figure 2. The prepared blocks were placed inside the furnace (program at p310, Ivoclar vivident / 2017, Austria) to undergo a crystallization procedure for 15 minutes at 840 °C temperature, according to the manufacturing company's instructions.

Preparation of fitting surface and teeth

All the prepared blocks were placed inside an ultrasound device (Easy Home ultrasonic cleaner, China) filled with distilled water for 60 seconds and then dried with an air syringe. Hydrofluoric acid was applied to the fitting surface of the blocks at 10% concentration for 20 seconds, then the surfaces were rinsed with water for the same time as the etching and dried with an air syringe. After that, a mono-bond plus universal primer was applied on the fitting surface for 60 seconds and dried with an air syringe. For groups G1 and G2, acid etch 37% phosphoric acid (Ivoclar Vivadent AG, 2021, Schaan/ Liechtenstein) was applied on the prepared surface for 15 seconds, then washed with water and dried with an air syringe. The bonding was applied on the etched surface and cured for 20 seconds, while for groups G3 and G4, teeth were just washed with water and dried with an air syringe.

Cementation of the restoration

The dual cure resin cement (Variolink-DL, Ivoclar Vivadent AG, 2021, Schaan/ Liechtenstein) was placed on the fitting surface of the glass ceramic blocks and the blocks were placed on the middle third of the prepared surface of the teeth under perpendicular pressure of 1000 grams that was applied to the top of the ceramic block surface using the surveyor for 5 minutes, with the sample fitted on the tray of the surveyor using adjustable screws. All the excess was removed using a micro-brush. Light curing of the cemented block was done for 40 seconds on each surface using a light cure device (LED curing light), as shown in Figure 3.

Aging of the samples and shear bonding test

After the cementation of the prepared blocks to the teeth's surfaces, all the samples were stored in artificial saliva for 24 hours at room temperature. The aging process in this study consisted of thermocycling using artificial saliva (Biotene, GSK goupe, Canada) for 5000 thermal cycles (between 5°C and 55°C). The thermocycling machine had two baths: one hot and one cold. The hot bath had a boiler and a thermostat to keep the temperature at 55±2 degrees Celsius. The cold bath had a refrigerator compressor and a thermostat to keep the temperature at 5±2 degrees Celsius. The samples were placed in a basket connected to a handle to automatically transfer the basket between baths, for 30 seconds in each bath and a 3-second gap between baths. By inserting one probe in the hot bath and one probe in the cold bath, a thermocouple (HT-9815 Thermocouple Thermometer) was used to monitor the temperature of the baths. A universal testing machine (UTM) (TERCO company, MT3037, Germany) was used for the SBS test. The samples were fixed in a vertical position with a metal jig, and the load was applied vertically by pin with chisel head (3mm) at the ceramic block. At 1.0 mm/min crosshead speed until failure, as shown in Figure 4. The shear bonding strength was defined as the bonding area divided by the fracture load. The statistical analysis was done using a one-way ANOVA test followed by Tukey's post hoc test (p<0.05).
Immediate dentin sealing and bonding strength

Figure 2: The designed lithium disilicate block being prepared for milling using CAM machine (CORiTEC 150i PRO, Germany).

Figure 3: Cementation protocol for preparing the lithium disilicate blocks: A: The prepared blocks inside the ultra-sound device, B: Hydrofluoric acid 10% application, C: Mono bond application, D: Resin cement application, E: Removing excess cement, and F: Light curing.

Results

The descriptive statistics for mean values and standard deviation of shear bonding strength in MPa for all four groups revealed that group G3 had the highest bonding strength (15.50 ± 3.873 MPa) compared to the other groups, while group G2 had the lowest bond strength (6.25 ± 2.125 MPa). The ANOVA test conducted to compare the groups revealed significant differences between the four groups (p<0.05), as shown in Table 1. Tukey’s post hoc test was conducted to compare the groups as shown in Table No. 2. The test shows no significant differences between G1 and G2, G1 and G4, and G2 and G4 at p>0.05. In contrast, significant differences were observed between G3 and G1, G3 and G2, also G3 with G4 at p<0.05.
**Table 1:** ANOVA test to compare fracture resistance among groups.

<table>
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<tr>
<th>Groups (MEGAPASAL)</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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<tr>
<td>Between Groups</td>
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<td>3</td>
<td>170.573</td>
<td>17.207</td>
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</tr>
<tr>
<td>Within Groups</td>
<td>356.875</td>
<td>36</td>
<td>9.913</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>868.594</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Table 2:** Tukey’s post hoc test.

