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Original Article

Effects of Erbium Family Laser on Shear Bond Strength of Composite to Dentin After Internal Bleaching

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Abstract

Introduction: The aim of this study was to assess the effect of surface treatment with erbium: yttrium-aluminum-garnet (Er:YAG) and erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) lasers on shear bond strength of composite resin to recently bleached dentin.

Methods: In this study, 40 extracted human premolars were selected. The teeth were cut 4 mm apical to the cusp tip and were randomly divided into four groups (n=10 in each group) for shear bond strength testing. For bleaching, 35% hydrogen peroxide (H_2o_2) gel (Opalescence Endo, Ultradent, South Jordan, UT, USA) was applied to dentin surfaces of all specimens for 10 days. Before etching and bonding, in Er,Cr:YSGG and Er:YAG laser groups, dentin surfaces were irradiated with Er,Cr:YSGG and Er:YAG lasers, respectively. In Er,Cr:YSGG group, Er:YAG group and control group, composite restoration was performed immediately after bleaching while in common procedure group, composite restoration was performed after seven days. The teeth were then subjected to shear bond strength testing machine. The data were statistically analyzed using analysis of variance (ANOVA) and Tukey test.

Results: The mean and standard deviation (SD) of shear bond strength was 4.3 ± 1.4 MPa for control group, 6.7 ± 2.0 Mpa for Er,Cr:YSGG group, 14.4 ± 3.7 Mpa for Er:YAG group and 19.4 ± 2.6 Mpa for common procedure group.

Conclusion: The shear strength of composite to Er:YAG laser-treated bleached dentin was significantly higher than control group while significantly lower than common procedure.

Keywords: Er:YAG; Er,Cr:YSGG; Shear bond strength; Internal Bleaching; Composite.

Introduction

Tooth discoloration varies in etiology and localization and can be of extrinsic or intrinsic origin. An intrinsic discoloration is defined as one with its origin within the pulp chamber. The most common causes of internal chromatic alteration are hemorrhage, necrosis, calcification and iatrogenic discoloration due to dental treatments.[1]

Non-vital bleaching by intra-coronal application of bleaching agents is a conservative method that often yields a successful esthetic outcome and is an alternative to more invasive prosthodontic interventions.[2] Hydrogen peroxide (H_2o_2) at concentrations of 30% to 35% is currently the most commonly used bleaching agent. H_2o_2 is able to penetrate into the tooth structure and produce oxygen and hydroxyl free radicals.[3] These radicals act on long-chain molecules of pigments and cleave them into smaller molecules of carbon dioxide and water by means of oxy-reduction reactions.[1,4]

In the walking bleach method, H_2o_2 and sodium perborate, either alone or in combination, are placed in the access cavity for a few days.[5] After achieving the desired bleaching result, non-vital bleaching is followed by restoration of the access cavity. A sealed restoration with minimal coronal leakage is a prerequisite for the long-term success rate of both endodontic and bleaching treatments.[6]

A number of studies have shown a decrease in bond strength of adhesive restorations to bleached tooth structure.[7-13] Reduction in bond strength may be due to the presence of residual oxygen on the bleached surface that affects the resin polymerization and reduces the sealing of composite restorations.[14-16] Based on the fact that the residual oxygen slowly dissipates over time,

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several studies have recommended that a longer time lapse after bleaching can help achieve a good adhesion,[7,11,13,17-19] and the bond strength values tend to normalize after a minimum of one week.[3,18,19]

In the past decade, new laser appliances have been introduced for dental restorative purposes. The family of erbium family lasers (erbium: yttrium-aluminum-garnet [Er:YAG] and erbium, chromium: yttrium-scandium-gallium-garnet [Er,Cr:YSGG]) with 2 different wavelengths has been widely used for cavity preparation and dental surface conditioning in adhesive esthetic procedures.[20-24] Erbium family lasers have wavelengths corresponding to the peak absorption of hydroxyapatite and water and hence. This results in a water-mediated ablative effect. Evaporation of water in the tissue leads to micro-explosions and ablation of tooth structure.[3,22,24,25] In other words, the increased internal pressure due to evaporation of water results in explosive ablation.[26,27]

The ablative effect of the erbium lasers may be able to accelerate the release of free radicals and neutralize the effects of bleaching agents on bond strength. Thus, the objective of this study was to assess the effect of surface treatment with erbium family lasers on bond strength to bleached dentin.

