Influence Of Post-Immediate Dentin Sealing Surface Treatment On Shear Bond Strenght Of Lithium Disilicate

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ABSTRACT

Background: *Immediate Dentin Sealing (IDS) is a conservative procedure performed to protect the exposed dentin surface after tooth preparation, especially for indirect restorations. Post-IDS surface treatment methods can help enhance the bonding strength. The research aims to investigate the influence of different post-IDS surface treatment on the shear bond strength of lithium disilicate.*
Method: *The study involved 30 upper premolar teeth, divided into three groups. After crown portion buccal surface preparation, all samples underwent IDS, followed by immersion in water and 24-hour incubation. Subsequently, each group received a specific surface treatment: Group I with nylon brush, Group II with nylon brush + pumice, and Group III with sandblasting using aluminum oxide. Lithium disilicate was then cemented on all samples, followed by another 24-hour incubation before shear bond strength testing. Shear bond strength values in MegaPascals (MPa) were analyzed using one-way ANOVA and post hoc Games-Howell tests with a 95% confidence level.*
Result: *The statistical analysis revealed a significant influence of the different treatment groups on shear bond strength ($p < 0.05$).*
Conclusion: *this study demonstrates a significant impact of varying post-IDS surface treatments on the shear bond strength of lithium disilicate.*

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INTRODUCTION

Indirect restorations are a type of restoration commonly used to replace the structure of the dental crown. Examples of indirect dental restorations include jacket crowns, bridge prostheses, endo crowns, inlays or onlays, and veneers. The design of the preparation, oral cavity hygiene, mechanical strength, and the restorative materials used are factors that can influence the success of all types of indirect restorations.[1] Some disadvantages of indirect restorations include the formation of micro/nano-sized gaps at the margins/edges of the restoration caused by errors during preparation or processing. This can lead to plaque accumulation, sensitivity, shrinkage of the cementation material due to polymerization, discoloration of the restoration edges, as well as edge fractures and an increased risk of secondary caries.[1,2]

The Immediate Dentin Sealing (IDS) procedure is a conservative procedure that can be performed to protect exposed dentin surfaces. The IDS concept was introduced by Magne in 2005, explaining the procedure and its benefits. The IDS procedure involves the application and polymerization of adhesive materials on the tooth surface before the final impression of the indirect restoration.[3] Other benefits of the IDS technique include increased patient comfort, reduced need for anesthesia during the cementation procedure, and reduced post-treatment sensitivity.[4]

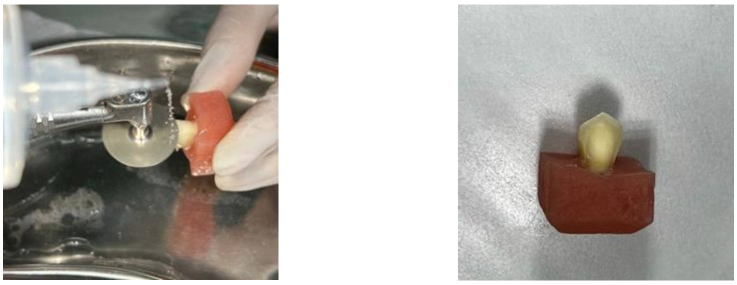
The IDS technique requires many steps in its application to meet four basic principles, making it more technique-sensitive. The four basic principles of IDS are: 1) only freshly cut and uncontaminated dentin provides an optimal basis for bonding. 2) If the DBA (Dentin Bonding Agent) and composite layer are light-cured together, the hybrid layer can be damaged by the pressure from the placement of the composite or restoration. Therefore, precuring (initial curing) of the DBA can be performed to achieve better bonding strength. 3) IDS and delayed restoration placement allow dentin bonding maturation in an environment free from chewing forces and the shrinkage of the overlying composite. 4) IDS reduces fluid and bacterial penetration.[5]

A clean tooth surface from compounds that can reduce bonding strength to the restorative material is important to consider. Bonding strength can be determined by the size of the enamel, dentin, and pre-surface treatment before cementatio.[6] Surface treatment performed after IDS application not only provides micro-roughness to the surface, enhancing micromechanical bonding, but also cleans the surface and allows chemical copolymerization of the resin-based cement with IDS.[7] another research stated that almost all temporary restorative materials proved incompatible with IDS. Observations showed that composite resin-based temporary restorative materials (bis-acryl) bonded directly to the IDS surface, requiring removal and re-preparation. Acrylic-based temporary restorations failed to prevent leakage, contaminating the IDS surface and losing adhesion.[8]

The research aims to determine the effect of post-immediate dentin sealing surface treatment on the shear bond strength of lithium disilicate.

