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Effect of Various Laser Surface Treatments on Repair Shear Bond Strength of Aged Silorane-Based Composite

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Abstract

Introduction: Successful repair of composite restorations depends on a strong bond between the old composite and the repair composite. This study sought to assess the repair shear bond strength of aged silorane-based composite following surface treatment with Nd:YAG, Er,Cr:YSGG and CO2 lasers.

Methods: Seventy-six Filtek silorane composite cylinders were fabricated and aged by 2 months of water storage at 37°C. The samples were randomly divided into 4 groups (n = 19) of no surface treatment (group 1) and surface treatment with Er,Cr:YSGG (group 2), Nd:YAG (group 3) and CO2 (group 4) lasers. The repair composite was applied and the shear bond strength was measured. The data were analyzed using one-way analysis of variance (ANOVA) and Tukey post-hoc test. Prior to the application of the repair composite, 2 samples were randomly selected from each group and topographic changes on their surfaces following laser irradiation were studied using a scanning electron microscope (SEM). Seventeen other samples were also fabricated for assessment of cohesive strength of composite.

Results: The highest and the lowest mean bond strength values were 8.99 MPa and 6.69 MPa for Er,Cr:YSGG and control groups, respectively. The difference in the repair bond strength was statistically significant between the Er,Cr:YSGG and other groups. Bond strength of the control, Nd:YAG and CO2 groups was not significantly different. The SEM micrographs revealed variable degrees of ablation and surface roughness in laser-treated groups.

Conclusion: Surface treatment with Er,Cr:YSGG laser significantly increase the repair bond strength of aged silorane-based composite resin.

Keywords: Silorane-based composite; Surface treatment; Laser; Aging.

Introduction

Despite the improved long-term clinical service of tooth-colored restorations, chipping, wear and small fractures still occur and are the main reasons for replacement of these restorations.[1,2]

In most cases, intraoral repair of restorations is preferred to their replacement.[3] Adhesive dentistry is based on conservative cavity preparation and use of adhesive restorative materials. This approach not only enables conservative caries removal, but also allows for the repair of existing restorations instead of their replacement.[4] Clinical service of composite restorations depends on the properties of their polymer network and fillers.[5-7] These properties are different in various types of composites and are important for assessing the efficacy of different surface treatment methods for composite restoration repair.[8] Uniformity and compatibility of the repair composite with the old composite are achieved via 3 mechanisms namely chemical bond to the organic matrix, chemical bond to the exposed filler particles and micromechanical interlocking.[9] Previous studies have shown the optimal efficacy of micromechanical retention created by diamond burs, sandblasting and acid etching for increasing the repair bond strength of composite.[10,11] Laser has been recently used for surface roughening in dental procedures and Er,Cr:YSGG, CO_2 and Nd:YAG lasers have been used for this purpose.[12-16]

On the other hand, silorane-based composites with ring opening polymerization mechanism were introduced to overcome the polymerization shrinkage and the

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subsequently created stresses in dimethacrylate-based composites.[17,18] Irrespective of the structural differences of composites, repair or replacement of restorations is often required after a period of clinical service due to wear, discoloration or chipping of composites. Thus, age of a restoration plays a fundamental role in repair bond strength of composites.[19,20] Aging causes hydrolytic degradation of resin matrix and silanizes non-organic fillers in the oral cavity.[21] A previous study on repair of composites showed significant reduction in bond strength at the interface of aged and new composite.[22] Considering the effect of aging on the success of composite repair and the significance of repair bond strength in low-shrinkage silorane-based composites, this study aimed to assess the effect of surface treatments with Er,Cr:YSGG, Nd:YAG and CO_2 lasers on repair shear bond strength of aged Filtek silorane composite.

Methods

In this in vitro study, 76 cylindrical composite samples measuring 6 mm in diameter and 4 mm in height were fabricated of Filtek silorane composite resin (3M ESPE Dental Products, St. Paul, MN, USA). The composite resin was incrementally applied in 2 layers to a plastic mold and each layer was cured for 40 seconds using a light-curing unit (Astralis 7, Ivoclar Vivadent, Schaan, Lichtenstein) with a light intensity of 400 mW/cm^2. The final layer was covered with a Mylar strip and after curing, the samples were polished by Soflex polishing discs up to 1000 grit (3M ESPE, St. Paul, MN, USA) and were then stored in distilled water at 37°C for 2 months for the purpose of aging. Table 1 presents the properties of the materials and lasers used in this study. Seventy-six aged samples were divided into 4 groups (n = 19) based on the type of surface treatment:

Group 1: No surface treatment.