Methods

Specimen Preparation

Forty human premolars extracted for orthodontic reasons were used in this study. The teeth with visible cracks, fractures, restorations or caries were excluded. The soft tissue debris was removed by a periodontal scaler (SONICflex 2000, Kavo Dental GmbH/Kaltenbach & Voigt GmbH, Biberach, Germany). The teeth were immersed in 0.5% chloramine T solution (Chloramine T trihydrate, Merck KGaA, Darmstadt, Germany) for the purpose of disinfection and stored in distilled water at 4°C until use. The roots were embedded in autopolymerizing acrylic resin up to the cementoenamel junction. Occlusal surfaces were cut 4 mm apical to the cusp tip parallel to the occlusal surface under water-cooling with a diamond wire saw (Well precision wire diamond saw, Mannheim, Germany). A flat dentin surface on the remaining tooth structure was exposed. The surface texture and the smear layer of all teeth were standardized using 600 grit silicon carbide abrasive papers. The teeth were randomly divided into four groups (n=10) for shear bond strength testing.

Bleaching and Restoration

In this study, 35% H_2o_2 gel (Opalescence Endo, Ultradent, South Jordan, UT, USA) was used for internal bleaching. To simulate the walking bleach technique in the clinical setting, the bleaching material was applied on the dentin surfaces of all specimens. Then, the teeth were stored in a closed container in an incubator (37°C and 100% humidity) for 10 days. Before applying the composite, dentin surfaces in Er,Cr:YSGG group were irradiated by Er,Cr:YSGG laser (Waterlase MD, Biolase Technology Inc., Irvine, CA, USA) and in Er:YAG group by Er:YAG laser (USD20, DEKA, Florence, Italy). Er:YSGG laser was irradiated at a 2780 nm wavelength, 0.5 W power, 10 Hz frequency and 60 µs pulse duration in non-contact mode with 4 mm distance from the dentin surface. Er:YAG laser was irradiated at a 2940 nm wavelength, 0.5 W power, 10 Hz frequency and 230 µs pulse duration in non-contact mode with 4 mm distance from the dentin surface.

Composite restoration was done immediately after the bleaching treatment in all groups except for the common procedure group in which, composite restoration was delayed for seven days. After laser treatment, all the specimens were etched with 37% phosphoric acid gel (Etch Royale, Pulpdent, Watertown, USA) for 15 seconds, washed for 10 seconds and dried with a cotton-pellet. Two consecutive coats of adhesive agent (Adper Single bond 2, 3M ESPE, St. Paul, MN, USA) were applied and agitated by an applicator, followed by air drying and light curing with a light intensity of 600 mW/cm^2 (Coltolux LED, Coltene, Cuyahoga Falls, OH, USA) for 10 seconds. Afterwards, a plastic cylindrical tube measuring 3 mm in diameter and 5 mm in height was placed over the treated flat dentin surface in all groups. The tube was bulk-filled with Filtek Z250 composite resin (3M ESPE, St. Paul, MN, USA) and light cured for 40 seconds. Next, to ensure the degree of conversion, the tube was removed and light curing was continued for an additional 40 seconds.

The specimens were immersed in distilled water at 37°C for 24 hours. The shear bond strength was measured by a universal testing machine (Zwick, Ulm, Germany). A parallel knife-edge shearing device was aligned over the bonded interface and the specimen was loaded at speed of 0.5 mm per minute until failure. The bond strength was recorded in MPa.

Statistical Analysis

The data were analyzed by SPSS software version 22.0 for Windows (SPSS; Chicago, IL, USA) and one-way analysis of variance (ANOVA). In case of significant differences among groups ($P < 0.01$), the Tukey HSD (honest significant difference) test was used for multiple comparisons considering the homogeneity of variances. The confidence level was set at 95% ($P < 0.05$). Kolmogorov-Smirnov test was used for testing the normality of sample distribution and Levene test was carried out for testing the homogeneity of variances.