RESEARCH METHOD

This research obtained Ethical Clearance with number 187/UN1/KEP/FKG-RSGM/EC/2023 from the Research Ethics Commission of the Faculty of Dentistry-RSGM Prof. Soedomo, Universitas Gadjah Mada Yogyakarta. Fabrication of lithium disilicate in a dental laboratory with a diameter of 3mm and a height of 2mm. Thirty maxila premolar teeth that met the criteria were stored in a 10% neutral buffered formalin solution for disinfection for 2 weeks, followed by storage in distilled water until the research was conducted. The teeth were cleaned of calculus using an ultrasonic scaler, then washed and cleaned with a special brush rotated with a low-speed contra angle using pumice paste mixed with water to ensure the teeth were free of debris. The teeth were then embedded in acrylic resin, with the buccal side facing flush with the surface of the acrylic resin. Each group was assigned a numerical code to facilitate the identification of research samples during shear bond strength measurements. The teeth were cut on the buccal surface using a self-limiting depth-cutting bur to a depth of 0.7mm, and the prepared surface was marked with waterproof ink. The preparation was leveled using a separating disc until the ink was removed. The preparation protocol was repeated twice to achieve a depth of approximately 1.5mm in the preparation area.[9] (figure 1)



(a) (b)

Figure 1. Sample Preparation; (a) Tooth cutting process with a separating disc; (b) Tooth after cutting.

Tooth were randomly assigned to 3 groups, each receiving treatment according to their respective group, Group I (IDS with nylon brush for surface treatment): IDS + immersion + surface treatment + luting cement + lithium disilicate, Group II (IDS with nylon brush + pumice surface treatment): IDS + immersion + surface treatment + luting cement + lithium disilicate, Group III (IDS with sandblasting using aluminum oxide for surface treatment): IDS + immersion + surface treatment + luting cement + lithium disilicate.

The immediate dentin sealing procedure began with thoroughly drying the teeth for 5 seconds. This was followed by the application of adhesive material by dropping 1 drop and then spreading it using a new microbrush for each tooth, 8th generation bonding (G-Premio Bond GC) was applied with a self-etch technique on all dentin surfaces according to the manufacturer’s instructions. The material was applied once for 10 seconds then blown with maximum strength air for 5 seconds, followed by light curing for 20 seconds using an LED light curing unit. After 24 hours of immersion in an incubator, the IDS surface was treated with nylon brush, nylon brush + pumice, and aluminum oxide.[10] Group I underwent surface treatment on the IDS surface using a nylon brush rotated using a lowspeed handpiece at 1000rpm for 5 seconds. Group II underwent surface treatment on the IDS surface using a nylon brush + pumice (mixed with distilled water) at 1000rpm for 5 seconds. Group III underwent surface treatment with sandblasting using aluminum oxide at a pressure strength of 4 bar (58,015psi/0.4 MPa) for 5 seconds and a distance of 1 cm from the IDS surface at a 90-degree angle

(a) (b) (c)

Figure 2. (a) Group I; (b) Group II, (c) Group III.

Preparation for cementation of lithium disilicate; 1) A lithium disilicate disc with a diameter of 3mm x 2mm is etched with 0.9% hydrofluoric acid (Porcelain Etch, Ultradent) according to the manufacturer's specifications. Afterward, the etch is cleaned by rinsing with distilled water for 15 seconds to remove contaminants, 2) Apply silane (Silane, Ultradent) to the fitting surface of the disc using a microbrush, then allow it to dry for 10 seconds, 3) Apply resin cement (RelyX U200, 3M ESPE) using an automix syringe as per the product's technical instructions. The resin cement is applied to the buccal surface of the prepared tooth, then the lithium disilicate disc is placed on the dentin surface and loaded with 300 mg to equalize the pressing load and thickness of the resin cement. The cement is immediately cured for 20 seconds in 'ramp mode' from four directions parallel to the cement and ceramic surfaces for 20 seconds using a high-powered LED light curing unit. Ramp mode is designed to allow a gradual increase in intensity during the first 5 seconds up to a peak intensity of 1500 mW/cm2 for the remaining 15 seconds and is intended to minimize polymerization stress.[11]

All samples in acrylic resin fixation are immersed in plastic tubes containing distilled water for 24 hours in an incubator at 37°C to simulate the normal conditions of the oral cavity. After 24 hours, all research samples are removed from the plastic tubes and dried, then tested for shear bond strength.