Group 2: The samples were subjected to Er,Cr:YSGG (Biolase Europe GmbH, 92685 Floß, Germany) laser irradiation with a fiber optic tip diameter of 400 µ. It generated photons at a wavelength of 2780 nm with 20 Hz frequency, 3 W output power, 150 mJ energy per pulse and 200 µs pulse duration. The laser tip was used perpendicularly at 1 mm distance from the surface under 50% water and 60% air spray with 2 bar pressure. The application tip was swiped across the surface from the center of the composite disc to the peripheries with a circular movement for 5 seconds.

Group 3: The samples were subjected to Nd:YAG dental laser (Lambada Scientifica, Srl, Vicenza, Italy) irradiation with a fiber diameter of 400 µ. It generated photons at a wavelength of 1064 nm with 20 Hz frequency, 3 W output power, 150 mJ energy per pulse and 200 µs pulse duration. The laser tip was used perpendicularly at 1 mm distance from the surface under 50% water and 60% air spray with 2 bar pressure. The application tip was swiped across the surface from the center of the composite disc to the peripheries with a circular movement for 5 seconds.

Group 4: The samples were subjected to CO_2 surgical laser (Lambada Scientifica, Srl, Vicenza, Italy) irradiation. The laser handpiece had a hollow tube with a tip diameter of 400 µ. It generated photons at a wavelength of 10.6 µm with 20 Hz frequency, 3W output power, 150 mJ energy per pulse and 200 µs pulse duration. The laser tip was used perpendicularly at 1 mm distance from the surface under 50% water and 60% air spray with 2 bar pressure. The application tip was swiped across the surface from the center of the composite disc to the peripheries with a circular movement for 5 seconds.

In all groups, composite surfaces were laser-irradiated at 2mm distance for 15 seconds. The treated surfaces were rinsed with distilled water and dried. Silorane bonding agent (3M ESPE, St. Paul, MN, USA) was applied to the surface and light cured for 10 seconds. According to the manufacturer's instructions. A plastic mold measuring 2 mm in height and 4 mm in diameter was placed at the center of the surfaces. One layer of composite with 2

Table 1. The Properties of the Materials and Lasers Used in This Study

Material	Description & Composition	Manufacturer
Filtek™ silorane, low shrinkage posterior restorative material	A light curing radiopaque silorane-based composite. The monomer matrix is composed of siloxane and oxirane molecules (23% of the composition). The inorganic filler contains fine quartz particles and radiopaque yttrium fluoride (76%). Additional contents: initiator (0.9%), stabilizer (0.13%) and pigments (0.005%).	3M ESPE Dental Products, St. Paul, MN, USA
Filtek silorane bond	A filled, light-cure bonding agent for enamel and dentin bonding. It contains a 3M ESPE hydrophobic bifunctional monomer, camphor quinine/silane-treated silicofillers and stabilizer.	3M ESPE Dental Product, St. Paul, MN, USA
CO2 laser	Carbon dioxide laser, wavelength =10600 nanometers, repetition rate = 20 Hz, pulse duration =140 microseconds.	LAMBDA ScientificaSrl, Vicenza, Italy
Er,Cr:YSGG laser	Erbium, chromium: yttrium-scandium -gallium-garnet wavelength =2780 nanometers, repetition rate = 20 Hz, pulse duration=140 microseconds.	Biolase Europe GmbH, Floss, Germany
Nd:YAG laser	Neodymium:Yttrium-aluminum-garnet wavelength = 1064 nanometers, repetition rate = 20 Hz, pulse duration = 140 microseconds.	Nd:YAG Dental Laser, LAMBADA Scientifica, Srl, Vicenza, Italy

mm thickness was applied and cured for 40 seconds. The mold was then removed and the samples were light cured repeatedly from different directions for 20 seconds.

