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EFFECT OF DELAYED DENTIN SEALING VERSUS IMMEDIATE DENTIN SEALING ON TENSILE BOND STRENGTH OF CERAMIC RESTORATION MATERIAL (AN IN VITRO STUDY)

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ABSTRACT

Objective: The aim of this study was evaluating the effect of immediate and delayed dentin sealing on tensile bond strength of hybrid ceramic restorations. **Materials and methods:** Sixty extracted human molars were used. The occlusal surfaces were ground flat to expose the dentin surface using a low speed diamond saw. The prepared teeth were randomly divided into two groups according to the dentin sealing protocol. For group (D): Delayed Dentin Sealing was used and for group (I): Immediate Dentin Sealing was used. 60 vita enamic discs were machined into standard thickness of 2mm. For delayed dentine sealing treated teeth, it was covered by a layer of temporary filling material directly after cutting. The provisional restoration was then removed after 48 hours and dentin was cleaned using airborne-particle abrasion (CoJet, 3M ESPE). For immediate dentine sealing treated teeth, the single bond universal adhesive was applied and light cured immediately after cutting, and the provisionalization phase was done in the same manner of DDS group. The vita enamic discs were then cemented in its place for each group. The specimens in each group were then thermo-cycled, and tensile bond strength was measured using a Universal Testing Machine. One-way ANOVA was used to study the effect of different tested variables. **Results:** Samples with IDS protocol showed higher tensile bond strength with vita enamic discs than DDS protocol. **Conclusions:** Immediate dentin sealing treatment would be recommended in high tensile stresses as it positively affects the bond strength of indirect restorations

KEYWORDS: Hybrid ceramics, Dentin Sealing, Tensile bond strength

INTRODUCTION

Indirect ceramic restorations have been chosen as better options than direct resin composite restorations to restore wide dental cavities, such as large inlay and onlay restorations. Ceramic inlays are known for their biocompatibility, chemical durability and optical properties. Although ceramics were first used in dentistry more than 100 years ago, the lack of adequate adhesion between ceramic and tooth made their performance clinically unacceptable[1]. Today, with recent advances in dentin adhesives and resin luting agents, ceramic inlays have become more useful. New types of ceramics with improved esthetic features and durability have been released in the last few years as alternatives to the traditional feldspathic porcelain.

Successful adhesion to enamel has been achieved with relative ease. On the contrary, the development of predictable bonding to dentin has been more problematic. Bonding to dentin has been known as one of the major challenges in adhesive dentistry mainly because of the inherent characteristics of this substrate [2,3].

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Management of the dental tissues between the preparation and provisionalization phase of restorative treatment plays a pivotal role in the success of indirect bonded restorations. In the development of these restorations, the exposed vital dentin immediately after tooth preparation is susceptible to insult from bacterial infiltration and micro-leakage during the provisionalization phase. Bacterial and fluid penetration through the exposed dentinal tubules can result in colonization of microorganisms, post-operative sensitivity, and the potential for subsequent irritation of the pulp [(4)].

To avoid these possible sequelae, whenever a substantial accessible area of dentin has been exposed during tooth preparation for indirect bonded restorations, local application of a dentin bonding agent (DBA) is recommended [(5)]. The so-called immediate dentin sealing (IDS) has been extensively studied and significantly improved over the years with positive results with respect to bond strength, gap formations, bacterial leakage, and post-cementation hypersensitivity [(4)].

The principle of dentin bonding is to create an inter phase, also called the hybrid layer by the interpenetration of monomers into the hard tissues. Once the infiltrating resin is polymerized, it can generate a ‘‘structural’’ bond somewhat similar to the interphase formed at the dentinoenamel junction (DEJ) [(6)].

The immediate dentin sealing (IDS) technique has been suggested as an alternative to improve the quality of adhesion for indirect restorative procedures [(7)]. In this technique, dentin is hybridized using either a two-step self-etching or a three-step etch-and-rinse adhesive system immediately after preparation and prior to impression taking.

