Effect of Desensitization Using Bioactive Glass, Hydroxyapatite, and Diode Laser on the Shear Bond Strength of Resin Composites Measured at Different Time Intervals: An *In vitro* Study

Abstract

Background: Dentin desensitizers may change the properties of smear layer and have adverse effects on the bonding performance of adhesive systems. **Aim:** The aim of this study was to compare the effect of bioactive glass (BG), hydroxyapatite, and diode laser desensitization on shear bond strength of resin composites to dentin at different time intervals. **Materials and Methods:** Seventy-two caries-free maxillary premolars were selected. Buccal surfaces were flattened to expose dentin. Teeth were divided into four groups (Groups 1, 2, 3, and 4) according to treatment modality (control with no pretreatment, Sensodyne Repair and Protect, Teethmate Desensitizer, diode laser). Bonding was performed using self-etch adhesive followed by composite buildup. Universal testing machine was used to determine shear bond strengths immediately after bonding, after 3 months, and 5 months storage in artificial saliva. **Results:** Pretreatment with BG and hydroxyapatite desensitizers increased, whereas diode laser decreased mean shear bond strength of composite to dentin as compared to control group. No statistical significant difference in shear bond strength values was seen in groups after storage. **Conclusion:** Desensitizing toothpastes incorporating remineralizing agents not only occluded open dentinal tubules but also increased shear bond strength of composite to dentin.

Keywords: *Bioactive glass, diode laser, hydroxyapatite, shear bond strength*

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Introduction

Pain is an unpleasant experience that, perhaps, motivates the individual way more than the other life expertise. Dentin hypersensitivity (DH) is one of the oldest recorded complaints of discomfort to humankind. When exposed, dentin contacts an external stimulus, such as chemical, thermal, evaporative, tactile or osmotic stimulus, causing a transient, sharp pain that can, in many cases reach the maximum level of any pain scale.[1] The prevalence of DH is high enough (72.5%–98%) to warrant the development of effective treatment. It mostly affects the buccal and cervical regions of the teeth. According to “hydrodynamic theory” and Poiseuille–Hagen equation, the occlusion of dentinal tubules should be effective to reduce dentin permeability and thus manage DH.[2] Various treatment strategies including self-care as well as professional treatment have been postulated to treat DH. The foremost common variety of management is the placement of a topically applied agent either by a dental professional or by the patient at home. Commonly used agents are potassium and strontium salts. Potassium is thought to diffuse inside the dentinal tubules and lower the excitability of the pulpal nerve fibers. Several arguments oppose this theory. One is that the diffusion distance in human teeth is larger than that in tested animals. Another argument is that the flow of dentinal fluid is outward from the pulp toward the tooth surface, which might hinder diffusion toward the pulp.

Of all the dental tissues, dentin is the most critical, mainly because of the formation of hybrid layer. Studies have shown that the addition of mineral in demineralized dentin can promote the remineralization process.[2] Research in this direction has led to the advent of remineralizing agents. There are two types of remineralization processes: net and functional. The concept of functional remineralization involves different strategies. One of the most promising methodologies is the nanoparticle technology. Nanoparticles may easily penetrate into dentinal tubules and act

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as mineralizing agents that block fluid movement within the tubules.[3] Examples include bioactive glass (BG), hydroxyapatite particles, and amorphous calcium phosphates.

In the last 15 years, the introduction of lasers gave potentialities to treat DH. High-power lasers such as diode 980 nm and 808 nm, KTP 532 nm, Nd:YAG 1064 nm, CO_2 10600 nm, Er:Cr:YSGG 2780 nm, and Er:YAG 2940 nm act on DH agitating a melting impact with crystallization of dentin inorganic component and coagulation of fluids contained into the dentinal tubules.[3]

BG and hydroxyapatite containing agents prove futile in defects involving inner half of dentin. In such a scenario, the clinician is left with no choice other than restoration. Self-adhesive resin cements are designed to bond without any pretreatment of dentin. However, pretreatments such as the application of desensitizing agents might amend the properties of smear layer and may influence the bonding quality of these self-adhesive resin cements.[4]

Thus, the aim of the study was to compare the effect of BG, hydroxyapatite, and diode laser desensitization on the shear bond strength of resin composites to dentin measured at different time intervals.

Materials and Methods

Seventy-two caries-free human maxillary first premolars extracted for orthodontic purposes were used for the study. Teeth with caries, restoration, endodontic treatment, or with surface defects were excluded from the study. Samples were cleaned of any visible blood and gross debris and immersed in distilled water. They were then immersed in 10% formalin (Nice Chemicals Ltd., Kochi, Kerala) for 7 days, followed by immersion in distilled water.

Specimen preparation and grouping

The buccal cervical surface of exposed crowns was kept parallel to horizontal plane. Enamel surface was abraded to expose middle dentin surface with care being taken not to expose pulpal anatomy followed by polishing with wet silicon carbide paper of grit size of P600. Samples were equally divided into four groups (one control group and three experimental groups, $n = 18$).

