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Original Article

Comparative Evaluation of Shear Bond Strength of a Traditional Composite and ACTIVA BioACTIVE After Enamel Preparation With Er:YAG Laser and Conventional Acid Etching: An *In Vitro* Study

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Abstract

Objective: Traditional composites are strong and esthetic, but they have no bioactive potential and require bonding agents that have been shown to leak, cause white lines, staining, and failure. ACTIVA BioACTIVE is the first composite with an ionic resin matrix and bioactive fillers that mimic the physical and chemical properties of natural teeth. The aim of the study was to compare shear bond strength of traditional composite and resin-modified glass-ionomer bioactive ionic resin-based composite after enamel preparation with erbium-doped yttrium aluminum garnet (Er:YAG) laser and conventional acid etching. **Materials and Methods:** Forty sound extracted molars were divided into four groups of 10 samples each. In group I, specimens were bur treated followed by bonding of composite. In group II, specimens were laser treated followed by bonding of composite. In group III, specimens were bur treated followed by bonding of Bioactive. In group IV, specimens were laser treated followed by bonding of ACTIVA BioACTIVE. Buccal tooth surfaces were prepared approximately half of the enamel depth. A tube was filled with composite and placed on the treated tooth surface. Once the curing was complete, the tube molds were removed. After thermocycling, the shear bond strength testing was performed using the Instron Testing Machine, and the data were statistically analyzed. **Results:** Bur preparation followed by bonding of Bioactive yielded the highest bond strength followed by laser preparation. **Conclusion:** Er:YAG laser preparation caused decreased shear bond strength compared to conventional bur preparation.

Keywords: *ACTIVA BioACTIVE, Er: YAG laser, shear bond strength*

Introduction

Over the last 30 years, dentistry has experienced a remarkable scientific advancement regarding the improvement of restorative materials and techniques. The advent of acid etching and further introduction of adhesive restorative systems have revolutionized the dental practice, modifying the principles of cavity preparation and allowing a greater preservation of sound dental structure and a more esthetic treatment. To achieve adhesion between dental tissues and restorative materials, the smear layer formed during dental tissue preparation should be either removed or modified.[1,2] This is achieved with the demineralization of dentin either by a separate acid etching step or by the use of a self-etching adhesive system. The adhesive systems have been developed to act on the tooth substrate prepared by conventional techniques. More recently, however, newer methods for cavity preparation have become widespread, such as laser irradiation.

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The erbium-doped yttrium aluminum garnet (Er:YAG) laser was first used in dentistry by Hibst and Keller in 1989 and has proved to be a promising system. It presents a notorious ability to remove dental hard tissues, with minimal injury to the pulp and without causing severe thermal side effects, such as cracking, melting, or charring of the remaining tooth structure and/or surrounding tissues.[3-5] The use of an Er:YAG laser to treat dental hard tissues is both safe and effective for caries removal, cavity preparation, and enamel etching, and was approved by the US Food and Drug Administration in 1997. There is agreeable patient comfortability during a dental treatment with lasers because of the reduced noise and decrease in pain sensitivity, which sometimes eliminates the need for local anesthetics.

Thus the benefits of laser in dentistry are reducing the need for local anesthetic injections and higher patient comfort; no pressure, vibration, and noise of the turbine; conservative cavity preparation; and antimicrobial effects on pulpal temperature change.

The first three benefits are important for behavioral control of children in pediatric dentistry.

In view of the widespread use of adhesive dentistry and the increasing approach of laser technology in dental practice, it seems relevant to assess the interaction pattern of the adhesive systems with lased dentin substrate, given its physiological dynamics, heterogeneous composition, and complex tubular structure.

ACTIVA BioACTIVE Restorative Composite (ABRC; Pulpdent Corp, Watertown, Massachusetts) is the first bioactive composite with an ionic resin matrix, a shock-absorbing resin component, and bioactive fillers that mimic natural teeth's physical and chemical properties. It releases and recharges calcium, phosphate, and fluoride ions, providing patients with long-term benefits and improved oral healthcare.[6] It is a highly esthetic material and provides all the benefits of glass ionomers in a strong, resilient, resin matrix that will not crumble or chip. It binds chemically to the teeth, seals against bacterial microleakage, releases more fluoride, is more bioactive than glass ionomers, and is harder and more resistant to fracture than composites. No bonding agent is needed when restoring primary teeth. The strength of the bond to Er:YAG-lased tooth substrate reported in the literature is often confusing and even contradictory. However, there are varying parameters and results in the literature available on the Er: YAG laser. The aim of the study was to use conventional acid etching and laser conditioning to compare the shear bond strength (SBS) of composite resin and ABRC to enamel surface.