A universal testing machine was used for measurement of shear bond strength. The upper fixture was attached to the superior jaw of the machine and the lower fixture with the sample was mounted on the inferior jaw of the machine. The crosshead blade was adjusted at the new-old composite interface and the load at fracture of the samples displayed on the monitor was recorded. The load was applied by the chisel-shaped blade of the machine at a crosshead speed of 1 mm/minute vertical to the old-new composite interface. The values were recorded in newton (N) and converted to megapascal (MPa) using the formula below:

$$Repair\ bond\ strength\ \left(MPa\right)\ = \frac{Force\left(N\right)}{\text{Sample surface area(mm2)}}$$

In groups 1 to 4, prior to applying the repair composite, 2 samples were randomly chosen and gold sputter-coated with 150 A° thickness in vacuum conditions (10^3 mbr). The surface topography of these samples was studied under a scanning electron microscope (SEM) (Tescan Vega-II, Tescan S.RO, Libusinia Trida, Czech Republic). The repair shear bond strength data were analyzed using one-way analysis of variance (ANOVA) and post hoc Tukey test at $P = 0.05$ level of significance.

Results

Table 2 shows the shear bond strength values of the 4 groups. As seen in Table 2, the highest and the lowest shear bond strength values were seen in the Er,Cr:YSGG (8.99 ± 1.16 MPa) and the control (6.69 ± 1.68 MPa) groups, respectively. One-way ANOVA revealed a significant difference in the repair bond strength of the 4 groups ($P < 0.0001$). Pairwise comparison of the groups with the Tukey post-hoc test revealed that the mean bond strength of Er,Cr:YSGG group was significantly different from that of the other groups ($P < 0.05$, Table 3). However, no significant differences were noted between shear bond strength values of the CO_2, control and Nd:YAG laser groups ($P > 0.05$, Table 2).

The SEM micrographs revealed micro-porous and irregular patterns in the Er,Cr:YSGG laser treated surfaces. In the groups treated with CO_2 and Nd:YAG lasers, ablated areas and increased surface roughness (but with a different pattern from that of erbium laser group) were seen (Figure 1A-D).

Table 2. Comparison of the Mean Shear Bond Strength (MPa) Values in the Study Groups[a]

Groups	Mean ± SD	95% CI of the Mean	
		Lower Bound	Upper Bound
Control	6.69 ± 1.68	5.8286	7.5644
Er,Cr:YSGG	8.99 ± 1.16	8.3897	9.5903
CO2	7.20 ± 1.27	6.5440	7.8583
Nd:YAG	7.33 ± 1.16	6.7401	7.9352

[a] One-way ANOVA, $P = 0001$.

Discussion

Repair of aged composites is a minimally invasive and cost-effective procedure. Several surface treatment methods have been introduced to enhance micromechanical retention and increase the wettability of old composites such as acid etching, diamond bur preparation, sandblasting and laser irradiation.[21] The immediate repair bond strength of composite is similar to its cohesive strength due to the presence of oxygen inhibited layer. However, after aging, factors such as decreased amount

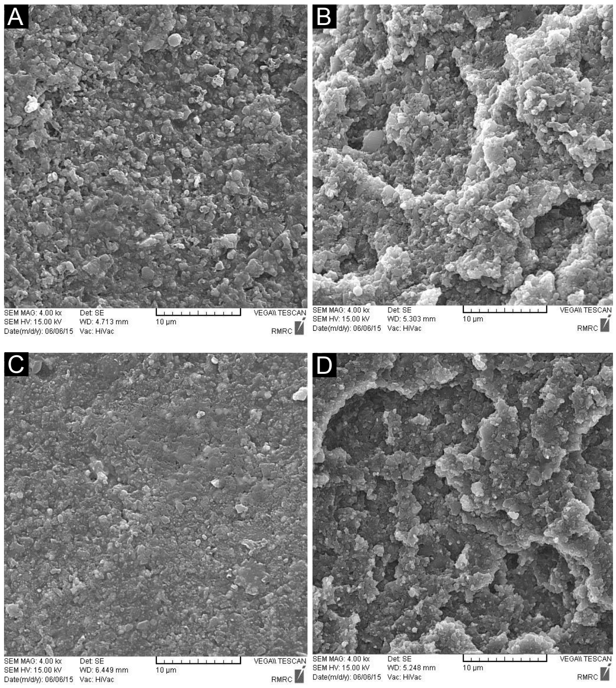

Figure 1. (A) Er,Cr:YSGG Laser Treated Surface. (B) Nd:YAG Laser Treated Surface. (C) CO2 Laser Treated Surface. (D) Surface Topography of the Control Group.