The IDS has been extensively examined and the technique helps to ensure robust bond strength[(8)],fewer gap formations[(9)], minimal bacterial leakage, and sensitivity limited to the post-operative period [(4)]. It was also found that the cyclic loading fatigue significantly decreased the fracture loads of composite resin and all-ceramic crowns, while adhesive cementation significantly expanded the fracture loads [(10)]. However, no studies to date have examined the intra-cavity bond strength of metal-free CAD/CAM restoration with and without IDS after cyclic loading [(11)].

Resin adhesives and resin cements are found in self-cure, light-cure and dual cure formulations. The degree of polymerization plays a vital role in determining the ultimate biological, physical and mechanical properties of the material. It is significant to establish a strong bond between restoration and dentin. A significant increase in bond strength has been suggested when the adhesive was cured prior to application of the resin cement in indirect restorations. This adhesive pre-curing step could prevent complete seating of the indirect restoration[(12)].

Recently, new hybrid CAD/CAM blocks were introduced to the dental field, composed of interpreting polymer and ceramic networks. This dual network structure reduced brittleness and surface hardness of the material allowing easier milling in a shorter time .The properties of resin infiltrated ceramics (RIC) make them an interesting choice as interim restorations during management of and rehabilitation of complicated cases. However, not much is known about the fatigue resistance of these new materials [(13)].

The purpose of this study was to evaluate the effect of immediate and delayed dentin sealing on tensile bond strength of hybrid ceramic restorations.

MATERIALS AND METHODS

Sample preparation:

Sixty periodontally affected sound human molars were extracted, hand scaled to remove all soft tissue, and stored in physiological saline solution. The occlusal surfaces were ground flat to expose the dentin surface using a low-speed diamond. The prepared teeth were randomly divided into two groups according to the dentin sealing protocol. For group (D): Delayed Dentin Sealing was used and for group (I): Immediate Dentin Sealing was used. Teeth were then embedded in self-cure acrylic resin (pink for IDS and yellow for DDS). VITA ENAMIC (VITA Zahnfabrik, Bad Zäckingen, Germany) blocks were rounded into a 4mm diameter cylinders using a milling machine. Sixty ceramic discs were machined from their respective cylinders by using a low-speed precision diamond saw. VITA ENAMIC cylinders were cut into uniform standard thickness of 2mm.These discs were cut under integrated coolant delivery system that flooded the samples from both sides of the blade while tracking the blade movement. The blade of thickness (0.4mm) travelled linearly providing constant feed rate cutting of 15.7 mm/min blade was of 2500 rpm in 50 rpm increments. A caliper was used to verify the thickness.

Finishing and polishing of discs was done using vita enamic polishing set.

Delayed dentin sealing group:

For the teeth to be managed with delayed dentine sealing, after proper dryness, it was covered by a layer of temporary filling material directly after cutting and immersed in saline solution for 48 hours. Following that delay, the provisional restoration was removed with an excavator and dentin was cleaned using (50µm aluminum-oxide powder) airborne-particle abrasion (CoJet, 3M ESPE), and then ceramic disc was cemented in its place.

Immediate dentin sealing group:

For the teeth to be managed with immediate dentine sealing, after proper air dryness for 5 seconds and with the aid of a micro-brush (Microbrush International, USA), the single bond universal adhesive was applied over all the dentinal surfaces according to the manufacturer's instructions immediately after cutting. A single coat of the adhesive was applied and rubbed for 20 seconds then blown with a gentle air blow for 5 seconds to evaporate the solvent and then light cured for 20 seconds using LED curing light (Elipar S10, 3M ESPE) at a light intensity of 1200 mw/cm2 and then isolated with petroleum gel to avoid any bonding with the subsequently applied provisional restoration. After 48 hours, the provisional restoration was removed in the same manner of DDS group and the ceramic disc was cemented in its place.

Vita enamic sections surface treatment:

For proper bonding, inner surface of the discs was etched using hydrofluoric acid gel (IPS Empress etching gel, Ivoclar, Vivadent, Liechtenstein, Schaan) for (60 seconds). Acid residue must be carefully and properly removed by adequate rinsing. Applying silane coupling agent (Monobond S; Ivoclar Vivadent, Liechtenstein, Schaan) to the etched surfaces and allow it to dry for (60 seconds) to ensure chemical adhesion prior to bonding.