G1: Stored in artificial saliva with no dentin pretreatment; G2: Specimens brushed with Sensodyne Repair and Protect (Group Pharmaceuticals Limited, Kasaba Hobli, Malur) for 3 min four times a day, for 7 days. G3: Teethmate Desensitizer (Kuraray Noritake Dental Inc., Kurashiki, Okayama, Japan) was applied for 30 s twice a day; and G4: Diode laser hydrogen fluoride (Hager and Werken GMBH and Co. Duisburg) with 980 nm wavelength and three watt power in a continuous mode with noncontact laser tip was applied for 1 min. The desensitized specimens were treated with a contemporary one step self-etch adhesive (Bond Force, Tokuyama Dental Corporation, Japan) according to manufacturer's instructions and composite (Filtek Z250 XT Nano Hybrid Universal Restorative Material, 3M ESPE, Dental Products Conway Avenue St. Paul, USA) microcylinders of 3 mm diameter and five millimeters height were bonded. Samples were then stored in artificial saliva. For evaluation of shear bond strength of composite to dentin, each group was further divided into three subgroups of six samples each according to the time intervals.

- Immediately after the bonding
- After 3 months storage in artificial saliva
- After 5 months storage in artificial saliva.

A universal material testing machine was used to determine shear bond strength. Shear force was applied with a load cell of 500N to the interface at a crosshead speed of 1 mm/min until failure occurred. The load required for debonding was recorded in Newton [Figure 1].

Formula used

m-SBS (MPa) = Maximum load (N)/Bonding surface area of the resin cement (mm^2)[5]

Energy dispersive analysis of X-rays

Two samples from each group were subjected to energy dispersive X-ray analysis (EDAX) analysis for evaluation of remineralization.

Statistical analysis

The recorded values were subjected to statistical analysis using the SPSS version 20 (IBM Corporation, Armonk, NY, USA). One-way ANOVA and *post hoc* Tukey honest significant difference test were performed for analyzing the inter- and intra-group comparisons. $P < 0.05$ was considered statistically significant.

Results

The results of the present study have revealed that when shear bond strength of composite to dentin was compared after pretreatment with different desensitizing agents at all the time intervals, statistically significant difference was observed. It was observed that use of Sensodyne Repair and Protect (bioactive) and Teethmate Desensitizer (hydroxyapatite) dentifrices led to an increase in shear bond strength values at all the time intervals, whereas diode laser when used as desensitizing agent proved to have negative effect on shear bond strength [Figure 2].

EDAX analysis showed deposition of calcium phosphate and silica mineral on the surface of samples treated with BG and calcium phosphate in hydroxyapatite-treated samples [Figure 3a-c].

Discussion

The main reason for DH is attributed to exposed dentinal tubules found in areas where tooth structure has been lost.

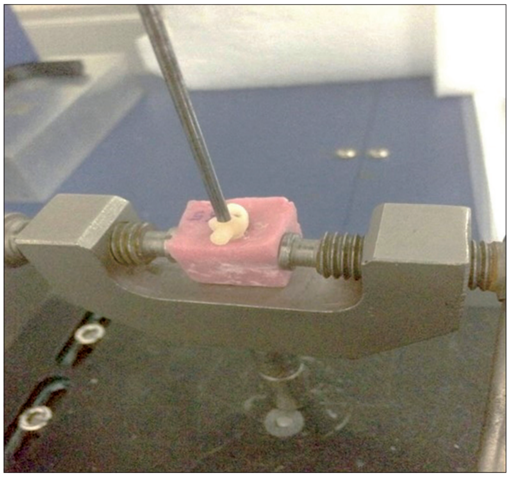

Figure 1: Specimen placed under universal testing machine

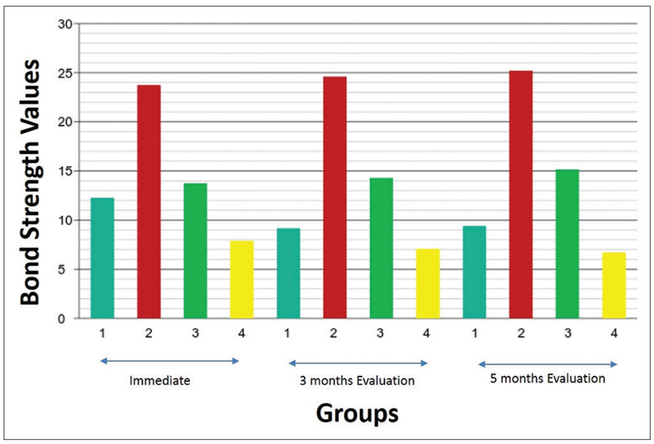

Figure 2: Shear bond strength values (in Mpa) of groups at three time intervals. 1 = Group 1, 2 = Group 2, 3 = Group 3, 4 = Group 4

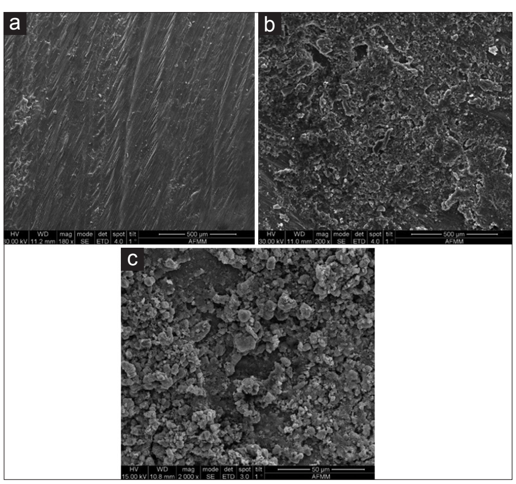

Figure 3: Energy dispersive X-ray analysis showing (a) Group 1, (b) Group 2, (c) Group 3

In an attempt to simulate these conditions, enamel surface was wet abraded to expose the dentin surface.

