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ASSESSMENT OF TENSILE BOND STRENGTH OF CERAMIC RESTORATION MATERIAL COMPARING TWO IMMEDIATE DENTIN SEALING PROTOCOLS (AN IN VITRO STUDY)

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ABSTRACT

Objective: The aim of this study was to evaluate the effect of two immediate dentin sealing protocols including sealed dentin surface refreshment with air abrasion versus sealed dentin surface refreshment with pumice on tensile bond strength of ceramic restoration material. **Materials and methods:** Twenty extracted human molars were used. The prepared teeth were randomly divided into two groups according to the surface refreshment method into group (C): Air abrasion using Cojet and group (P) using pumice slurry. Twenty ceramic discs were sliced into standard thickness of 2mm ceramic slices. The teeth were immediately sealed using single bond universal adhesive it was then covered using a layer of provisional filling material directly after cutting. The provisional filling was then removed and dentin was cleaned using either airborne-particle abrasion (CoJet, 3M ESPE) (Group (C) or Pumice (group (P). The specimens in each group were then thermo-cycled and tensile bond strength test was done, using Universal Testing Machine. One-way ANOVA was used to study the effect of different tested variables and their interaction. **Results:** Samples done using air abrasion with Cojet, showed higher tensile bond strength than those using pumice. **Conclusions:** Immediate dentin sealing treatment would be recommended within high tensile stresses, when surface refreshment done by air abrasion to the tooth structure.

KEYWORDS: Hybrid ceramics, air abrasion, Dentin Sealing

INTRODUCTION

Composite resins were used primarily as anterior restorative materials. However, recently these materials are being used in stress-bearing areas as in posterior restorations. To address the string of known problems faced by direct composite restorations such as limited depth of cure, short functional lifetime, and poor proximal contact, indirect composite techniques for processing outside the mouth were thus developed. On the other hand, ceramic material is also a very successful and durable tooth-colored restorative material which has been in use for many years. Within recent innovations in formulation and firing techniques, it has been possible to construct accurate inlays and onlays using dental ceramic materials. Notably, indirectly prepared inlay and onlay restorations have some advantages as example, maintaining a more stable occlusion than polymers and possessing superior color stability [(1)]. Therefore, conservative bonded restorations are more and more preferred to traditional metal restorations [(2)].

In-order to reduce tooth tissue loss and for better esthetic results, direct composite resin fillings or all ceramic inlay and onlay restorations may be used for the restoration of extensive cavities in posterior teeth[(3)].

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Ceramic Restorations are known for their biocompatibility, chemical durability and better optical properties. Although ceramics were primarily used in dentistry more than 100 years ago, the lack of adequate adhesion between ceramic and tooth made their performance clinically unacceptable, That's why with recent advances in dentin adhesive systems and resin luting agents that are being introduced on regular basis in the dental market, ceramic Restorations have become more useful [(4)].

Minimal invasive approach using adhesive technologies in dentistry allowed better preservation of tooth structure. Clinical performance of non-metallic fixed partial restorations made out of dental ceramic materials, either in the form of inlays, onlays or laminate veneers, substantially relies on the adhesion of the resin luting cements to these restorative materials and tooth structure [(5)]. For the adhesive cementation procedures, enamel, and dentin surfaces as well as the ceramic surface should be treated using different techniques [(6)].

In the classical approach, dentin exposures are initially ignored; the dentin bonding agent (DBA) is applied only at the last treatment stage before proceeding to the final step of cementing the restoration. In this case, the dentin bonding agent must be initially left uncured to allow for complete seating of the restoration. It has been suggested that the pressure of the luting resin cement during the seating of the restoration may create a collapse of demineralized dentin (collagen fibers) which will have negative affect on the adhesive interface cohesiveness.

Management of the dental structures between the preparation and provisionalization phase of restorative treatment plays a huge role in success of indirect bonded restorations. In the development of these restorations, the exposed vital dentin immediately after tooth preparation is susceptible to bacterial infiltration and micro-leakage during the provisionalization phase. Bacterial and fluid penetration within the exposed dentinal tubules will result in colonization of microorganisms, post-operative sensitivity, and the potential result of subsequent pulp irritation [(7)].