Materials and Methods

Forty sound freshly extracted permanent molars were selected for the study. The criteria for the selection were caries-free permanent teeth, teeth without cracks or any fracture, teeth without restorations, and teeth devoid of any developmental defects. The teeth were cleaned of any surface debris or calculus with the help of Universal hand scaler and polished with prophylactic paste and polishing rubber cup to remove any stains or any residual debris. Later, the radicular portions of the teeth were mounted in acrylic resin before preparation for bond strength testing.

The teeth were randomly assigned into four groups of 10 specimens each [Figure 1].

- Group I: Bur-treated surface followed by bonding with traditional composite
- Group II: Laser-treated surface followed by bonding with traditional composite
- Group III: Bur-treated surface followed by bonding with ABRC
- Group IV: Laser-treated surface followed by bonding with ABRC

For group I and group III, tooth preparation was performed with a standard high-speed dental handpiece (Midwest Dental Products Corp., Des Plaines, Illinois) using new No. 56 straight fissure carbide burs. Buccal surface was prepared approximately one half of the enamel depth.

Etching was performed on the prepared tooth surfaces with 37% phosphoric acid followed by application of

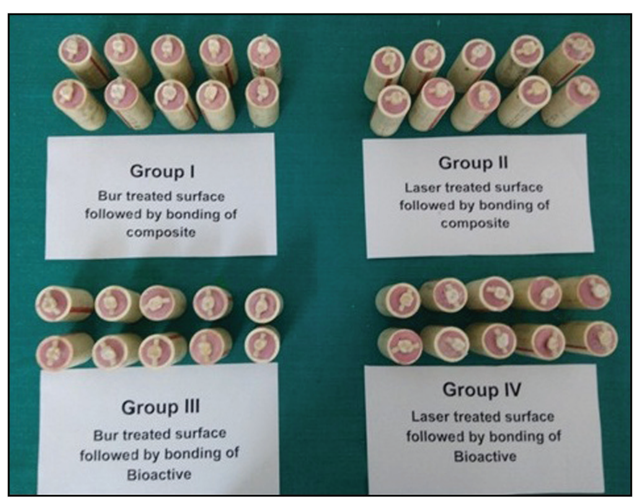

Figure 1: Sample distribution

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bonding agent and gently light cured for 10 seconds. A transparent plastic tube of 1.5mm inner diameter filled with 3mm of traditional composite was packed on all the treated tooth surfaces of group I and ABRC on the treated tooth surfaces of group III. The tube molds were carefully removed. Each tooth received one bonded cylinder on the prepared tooth surfaces. Hardening and retention of restoration was confirmed with the tip of an explorer. For groups II and IV, cavity preparation was performed with Er:YAG laser [Figure 1] followed by filling with traditional composite and ABRC, respectively; rest of the procedure was same as that for groups I and III.

All specimens were then subjected to 1000 thermocycles between 5°C and 55°C in water baths with a dwelling time of 30 seconds [Figure 2]. Thermocycled teeth with the bonded cylinder were then stored in normal saline till bond strength testing. SBS was measured using an Instron universal testing machine at a crosshead rate of 0.05mm/min using a knife-edged loading head. The teeth were oriented in a holding vise so that the loading head was perpendicular to the composite cylinder and was less than 0.25mm from the tooth surface. The SBS was recorded and data obtained were subjected to statistical analysis.

Results

The data were analyzed using the analysis of variance (ANOVA) and post hoc Scheffe statistical test. Results were expressed as numbers and mean scores. For the purpose of statistical interpretation, P value of 0.05 was considered statistically significant.