Ideal dentin bonding agents ought to give high bond strengths after polymerization of the adhesive resin and should be long-lasting. Studies on the longevity of bonded restorations and degradation of resin-dentin bonds ought to be conducted to investigate the sturdiness of dentin bonding mechanisms.[6] Hence, specimens were stored in artificial saliva before testing. Due to the strict necessity of alignment of specimens within the testing equipment for tests of tensile bonding and uneven stress distribution throughout loading, shear bond strength testing was done in the present study, which is consistent with the study done by Marchan *et al*.[7]

Results of the present study showed immediate mean bond strength of 12.25 Mpa for the control group samples. The reduced bond strength after storage for 3 and 5 months could be attributed to the excessive hydrophilicity of self-etch adhesives such as bond force. They act as semipermeable membranes, even after polymerization, permitting water movement from the substrate toward them.[8] As a consequence, small droplets can be found at the transition between the adhesive layer and the lining composite which also contribute to the hydrolysis of resin polymers and therefore, the ensuant degradation of tooth-resin bond over time.[9,10]

It has been shown that dental adhesives during the production of hybrid layer can also release enzymes from the dentin matrix that exhibit low collagenolytic activity.[11] Recent enzymographic research has revealed that collagenase A is primarily accountable for the hydrolytic breakdown of the hybrid layer.[12] A way to protect the interface against such enzymatic degradation processes are through the use of matrix metalloproteinase inhibitors or use of agents which enhance the chemical bonding.

The increase in the bond strength values of groups pretreated with BG can be attributed to its unique bonding properties. Because of the ability of bioglasses to adhere with the living tissue, they are classified as bioactive materials. In the aqueous environment of the tooth, sodium ions from the BG particles rapidly exchange with hydrogen cations (in the form of H_3O^+). This leads to release of calcium and phosphate (PO_4^{3+}) ions from the material. A localized, transient increase in pH occurs during the initial exposure of the material due to the release of sodium. This increase in pH helps precipitate the additional calcium and phosphate ions provided by the bioactive particles to create a precipitated calcium phosphate layer. As these reactions continue, this layer crystallizes into hydroxycarbonate apatite which is chemically and structurally equivalent to naturally occurring biological apatite. Results of the present study are in consistent with the results of Pires-de-Souza *et al*.[13] and Andreatti *et al*.[5]

To date, it is impossible for resin monomers to completely displace water within the extrafibrillar and particularly the intrafibrillar compartments of a demineralized collagen matrix, and infiltrate the collagen network completely. Studies relate that synthetic hydroxyapatite materials such as Teethmate have the potential to biomimetically remineralize dentin by replacing matrix water with apatite crystallites. This exchange would increase mechanical properties and inhibit water-related hydrolysis, thus enhancing the bond strength with time. The preservation of hydroxyapatite within the submicron hybrid layer may serve as a receptor for additional chemical bonding.[14] The presence of calcium and phosphate ions observed in EDAX analysis and the maximum bond strength at all the time intervals correlate to this phenomenon. This is consistent with the studies done by Garcia *et al*.[14] and Chermont *et al*.[15]

The decrease in bond strength values after laser desensitization is consistent with the studies done by Malekipour *et al*.[16] and Can-Karabulut[17] where they have reported that using laser for heating the surface decreases penetration of the bonding agent by creating morphological changes in dentin more than making useful changes in the surface for increasing the bond strength. Contrary to these, Maenosono *et al*.[18] have reported increase in bond strength values after using diode laser as desensitizing agent with both self-etch as well as total-etch adhesives. The difference in the results might be attributed to the heat provided directly by laser irradiation in the latter study, which could favor adhesive penetration and solvent evaporation.

There are certain limitations inherent in an *in vitro* study design. The specimens in the present study were hand-handled. Being an *in vitro* study, ideal bonding conditions were achieved unlike the oral cavity, where the restorations are subjected to a dynamic environment. The effect of other adhesive systems on the survival rate of restorations following desensitizing treatment can be further studied. Thus, this study opens vistas for further research.

This study highlights the biomimetic remineralization shown by desensitizing agents such as Sensodyne Repair and Protect and Teethmate. The definitive hike in the calcium and phosphate minerals with these agents in EDAX analysis corresponds to the increased bond strengths observed at all the time intervals.

Conclusion

In the present study, it was observed that the groups treated with BG and hydroxyapatite showed increased shear bond strengths, whereas control group and laser group showed a decrease in the bond strength values at all the time intervals.

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Conflicts of interest

There are no conflicts of interest.

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