Table 3. Pairwise Comparisons of the Groups Using the Tukey Test

Group	Group	Mean Differences	*P* Value[a]	Group	Group	Mean Differences	*P* Value[a]
Er,Cr:YSGG	Control	2.29	0.000	Er,Cr:YSGG	Co_2	1.78	0.001
Co_2	Control	0.50	0.693	Er,Cr:YSGG	Nd:YAG	1.66	0.003
Nd:YAG	Control	0.64	0.508	Nd:YAG	Co_2	0.46	0.991

[a] Tukey HSD test.

of active monomers, polishing and structural changes affect the repair bond strength of composite.[21,23] On the other hand, differences in the structure of polymer matrix and fillers can yield variable bond strength values.[24,25] This study aimed to assess the effect of surface treatments with different types of lasers on repair bond strength of aged silorane-based composite. Based on the results, the minimum and maximum bond strength values were noted in the control and Er,Cr:YSGG laser groups, respectively with significant differences with the other groups ($P=0001$). The results of our study were in line with those of Alizadeh Oskoee et al.[26]
Erbium lasers enable selective ablation and are used for surface treatment of composite restorations.[27,28] Composite resin ablation by erbium laser is done through explosive vaporization followed by hydrodynamic ejection.[27] During this process, quick melting and consequently changed volume of the melted material generate strong expansion forces. The generated forces within the composite structure form, prominences on the composite surface and melted material leaks out of the composite surface in the form of drops.[29] This type of ablation has also been reported to occur following the application of Er,Cr:YSGG laser.[27-30] The SEM micrographs showed round porosities without smear layer on the Er,Cr:YSGG laser treated surfaces (Figure 1A).The micro-retentive pattern of the surface of samples can increase the repair bond strength via increasing the surface area and balancing stress distribution,[31] which explains the obtained results in the Er,Cr:YSGG laser group in our study. On the other hand, low repair bond strength in the control group with no surface treatment highlights the important role of surface roughness in achieving optimal repair bond strength.[11,32] A noteworthy finding of the current study was that, although the repair bond strength of Nd:YAG and CO_2 laser groups was higher than that of the control group, the difference in values among the 3 groups did not reach statistical significance ($P>0.05$); this finding was in contrast to the results of Alizadeh Oskoee et al.[26]
Evaluation of the SEM micrographs of the surfaces treated with Nd:YAG and CO_2 lasers showed degradation of resin matrix, ablation and increased surface roughness with a different pattern from that in the Er,Cr:YSGG laser group (Figure 1B and 1C).
In the clinical process, aging occurs due to the exposure of composite material to the oral environment, foods and drinks as well as cyclic loading over long periods of time, which change the structure of the material.[21,23] Water storage is the most efficient aging protocol due to its hydrolytic effect on the matrix and filler interface.[21] During water storage, water is absorbed by the resin matrix via the diffusion mechanism and weakens the matrix and causes the leakage of unreacted monomers into the environment leading to eventual failure of resin-filler bond.[23]
It seems that water storage causes structural changes in the samples and consequently yields repair bond strength values different from those in immediate repair conditions.[26] According to Beyer et al,[33] the optimal clinical repair bond strength is 60%-70% of the cohesive strength of composite. Thus, it seems that laser irradiation is not suitable for surface treatment of aged silorane-based composites; however, generalization of the results to the clinical setting requires further studies with different methods and durations of aging.

Conclusion

Surface treatment with Er,Cr:YSGG laser significantly increases the repair bond strength of aged silorane-based composite resin.

Ethical Considerations

This study was approved by the ethical committee of the Vice Chancellor of Research, Tabriz University of Medical Sciences.

Conflict of Interests

The authors declare that they have no conflict of interest.

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