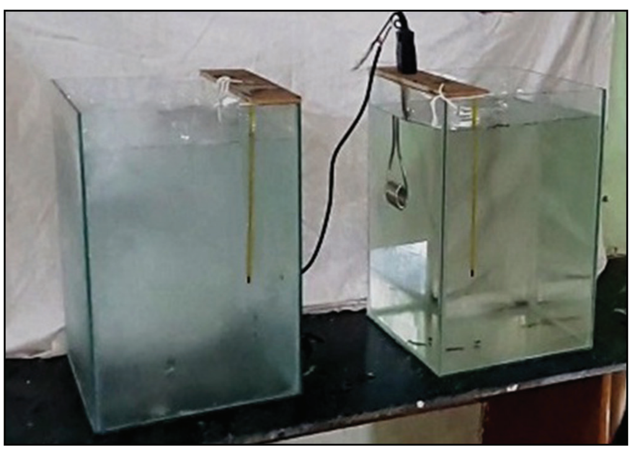

Figure 2: Thermocycling unit

Mean SBS data of traditional composite and ABRC bonded to bur-prepared and Er:YAG laser-prepared enamel are presented in Tables 1-3.

Inference

To compare groups with respect to the SBS values, we applied ANOVA and found significant difference between the four groups. After obtaining a statistically significant P value from the ANOVA, post hoc Scheffe test was applied to know which groups were particularly different from each other.

From Table 2, it can be seen that there is a significant difference between groups I and III, and groups II and III with the P value 0.016 and 0.002, respectively.

However, there is no significant difference between groups I and II (P = 0.843), groups I and IV (P = 0.797), groups II and IV (P = 0.314), and groups III and IV (P = 0.138).

Discussion

There is a continuous search for restorative materials that are biocompatible, esthetic, and having durable bond to the tooth and sufficient strength to withstand masticatory forces. Composite resins are being used with a larger rate today as an esthetic substitute to dental amalgam. Durable bonds are important to achieve mechanical as well as biological and esthetic properties in the midst of dental biomaterials and tooth structures. Bonding of restorative materials to dental substrates is a compulsory property as it is closely linked to the anticipation of material dislodging and marginal leakage.[7] An effective adhesion to tooth structure is of topmost importance to endure the stresses resulting from polymerization shrinkage, thereby necessitating retention and marginal integrity of restorations.[8] Other than acid etching, laser is also used to modify adhesion of resin composites to dental hard tissues. However, laser use is still controversial

Table 1: Shear bond strength of enamel bonded to traditional composite resin and ABRC resin (MPa)

Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
Group I	10	16.4370	3.04286	0.96224	14.2603	18.6137	11.38	21.18
Group II	10	15.3750	1.75708	0.55564	14.1181	16.6319	12.68	18.36
Group III	10	20.4450	3.20950	1.01493	18.1491	22.7409	13.85	24.75
Group IV	10	17.6160	2.15623	0.68186	16.0735	19.1585	12.88	20.86
Total	40	17.4683	3.15801	0.49933	16.4583	18.4782	11.38	24.75

Shear bond strength of enamel bonded to traditional composite resin and ABRC resin (MPa)

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Table 2: ANOVA

	Sum of squares	df	Mean square	F value	P value
Between Groups	143.280	3	47.760	6.999	0.001; Significant
Within Groups	245.669	36	6.824		
Total	388.949	39			

Anova

Table 3: Multiple Comparison using Post-HocScheffe test

Comparison	Mean difference	P value	Significance
Group I vs II	1.062	0.843	NS
Group I vs III	4.008	0.016	S
Group I vs IV	1.179	0.797	NS
Group II vs III	5.070	0.002	S
Group II vs IV	2.241	0.314	NS
Group III vs IV	2.829	0.138	NS

NS; $p > 0.05$; Not significant; S: $p < 0.05$; Significant

Multiple Comparison using Post-HocScheffe test

for these purposes; some studies have suggested using laser to prepare or etch dentin, but some other studies have reported that it is not an effective method. Erbium lasers appear to be most beneficial in this regard.