<table>
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<tr>
<th>Tukey’s post hoc test</th>
<th>Groups</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
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<td>Tukey’s post hoc test</td>
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<tr>
<td>Tukey’s post hoc test</td>
<td>G I vs G III</td>
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<tr>
<td>Tukey’s post hoc test</td>
<td>G I vs G IV</td>
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<td>G II vs G III</td>
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<tr>
<td>Tukey’s post hoc test</td>
<td>G II vs G IV</td>
<td>0.495</td>
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<td>Tukey’s post hoc test</td>
<td>G III vs G IV</td>
<td>0.000</td>
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**Discussion**

This study aimed to determine the effect of immediate dentin sealing on the shear bonding strength of lithium disilicate glass-ceramic restoration to the tooth surface. The material used for indirect restoration construction (veneer, inlay, or onlay) is glass ceramic lithium disilicate. Lithium disilicate is translucent enough to be used in aesthetic applications. Alumino-silicate glass containing fluorapatite crystals rather than leucite is also used in lithium disilicate glass ceramics, giving this material a high strength and fracture toughness in the range of 400 MPa. 26

For many years, only one manufacturer produced CAD/CAM lithium disilicate ceramic blocks (Ivoclar Vivadent, Schaan, Liechtenstein). However, recently (Rosetta SM, Hass, Gangneung, Korea) has produced them. Ahmed et al. 27 stated that there are no significant differences between the Rosetta SM and IPS emax CAD-CAM lithium disilicate-based ceramics because they have identical crystalline structures with comparable intensities and similar fracture resistance and bond strength.

The test results for the study groups show that G3 (immediate dentin sealing with 1mm preparation thickness) had the highest bonding strength (15.50 ± 3.873 MPa), while the lowest result, found in G2 (delayed dentin sealing with 1.5 mm preparation thickness), was 6.25 ± 2.125 MPa. These findings are consistent with previous studies 9,21,23 that stated that immediate dentin sealing has a higher bonding strength than delayed dentin sealing. 21 It was concluded that immediate dentin sealing had bonding strength of 13.36 ± 0.9 MPa, while the delayed dentin sealing method
had bonding strength of 6.64 ± 0.83 MPa. Another study\(^9\) concluded that immediate dentin sealing with enamel-only preparation improves bonding strength when compared to delayed dentin sealing with dentin involvement. Also,\(^{23}\) a further study reported the same result of higher bonding strength for immediate dentin sealing at 18.10 ± 0.67 MPa as compared to delayed dentin sealing at 12.47 ± 2.51 MPa.

The immediate dentin sealing protocol has been proposed as an effective method of sealing exposed dentin to improve restoration bonding strength, reduce bacterial contamination, and reduce tooth sensitivity during the provisionalization phase.\(^{26-30}\) A single coat of adhesive agent applied directly to the exposed dentin after preparation before cementation should be beneficial for improving resin cement-dentin bonding strength.\(^{31}\) This study revealed that immediate dentin sealing is more effective than delayed dentin sealing in reinforcing the bond strength of indirect glass-ceramic restoration, which was consistent with many previous studies,\(^{28,32-34}\) and preparation depth plays a significant role in determining the bonding strength of the restoration. Bonding of the restoration to the enamel surface is higher than bonding to dentin; therefore, minimum amount of thickness of the tooth preparation led to better bonding strength, a finding which is supported by the Gresnigt et al.\(^9\) study.

In this study, artificial saliva was used instead of distilled water as a storage medium at 24 °C for two weeks to provide an environment similar to the patient's mouth because the artificial saliva solution has higher mineral contents of (Ca - 5.08), (K - 519.56) and (Na - 82.02) and also higher PH than distilled water.\(^{35}\)

Using the biotin solution for storage and thermocycling significantly affects the storage and aging process, as proven in the Asli Secilmis et al.\(^{36}\) study. The aging process in this study consisted of thermocycling for 5000 thermal cycles (between 5°C and 55°C) that aged the inside of the patient's mouth by 4 to 5 years. The effect of thermocycling has a significant impact on long-term predictability. As a result, all of the tested samples received standardized thermal stress.\(^{20,23}\)

The null hypothesis for this study was that immediate dentin sealing and preparation depth have no statistically significant effect on the bonding strength of indirect glass-ceramic restoration. According to the obtained results, immediate dentin sealing and minimal preparation thickness result in higher bonding strength; hence, the null hypothesis was rejected with a significant difference (p<0.05).

This study results indicated that immediate dentin sealing with minimal preparation thickness could provide high shear bonding strength when combined with sealing the freshly cut tooth surface with a dental bonding agent after preparation and before taking impressions.

The limitations of this study include a lack of instrumentation and materials; the shear test machine was large in comparison to the current sample, and it would have been preferable to check the shearing force with a smaller machine. Another limitation was the use of a small ceramic block (Rosetta SM- C14); it would have been preferable to use the Rosetta SMP9810 disc, which would have made it easier to mill the ceramic block. Recommendations for future research include determining the influence of immediate and delayed dentin sealing on microleakage, as well as testing the micro-tensile bonding strength.

**Conclusion**

Within the limitations of this in vitro study, IDS showed more bonding strength for glass ceramic indirect restoration than DDS. The bonding strength of the restoration will be higher if preparation stays within the enamel surface, since less dentin exposure results in higher bonding strength.

**References**