To avoid these possible sequelae, whenever any accessible area of dentin been exposed during tooth preparation for indirect bonded restorations, it's always recommended to apply a dentin bonding agent [(8)].

Over the past few years immediate dentin sealing (IDS) has been extensively studied and significantly improved which led into positive results with respect to bond strength, gap formations, bacterial leakage, and post-cementation hypersensitivity [(7)].

The immediate dentin sealing technique has been suggested as an alternative to improve the quality of adhesion for indirect restorative procedures [(9,10)]. In this technique, dentin is hybridized using either a two-step self-etching or a three-step etch-and-rinse adhesive system directly done after tooth preparation and before the impression taking step. It's been reported that this technique resulted in increased tensile bond strength (TBS) and reduced postoperative sensitivity [(11,12)].

Conditioning of the sealed (IDS) or unsealed (DDS) dentin surface for better restoration bonding was of interest in this study, since different conditioning materials might influence the bond strength or the surface configuration, Different conditioning methods were found to influence the bond strength of ceramic restorations regardless of the sealing method used [(13)].

In 2005, this concept evolved to immediate dentin sealing (IDS) [(11)]. Prior to luting in the second visit, it was commonly recommended decontaminating the IDS by air borne abrasion. This cause micro-roughness to the surface, which thereby cause improving in micromechanical interlocking, it also cleans the surface and enables chemical copolymerization of the resin-based dental cement with the IDS. Falkensammer et al [(13)] concluded that polishing and airborne particle abrasion with silica-coated alumina (Al_2O_3) and glycine were found to be equally efficient methods of conditioning IDS surfaces. Other studies showed that soft air abrasion, airborne particle abrasion with Al_2O_3, or fluoride-free pumice paste systems resulted in the highest bond strength. However, it is still unknown which method is most suitable for conditioning IDS prior to cementation. Results from a recent systematic review indicated that the effect of IDS on bond strength is tested mainly by using a TBS approach.38. The TBS test is generally accepted as one of the most valid bond-strength tests because it is performed perpendicular to the adhesive interface. Using a TBS test, a more favorable stress distribution is achieved, resulting from the small specimen size [(14)].

Therefore, the aim of this study was to evaluate the effect of two immediate dentin sealing protocols: including sealed dentin surface refreshment with air abrasion (Cojet) versus sealed dentin surface refreshment with pumice when using polymer infiltrated ceramic network material (Vita enamic). A null hypothesis was suggested where no significant difference between the variables was expected.

MATERIALS AND METHODS

Twenty caries-free extracted human molars were hand scaled to remove all soft tissue and were stored in physiological saline solution. After embedding the teeth in self-cure acrylic resin, the occlusal surfaces were ground flat to expose the dentin surface using a low speed diamond saw (MetSAW®- **MSH**-04-112, R&B, Korea) under water cooling. Then polishing at 600-1000 grit was followed to smoothen the exposed dentin surfaces and to remove contaminations produced by a smear layer. The prepared teeth will be randomly divided into two groups according to the surface refreshment method into Group (C): Cojet air abrasion, and Group (P): Pumice.

VITA Enamic blocks (Vita Zahnfabrik, Germany), were rounded into 4 mm diameter cylinders using a milling machine. Twenty ceramic discs were machined from their respective cylinders by using a low speed precision diamond saw and the VITA Enamic blocks 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 15.7mm/min blade was of 2500 rpm in 50 rpm increments. A digital caliper (Mitutoyo 500- 196- 30, USA), was used to verify the thickness. All samples were prepared by the same operator following manufacturer's recommendations for the purpose of standardization.

The single bond universal adhesive (3M ESPE, St Paul, MN, USA), was applied over all the dentinal surfaces according to the manufacturer's instructions after proper air dryness for 5 seconds and with the aid of a micro-brush. After that 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.

As for the surface refreshment, after 48 hours, surface refreshment was divided into 2 groups: Group (C) using 50µm aluminum-oxide powder airborne-particle abrasion (CoJet, 3M ESPE) for 15 seconds at a pressure of 2.7 atomosphere perpendicular to the bonding surface 10 mm away from the tooth surface standardized by holding the tooth and tip of the sandblaster at fixed distance by the aid of a ruler and Group (P) using Pumice powder (KAVO KERR, USA) for surface refreshment.