Er:YAG laser reported the least thermal damage.[9] The use of Er:YAG laser in pediatric dentistry has increased due to more comfort, less work time, noise, pain, and fear. Er:YAG laser caries removal mechanism is based on water molecules absorbing laser energy in dental hard tissues. This results in increased spot pressure from radiation and micro-explosions that cause microparticles to be ejected from dental hard tissue. This is performed with minimal or no thermal damage.[10] During the laser ablation process of the Er:YAG, enamel tissue undergoes structural changes such as no formation of smear layers, surface irregularities, and exposure to enamel prism. These changes are meant to increase the resin composite bond strength, but these laser-ablation-generated micro-porosities do not have the same ideal pattern obtained by applying acid phosphorus. Therefore, this heterogeneous structure in lased enamel affects the strength of the resin composite bond.[11]

Adhesive materials may have either chemical bonding or micromechanical tooth bonding. In a strong resin matrix, ABRC provides all the benefits of glass ionomers. It binds chemically to the teeth, seals against bacterial microleakage, releases fluoride, is more bioactive than ionomers of glass, and is more resistant to hardness and fracture than composites. ABRC comprises glass particles and polyacid components of resin-modified glass ionomer cements that are subjected to acid/base neutralization that harden all glass ionomer systems. They also contain a bioactive ionic resin matrix that allows for polymerization of both light cure and chemical cure. There are some studies evaluating the strength of the shear bond of the resin composites to lased enamel, but not enough studies are available to lased enamel about the strength of the shear bond of ABRC. This study, therefore, aimed at evaluating and comparing traditional composite and ABRC SBS after their preparation with Er:YAG laser and conventional acid etching method. Due to possible disadvantages with enamel acid etching, the prospect of laser etching enamel surfaces was welcomed. Acid demineralization with 37% phosphoric acid may increase the susceptibility of enamel surfaces to caries, particularly if resin impregnation is inadequate or defective. Due to the lack of demineralization and reduction in water and organic components, laser etching was thought to reduce caries risk.[12]

The extensive cracking and underground cracking with the Er:YAG laser on enamel surfaces, however, negates any potential benefits and prevents its use. In this study, the enamel specimens irradiated with the Er:YAG laser showed significantly lower mean bond strengths than the rotary-prepared acid-etched enamel specimens in which ABRC was packed. ABRC contains groups of antimicrobial phosphate acids that improve the interaction between the resin and the reactive glass fillers and enhance the interaction with the tooth structure. Through a water-based ionization process, hydrogen ions snap off the phosphate groups and are replaced in tooth structure with calcium. This ionic interaction binds the resin to the minerals in the tooth, creating a strong complex of resin–hydroxyapatite and a positive microleakage seal. The rubberized resin component of ABRC provides unequaled resilience and toughness. This can explain the highest value obtained in the samples of group III as compared to the samples of other groups.

The highest bond strength in enamel samples was seen in the acid etched and bur group, whereas the lowest was seen in the group in which bur, laser, and acid etching were used in combination. First, although surfaces prepared by laser were mostly rough, they had irregular porosities and did not follow a uniform pattern. The second reason was reported to be the thermal denaturation of collagen fibers. This bond strength reduction was also reported in enamel samples, which have approximately 0.5% collagen. They stated that the conventional method of cavity preparation and etching would yield the best results.[13]

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Chemical changes can occur as a result of crystal liquefaction, that is, when the tooth is subjected to high temperatures.[14,15] This liquefaction process is caused during the rapid cooling of the dental tissue and is responsible for increasing the hydroxyapatite crystals that obliterate the microporous surface.[16] Furthermore, it has been reported that Er:YAG laser irradiation modifies the calcium-to-phosphorus ratio, reduces the carbon-to-phosphorus ratio, and leads to the formation of more stable and less acid-soluble compounds that may hinder ionomeric cements' chemical adhesion.[17] Korkmaz *et al.*,[18] investigated the SBS between ABRC and enamel or dentin after acid etching, after Er:YAG laser etching, or after combined treatment. They concluded that etching with phosphoric acid increased the SBS, but the laser group showed a lower bond strength that was in accordance with the results of this study. There is need for more studies that evaluate the interaction of laser-prepared surfaces with new generation of glass ionomers ionic resin-based composites.

Conclusions

It may be concluded that within the limitations of this *in vitro* study:

(1) For enamel, the highest bond strengths were recorded when the specimens were prepared with the diamond bur, followed by ACTIVA BioACTIVE bonding.
(2) Er:YAG laser pretreatment did not improve the tooth surface adhesion of composite resin.
(3) Improvement in laser technology and increased interest in their potential for application of hard tissue warrant further investigations with resin-based composites of Er:YAG laser-prepared teeth and adhesion.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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