Ceramic sections cementation:

A single layer of single bond universal was applied on the dentin surface in the same manner for both IDS and DDS samples and then light cured for (20s). Vita enamic discs (after surface treatment) were cemented to the dentin surface by using Rely X Unicem (3M ESPE, St Paul, MN USA) (Self-Adhesive Universal Dual Cure Resin Cement). It was gently dispensed directly on the dentin surface and the ceramic discs were seated in their corresponding places. A static load (1Kg for 5 minutes) was applied during disc cementation using a specially designed cementation device. Excess cement was removed immediately with a micro-brush and the exposed margins were covered with glycerin gel to ensure complete polymerization. The margins were cured with a LED curing unit for 20 seconds.

Thermocycling of the specimens:

The specimens in each group were thermocycled using Mechatronicks THE 100 thermocycler (Germany) for 5000 cycles (5-55˚C) with 30 seconds dwell time.

Special mold construction:

Custom made Stainless steel mold was prefabricated to aid in the tensile bond strength test. It was made of two parts, circular part (4 mm diameter and 2 mm depth) to fit the ceramic disc inside it, and a handle which was perforated at its end to aid in the attachment of the sample to the upper compartment of the Universal Testing Machine. After cementation of the ceramic disc to the dentin surface, the mold was cemented to the ceramic disc using cyanoacrylate adhesive.

Tensile bond strength test:

Tensile bond strength was determined in a Universal Testing Machine (Zwick 1445, Zwick, Ulm, Germany) at a crosshead speed of 5 mm/min. Specimens were positioned in the jig of the testing machine to the loading direction using a special test configuration, which provided a moment-free axial force application. A collet held the acrylic cylinder while an alignment jig allowed self-centering of the specimen. The jig was attached to the load cell and pulled apart by an upper and lower chain, allowing the whole system to be self-aligning.

Each specimen (teeth embedded into acrylic resin cylinders) was fixed to the lower compartment of the universal testing machine and the customized mold cemented to the ceramic disc was attached to the upper compartment. (Figure 1).

The TBS calculated with the following formula: fracture load/bonding area; N/mm^2 MPa

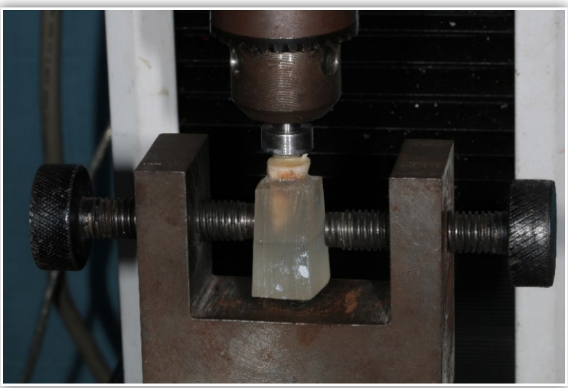

FIG (1) Mounting of the sample in universal testing machine for tensile test

Failure mode Analysis:

The tested samples were collected and mode of failure was examined visually and under stereomicroscope (Zeiss Discovery V20, Zeiss, Goettingen, Germany) at 40 x magnifications to determine different failure modes.

Failure modes were classified into five types [(14)]: a) cohesive failure into resin cement, b) adhesive failure between dentin and adhesive or resin cement., c) adhesive failure between resin cement and restorative material, d) cohesive failure into restorative material, and e) mixed failure when more than one type occurred.

Statistical analysis:

Categorical data were presented as frequencies and percentages and were analyzed using Fisher's exact test. Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; they were represented by mean and standard deviation (SD) values. One-way ANOVA followed by Tukey's post hoc test was used to study the effect of different tested variables.

RESULTS

Effect of sealing protocol on tensile bond strength (MPa)

Mean and standard deviation (SD) values of tensile bond strength (MPa) and sealing protocols were presented in table (1)

Vita Enamic samples with immediate dentine sealing (IDS) (18.10±0.67) had a significantly higher tensile bond strength value than samples with delayed dentine sealing (DDS) (12.47±2.51) ($p<0.001$).