For VITA Enamic sections, etching the inner surface with hydrofluoric acid gel (Ivoclar, Vivadent, Liechtenstein Schaan), for 60 seconds was done.

Acid residue was carefully removed by proper rinsing with copious water spray. Applying silane (3M ESPE-Sil,USA) to the etched surfaces(60s).

Ceramic discs were cemented to the dentin surface by using Rely X Unicem (Self-Adhesive Universal Dual Cure Resin Cement, 3M ESPE, USA). It was gently dispensed directly on the dentin surface using the auto-mixing tips followed by seating the ceramic discs 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 using glycerin gel to ensure complete polymerization of the cement. The margins were cured with a LED curing unit for 20 seconds.

The specimens in each group were thermocycled using Mechatronicks THE 100 thermocycler (Germany) for 5000 cycles (5-55° C) with 30 seconds dwell time. Two mm of Ceramic discs were cemented into a special mold which is custom made stainless steel mold 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.

TBS 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.

The TBS was calculated with the following formula: fracture load/bonding area; N/mm^2= MPa. Each specimen (teeth embedded into acrylic resin cylinders) was mounted on the lower fixture of a universal testing machine and the customized mold cemented to the ceramic disc was attached to the upper fixture then applying the test, (figure 1).

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. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM® SPSS® Statistics Version 26 for Windows.

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. Failures modes were classified into five types, these types include, adhesive failure either between dentin and cement or between resin cement and restorative material interface, cohesive failure which might occur into dentin, cement or the restorative material or maybe mixed when more than one type of failure occurs.

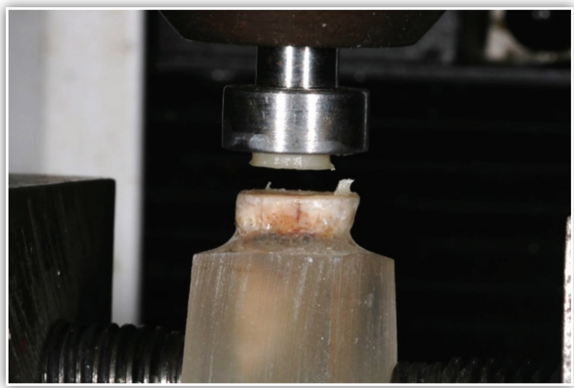

FIG (1) Detached ceramic sample from the tooth substrate after tensile bond strength test.

RESULTS

I- Tensile bond strength (MPa)

There was a significant difference between different groups (p<0.001). The highest tensile bond strength value was found in IDS-sandblasting subgroup (18.10±0.67) followed by IDS-pumice (16.05±0.60. Post hoc pairwise comparisons showed values of different subgroups to be significantly different from each other (p<0.001). (table 1)

II- Mode of failure

Majority of samples had a cohesive failure mode and the difference was not statistically significant (p=0.725).

Table (1): Mean ± standard deviation (SD) of tensile bond strength (MPa) for different materials and surface refreshment methods in IDS samples

Material	Surface refreshment method (mean ± SD)		p-value
	Sandblasting	Pumice	
Vita Enamic	18.10±0.67	16.05±0.60	**<0.001***

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

DISCUSSION

This study was conducted to evaluate the influence of two immediate dentin sealing modalities. These modalities were surface refreshment of dentin after temporization by air abrasion and by pumice powder immediately before application of resin cement. The null hypothesis was rejected as there was a statistically significant difference between the surface refreshment methods after immediate dentin sealing.

Dental Ceramic material are considered successful restorative materials due to their esthetic quality and biocompatibility; their smooth surfaces minimize oral biofilm accumulation. That's why different dental Ceramics with different compositions have been introduced to satisfy patient's demand for natural-looking restorations. Monolithic materials appeared with the purpose of combining adequate translucency and excellent mechanical properties.

The mechanical properties of hybrid CAD/CAM ceramics needed more research especially concerning newly introduced materials & recent advances in technique of fabrication. VITA Enamic is a compound hybrid ceramic material. The ceramic network makes up about 86% share of the material and is reinforced by a polymer network [15].