Samples are placed on the table and fixed so that they cannot move. After that, the machine is turned on so that the load will move down until it shears the lithium disilicate at a speed of 1 mm/minute.[10] The monitor screen connected to the universal testing machine will display a number indicating the magnitude of the shear force used to shear the lithium disilicate until it detaches from the tooth surface. The shear bond strength is recorded in Newtons and converted into Megapascals (MPa). Samples that detach before testing are considered to have a shear strength of 0 MPa.

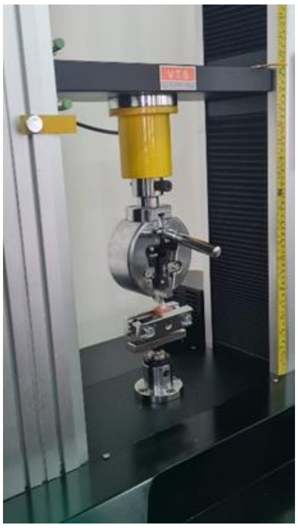


Figure 3. Shear bond strength test using a universal testing machine (UTM)

RESULTS

Shear bond strength testing was performed using a Universal Testing Machine (UTM) and observed by three observers to validate the data results. The test results for each sample in the group were then recorded.

Table 1. Mean and standard deviation of shear bond strength of lithium disilicate on the immediate dentin sealing surface (MPa)

Group	n	x̄ ± SD
I	10	106,899 ± 13,593
II	10	126,173 ± 6,944
III	10	137,889 ± 2,976

Explanation:
n : Number of samples
x̄ ± SD : Mean and standard deviation
Group I : Surface treatment with nylon brush
Group II : Surface treatment with nylon brush and pumice
Group III : Surface treatment with aluminum oxide

Table 1 shows the mean and standard deviation of shear bond strength of lithium disilicate for each treatment sample. Group I, with surface treatment using a nylon brush, has a mean and standard deviation of shear bond strength of 106.899 ± 13.593 MPa. Group II, with surface treatment using a nylon brush and pumice, has a value of 126.173 ± 6.944 MPa. Group III, with surface treatment using aluminum oxide, has a value of 137.889 ± 2.976 MPa. Subsequently, a normality test was conducted to determine the data distribution, and a homogeneity test was performed to assess the sample variance.

Table 2. Results of the Shapiro-Wilk normality test

Group	Statistic	p
I	0,957	0,764
II	0,898	0,208
III	0,892	0,178

Explanation:
p : significance value
I : Surface treatment with nylon brush
II : Surface treatment with nylon brush and pumice
III : Surface treatment with aluminum oxide

The research data are ratio data, followed by a normality test to determine the data distribution and a homogeneity test to assess the sample variance as prerequisites for parametric testing. Table 2 shows the results of the normality test using the Shapiro-Wilk analysis. The results are as follows: surface treatment with a nylon brush has a significance value of $p=0.764$, surface treatment with a nylon brush and pumice has a normality value of $p=0.208$, and surface treatment with aluminum oxide has a significance value of $p=0.178$. The normality test results for each group have p-values > 0.05, indicating that all data are normally distributed. The homogeneity test conducted with Levene's Test shows that the data have a p-value of 0.001 ($p<0.05$), indicating that the data variation is not homogeneous, thus not meeting the assumptions for a one-way ANOVA test. Despite the non-homogeneous data variation, a one-way ANOVA test can still be performed, but subsequent testing should use the post hoc Games-Howell test to determine which groups have significant differences.

Table 3. Results of the one-way ANOVA test on the shear bond strength of lithium disilicate on the immediate dentin sealing surface

	Degrees of Freedom	Mean Square	F	p
Between Group	2	2448,553	30,370	0,000*

Explanation:
F : F calculated/ one-way ANOVA value
p : significance value
* : significant (p<0.05

The one-way ANOVA test, which can be seen in Table 3, indicates that there is an effect of the shear strength of lithium disilicate attachment on the IDS layer after surface treatment, with a result of p=0.000, which means there is a significant difference in each treatment group (p<0.05). Subsequently, a post hoc test was conducted, the results of which can be seen in Table 4.