Failure mode:

Majority of samples in DDS groups had an adhesive failure mode while for IDS most of the samples (60%) had mixed failures and the difference was not statistically significant (p=0.531).

TABLE (1) Mean ± standard deviation (SD) of tensile bond strength (MPa) and sealing protocols

Material	Sealing protocol (mean±SD)		p-value
	DDS	IDS	
Vita Enamic	12.47±2.51	18.10±0.67	**<0.001***

*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

DISCUSSION

The immediate dentin sealing protocol has been proposed as an effective technique of sealing the dentinal tubules in order to prevent or reduce bacterial contamination and tooth sensitivity during the provisionalization phase while also enhancing the bond strength of the final restoration.

Application of a single coating of adhesive resin to the exposed dentin surface prior to cementation should be useful for improving resin cement-dentin bond strength. The wettability and permeability of resin adhesive to both resin cement and dentin may also contribute to the bond strength[11].

The results of TBS in this study clarified that IDS is effective in reinforcing bond strength of final indirect restoration than DDS. This was in agreement with many literartures [4,15-17].

The study by Magne et al.[18] Strongly suggests that the IDS technique provided improved the bond strength of the final restoration. This increased bond strength has been demonstrated with both total-etch and self-etch dentin bonding agents. Which also in agreement with Ozturk et al. (2003) [19], who stated that the tensile bond strength was reported to be significantly improved following the IDS protocol regardless of the ceramic inlay system (Ceramco 2 or IPS Empress) or the adhesive system (total-etch or self-etch adhesives) used.

Effective adhesion between an immediate dentin sealing layer and resin cement probably occurs due to the presence of unreacted methacrylate groups still present in the adhesive layer. Thus, a copolymerization between fresh resin cement and adhesive previously applied during the sealing may occur [20]. Magne and others [21] reported that resin cement/sealed dentin bonding might occur due to the presence of residual free radicals, van der Waals interactions (intermolecular forces), and micromechanical retention.

In this study, the aging consisted of thermocycling for 5000 thermal cycles (5°C/55°C; dwell time, 20 seconds), which corresponds to approximately 4 to 5 years clinical service. The effect of thermocycling plays an important role in long-term predictability, because studies have shown that intraoral thermal changes are easily simulated by using the thermoycling method [22]. In this way, all tested samples received a standardized and reproducible thermal stress.

The rationale behind using the immediate sealing technique can be summarized in the following points [4]. First, the most favorable substrate for bonding is the freshly cut dentin which is available only at the time of cavity preparation before impression taking. Many studies showed marked decrease in the bond strength due to dentin contamination during provisionalization period. Second, higher bond strength values can be achieved due to pre-polymerization of the dentin bonding agent (DBA). However, this pre-polymerization can generate major problem in restoration seating when it is done at the time of cementation. On the other hand keeping the DBA unpolymerized during insertion of the final restoration will lead to movement of the dentinal fluids with its dilution and blocking the retentive areas that are created to be impregnated with DBA [4].

The use of hybrid ceramics as indirect restoration in this study was based on different literatures that showed significantly better results when used than glass ceramics [11,23]. It would be expected that adhesion between the hybrid material and the resin cement was higher due to the chemical interaction between the polymers present in both materials. The etched surface topography contributes to this belief. Thus, it is believed that the highly polymerized resin matrix (UDMA and TEGDMA) did not present many reactive bonds that could interact with the resin cement, thereby diminishing bond strength [24].

A study by Noriko ISHII, [11] stated that the immediate dentin sealing (IDS) improves not only the intra-cavity bond strength, but also the bond reliability of metal-free CAD/ CAM onlay restorations. The internal bond strength of restorations using two popular resin composite blocks (L and E) was significantly greater than that of restoration using a typical glass-ceramic block (V), regardless of IDS. Resin composite block restorations exhibited excellent bonding states, in terms of bond strength and reliability, as compared with glass-ceramic block restorations [11].

CONCLUSION

Immediate dentin sealing would be recommended in high tensile stresses as sealing the freshly cut dentin with DBA after preparation improves the tensile bond strength of hybrid ceramic indirect restorations.

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