Tooth Restoration treatment for patient might be performed more conservative with this type of material as the extent of tooth preparation may be reduced.as claimed by the manufacturer, the dominant basic ceramic network provides stability, and the polymer network provides elasticity [16]. It was also suggested that this material absorb masticatory forces and stop crack formation [17].

The immediate dentin sealing protocol has been proposed as an effective technique of sealing the dentinal tubules to prevent or decrease bacterial contamination and tooth sensitivity during the provisionalization phase, In addition to enhancing the bond strength of the final restoration [18] . Effective adhesion between an immediate dentin sealing layer and resin cement probably occurs because of the presence of unreacted methacrylate groups that are still present in the adhesive layer. Thus, a copolymerization between fresh resin cement and adhesive that was previously applied during the sealing procedure may occur.

It is reported that the bonding between resin cement and sealed dentin bonding might be due to the presence of free residual radicals, van der Waals interactions (inter-molecular forces), and micromechanical retention[19]. Consequently, surface refreshment of adhesive layer must be done after contamination as it is considered very critical and highly affects bond strength. There are different methods of surface refreshment either by air-abrasion or pumice application or others.

Away from the use of a conventional or resin cement, proper cleaning of the abutment teeth must be done before final cementation of the restoration which is critical to the final bonding of the restoration. After reviewing the literature, it was concluded that soft-air abrasion, air borne particle abrasion with aluminum oxide, fluoride-free pumice paste systems, are some of mostly efficient methods of cleaning the IDS surface [11,18,20].

In this study, the aging of specimens 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[21]. The effect of thermocycling plays a major role in long-term restoration's success, because studies have shown that intraoral thermal changes are easily simulated when using the thermocycling method[2]. By using this way, all tested samples received a standardized and reproducible thermal stress.

The results of this study show that immediate dentin sealing has an effect on tensile bond strength. The study by Magne et al. [23] strongly suggested that the IDS technique showed great improvement in the bond strength of the final restoration. This increased bond strength has been demonstrated using both total-etch and self-etch dentin bonding agents. It was also in agreement with Ozturk et al. [24] who stated that the tensile bond strength was reported to be significantly improved following the IDS protocol regardless of the ceramic inlay system or the adhesive system used.

Immediate dentin sealing has multiple techniques, one of these techniques is air abrasion that showed an increased effect on the tensile strength, this is in agreement with Magne et al [25]. Airborne particle adhesive with aluminum oxide cleaned the sealed surface and eliminated any dentin substrate to be optimally bonded with the ceramic restoration.

Similarly, Mujdeci et al.[26] and Rafael et al.[27] in another study showed that tensile bond strength between refreshed immediate sealed dentin and ceramic restorations significantly increased after using airborne-particle abrasion which showed higher roughness of the inter-tubular dentine after the dentin sandblasting procedure that led to expanding the contact area for adhesion area. Additional mechanical retention means along with the adhesive system correlates with increased amount of exposed inter-tubular dentine available, which causes expansion of contact area for adhesion[28].

On the other hand, the alternative technique used was pumice application for refreshment which also showed an impact on tensile bond strength. Grasso et al [29] Magne et al [30] and Van den Breemer et al [14] showed that pumice resulted in the highest bond strength. Meanwhile Paul and Scharer [31] showed that removal of remnant provisional cement with a cotton and pumice were not very effective. Bachmann et al [32] investigated the bond strength of dentin bonding agents after teeth were cleansed using scaler and a cotton pellet with pumice. All these methods showed decreased values of bond strength.

The results of this study demonstrated that air-abrasion has given higher tensile bond strength than pumice. Augusti et al. [33] has reported a negative effect of the use of pumice on the bond strength of the resin to fresh dentin due to obscuration of the dentinal tubule openings by pumice residues. Thus, the use of air-abrasion still shows to be more beneficial to increase the adhesion of resin cement to IDS. Also, Weibull distribution stated that pumice provided less reliable adhesion results as opposed to air abrasion.

CONCLUSION

Within the limitations of this in vitro study the following conclusion can be drawn: airborne abrasion is more effective in improving tensile bond strength as a surface refreshment method than pumice powder after immediate dentin sealing procedure under vita enamic indirect restorations.

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