Table 4. Results of the Games-Howell post hoc test for the shear strength of lithium disilicate attachment on the immediate dentin sealing surface

Group Pair	Mean Difference	p
I - II	-19.274	0,004*
I - III	-30.990	0,000*
II - I	19.274	0,004*
II - III	-11.716	0,001*
III - I	30.990	0,000*
III - II	11.716	0,001*

Explanation:
p : significance value
I : Surface treatment with nylon brush
II : Surface treatment with nylon brush and pumice
III : Surface treatment with aluminum oxide
* : significant (p<0.05

he results of the Games-Howell post hoc test show that there is a significant difference (p<0.05) in the shear strength of the lithium disilicate attachment on the immediate dentin sealing surface among all groups.

DISCUSSION

This study was conducted to determine the effect of surface treatment on Immediate Dentin Sealing (IDS) on the shear bond strength of lithium disilicate. Data from this study were analyzed using a one-way ANOVA test (Table 3), which showed a difference in the shear bond strength of lithium disilicate after surface treatment with nylon brush, nylon brush + pumice, and sandblasting using aluminum oxide on the IDS surface. The results of this study (Table 1) showed that Group III (Aluminum oxide) had the highest mean shear bond strength compared to Groups I and II, at 137.889 MPa. This result is likely due to differences in material composition characteristics, pressure stability, exposure time, and the size and type of materials used, which affect the abrasive capability of each surface treatment method applied.

Nylon brushes, pumice, and aluminum oxide are materials used for surface treatment. Beyond the method/type of surface treatment applied, these three materials have different compositions, sizes, and particle types that likely affect their abrasive capabilities. Post-IDS surface treatment has been shown to influence bonding strength with cementation materials because it can alter the surface configuration of IDS materials. Aluminum oxide is a commonly used surface treatment material for IDS layer testing.[12] The increased bond strength after sandblasting with aluminum oxide is due to aluminum oxide particles creating roughness on the IDS surface and cleaning it of contaminating compounds.

Surface treatment with aluminum oxide of 29 µm size has proven to be sufficiently abrasive to remove contaminants adhering to the IDS surface but not too harsh to damage the IDS surface itself. The differences in aluminum oxide particles can affect the bonding ability to IDS.[13] The study compared three particle sizes of aluminum oxide: 27µm, 30µm, and 50µm. Surface treatment with 30µm aluminum oxide showed better bonding ability to IDS compared to the other two groups.

The mean shear bond strength in Group III of 137.889 MPa was achieved due to the creation of a rough surface on the IDS layer by aluminum oxide particles during surface treatment. Aluminum oxide particles collide with the surface of the material/dentin, releasing kinetic energy that breaks microscopic fragments, thereby creating a rough surface conducive to bonding.[14]

Pumice as a surface treatment material is also widely used. Pumice is typically applied to a rubber cup or nylon brush to clean tooth surfaces. The use of pumice is considered effective for cleaning and creating a rough surface. This study showed that Group II had a mean shear bond strength of 126.173 MPa.

The nylon brush group in this study showed the lowest results compared to other groups. This may be because the abrasive capability of the nylon brush is lower, especially when compared to the aluminum oxide group. The rotational speed of the nylon brush in this study was limited to 1000 rpm for 5 seconds, according to the study by Falkensammer.[12] In a different study, surface treatment with sandblasting or mechanical methods (nylon brush or pumice) yielded similar results. Differences between this study and previous research may be due to differences in the pressure and rotational speed of the nylon brush. That study limited the rotational speed of the nylon brush to 1500 rpm with a longer exposure time of 15 seconds, resulting in higher abrasive effects and damaging the IDS surface.[15]

A one-way ANOVA test showed a significant difference in post-IDS surface treatment techniques ($p<0.05$). This result is likely due to the different abrasive capabilities of the nylon brush, pumice, and aluminum oxide, related to particle size and differences in surface treatment techniques, creating different IDS surface conditions.