Results

The shear bond strength values of all groups are presented in Table 1 and Figure 1. The results of ANOVA showed statistical differences among the groups ($P < 0.001$). Tukey HSD test revealed significantly higher bond strength in the common procedure group when compared to other groups. Normal distribution of the data is confirmed with one-sample Kolmogorov-Smirnov test ($P = 0.465$)

Table 1. Shear Bond Strength Results of Study Groups

Group	Shear Bond Strength			
	Minimum	Maximum	Mean	SD
Er,Cr:YSGG group (immediate bonding)	3.53	10.46	6.652	1.955
Er:YAG group (immediate bonding)	8.11	19.87	14.448	3.679
Control group (No laser–No delay)	2.97	6.93	4.260	1.376
Control group (No laser- delayed bonding after 7 days)	15.08	23.13	19.351	2.587

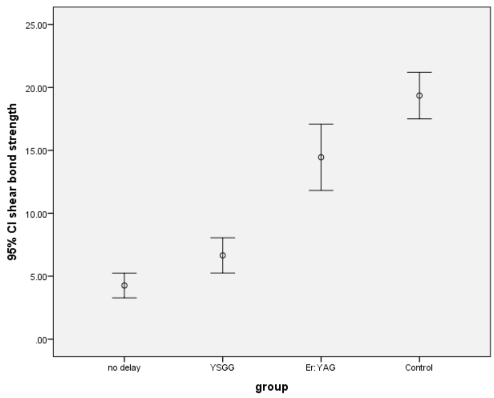

Figure 1. The Comparison of Mean ± Standard Deviation of Shear Bond Strength of All Groups.

and homogeneity of variances was verified by means of Levene test ($P = 0.091$).

There was a significant difference between Er:YAG and common procedure groups in bond strength ($P = 0.001$). In Er:YAG group, laser irradiation resulted in significantly higher bond strength compared to the Er,Cr:YSGG group and control group ($P < 0.001$). No significant difference was seen between Er,Cr:YSGG group and control group ($P = 0.173$).

Discussion

The walking bleach technique is a method for bleaching discolored non-vital teeth. In this procedure, the bleaching agent is placed into the pulp chamber for a few days until favorable result is obtained.[1] After bleaching, the access cavity should be restored with composite resin but the residual peroxide and reactive oxygen species inhibit the polymerization of composite resin.[2] Residual peroxide becomes inactive over time and time elapsed after bleaching decreases the adverse effects of H_2o_2 on the bonding procedure.[8,12,17,18]

Erbium lasers (Er:YAG at a wavelength of 2940 nm and Er,Cr:YSGG at a wavelength of 2780 nm) are the most promising lasers for use on mineralized tissues because both wavelengths are highly absorbed by water and hydroxyapatite. The water molecules among the hydroxyapatite crystals absorb the beams and evaporate; as a result, the internal pressure increases and micro-explosions occur leading to substrate ejection and microstructural alterations.[25,28,29]

Although several studies have assessed the effects of erbium family lasers on bleached enamel,[3,30-32] to the best of our knowledge no study has compared the effects of Er:YAG and Er,Cr:YSGG lasers on bleached dentin.

Based on our results, Er:YAG laser irradiation led to significantly higher bond strength compared to the control group. A possible explanation for this finding is that laser-induced heat as well as the ablative effect of Er:YAG laser irradiation may result in evaporation of the remaining bleaching agents in the tissues.[3,32] Furthermore, lased dentin produces an irregular surface pattern that can increase micromechanical retention of adhesive and enhance effective bonding.[28,32,33] Finally, reduction in microbial count due to erbium laser irradiation may also explain the higher bond strength values. [25,34-37]

Although Er,Cr:YSGG laser treatment caused an increase in bond strength compared to the control group, the amount was insignificant. The drop in shear bond strength values in the Er,Cr:YSGG group compared to the Er:YAG group may be due to the difference in the morphology of the lased dentin surface. Er,Cr:YSGG yielded a denuded scale-like surface that seemed to be more thermally affected than the Er:YAG laser irradiated surfaces. Er:YAG laser irradiation yields a rough surface similar to an acid-etched surface which is more favorable as a bonding substrate.[22] In addition, Er,Cr:YSGG laser is absorbed by OH^- in hard tissues which cause higher surface temperature than Er:YAG laser. This may lead to thermal damage, chemical changes and resistance to demineralization.[24]

Although erbium laser groups in our study did not show bond strength values as high as those in the common procedure, erbium laser treatment of bleached dentin surfaces seems to offer promising results. In the current study, the effect of change in irradiation parameters on the results was not evaluated. Thus, further studies on the use of lasers with different irradiation parameters on bleached dentin may be necessary to find the best exposure settings for optimal immediate bond strength.

Conclusion

Within the limitations of this in vitro study, it is founded that Er:YAG laser irradiation prior to etching can improve the bond strength of composite to bleached dentin but not to the acceptable level for an adhesive restoration. Therefore, this procedure is not recommended for use in the clinical setting.

Conflict of Interests

The authors declare no conflict of interest.

Ethical Considerations

Not applicable.

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