Post hoc Games-Howell tests showed significant differences in shear bond strength in each treatment group. Group I (nylon brush) had the lowest mean shear bond strength compared to Group II (nylon + pumice) and Group III (aluminum oxide), indicating that surface treatment with nylon on the IDS surface has the weakest bond with the cementation material compared to other techniques and materials. This result aligns with Ding (2023), which showed that surface treatment with sandblasting using aluminum oxide particles has better cleaning capabilities and maintains bond strength with the cementation material.[16]

The duration of treatment applied to each sample in the group also influenced the study results. The treatment duration for all samples was limited to 5 seconds to avoid unbalanced results if there were differences in treatment time. The duration of sandblasting exposure with aluminum oxide on the IDS surface can increase abrasive capability, making the IDS surface configuration rougher.[13] Another Research showed different results, stating no significant difference between two different exposure times during sandblasting with aluminum oxide, i.e., between 4 seconds and 10 seconds. This may occur due to differences in aluminum oxide particle size and the silica layer used.[13]

Pumice as a surface treatment material is also a choice due to its abrasive capability. In this study, Group II had better bonding ability than Group I. Surface treatment on composite resin surfaces using pumice can provide adequate roughness, increasing the bonding strength of the restoration. That study compared surface roughness ability on composite resin between pumice, prophylaxis paste with nylon brush, and prophylaxis powder with jet polisher, where all could create surface roughness, but pumice powder resulted in the lowest roughness. The study's results align with this research, where pumice powder still improved bonding ability compared to Group I but was not better than Group III using aluminum oxide with sandblasting technique.[17]

The shear bond strength of IDS is not only influenced by surface treatment techniques. The use of eighth-generation bonding as an adhesive and IDS material also affects the test results. Eighth-generation bonding can withstand mechanical strength and shrinkage stress and bonds mechanically and chemically with enamel, dentin, and the resin matrix of the cementation material. Good bonding with the resin matrix is because eighth-generation bonding contains nano fillers with acid-modified methacrylate ester monomers and SiO2 nanoparticles with a diameter of 20 nm, forming a thick and flexible adhesive layer, enhancing the material's mechanical properties.[18]

Nanoparticles can reduce shrinkage during polymerization by creating cross-links during the process. The presence of nanoparticles during polymerization maintains the interfibrillar space in dentin, preventing shrinkage that can cause dentin to lose its elasticity and reduce bonding strength with dentin.[19] Eighth-generation bonding also has three functional monomers (4-MET, MDP, and MDTP), providing strong and stable bonding with dentin and restorative materials, including ceramics.[20] Differences in this study's results and previous research may be due to using eighth-generation bonding as an IDS material.

The distilled water used for sample immersion/storage aims to minimize damage and is replaced at least every two months. Preservatives like formalin cannot be used as immersion media for bond strength tests because they can react with dentin due to formaldehyde content. Other materials, such as phenol, can inhibit resin polymerization, affecting the study results.

Bonding failure in this study may also occur due to IDS layer contamination with water, a major component of saliva. A significant decrease in shear bond strength was reported after teeth were stored in distilled water for three months, this is due to water absorption/diffusion into the polymer chains, causing resin softening, polymer expansion, and polymer release.[21] Water molecules in saliva cause degradation of siloxane bonds (bonds between silanol groups on the silica surface and silane coupling agents) through hydrolysis reactions, destabilizing bonds between filler and resin matrix.[22]

Distilled water, as a medium for aging samples, contains pure H2O without minerals or proteins. Unlike the oral cavity, saliva is the main fluid containing complex proteins and minerals, which can interfere with bonding strength. Saliva contamination could affect composite resin bonding strength.[23] Variations in saliva pH can also affect composite resin bonding strength due to degradation processes influenced by saliva pH levels.[24] The use of distilled water as an aging medium in this study is considered less representative of oral cavity conditions, so the use of artificial saliva is more recommended by researchers.

The study results were observed for each sample using a stereo microscope with 20x magnification. However, the type of bond failure between IDS, cementation, and lithium disilicate was not clearly visible from these observations. Observations with higher magnification should be considered for clearer results, making the study findings more applicable for clinical practice.

CONCLUSION

Based on the research results, it can be concluded that:

1. Different techniques and materials for surface treatment post-IDS result in varying shear bond strengths.
2. Surface treatment with sandblasting using aluminum oxide has the highest shear bond strength.

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