[**Influence of various laser surface treatments on the repair shear bond strength of** [**aged silorane based composite**](http://www.sciencedirect.com/science/article/pii/S0109564111008712)](http://www.ncbi.nlm.nih.gov/pubmed/26156281)

**Introduction**

Despite the improved long-term clinical service of tooth-colored restorations, chipping, wear and small fractures are the main reasons forreplacement 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 invarious 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 repairing composite with the old composite are achieved via three mechanisms namely chemical bond with the organic matrix, chemical bond with 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, CO2 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 subsequently created stresses in dimethacrylate-based composites .17,18 In silorane-based composites, cationic ring opening reactions compensate for the polymerization shrinkage and decrease the overall shrinkage compared to that of methacrylate-based composites, which undergo free radical polymerization.17 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 The aging process causes hydrolytic degradation of the resin matrix and silanized non-organic fillers in the oral cavity.21investigations about repair of composites have shown significant reduction in bond strength at an aged composite interface.22 Considering the role of aging in the process of composite repair and the importance of assessment of the inter-facial bond in repair of low-shrinkage silorane-based composites, this study aimed to assess the effect of aging on repair shear bond strength of Filtek silorane composite following surface treatment with Er,Cr:YSGG, Nd:YAG and CO2 lasers.

 **Methods**

In this in vitro study, 76 cylindrical composite samples measuring 6mm in diameter and 4mm in height were fabricated of Filtek silorane composite resin (3M ESPE Dental Products, St. Paul, USA). The composite resin was incrementally applied to a plastic mold and each layer was cured for 40 seconds using a light-curing unit (Astralis 7, IvoclarVivadent, Schaan, Lichtenstein) with alight intensity of 400mW/cm2. The final layer was covered with a Mylar strip and after curing, the samples were polished by Soflex polishing discs (3M ESPE, St. Paul, MN, USA) and were then stored in distilled water at 37°C for two months for the purpose of aging. Seventeen other samples were also fabricated measuring 6mm in diameter and 6mm in height for measurement of cohesive strength of the material.The properties of the materials and lasers used in this study are presented in Table 1. Seventy-six aged samples were divided into four groups based on the type of surface treatment:

Group 1: No surface treatment

Group 2: The samples were subjected to G type Er,Cr:YSGG (Biolase Europe GmbH, 92685 Floß, Germany) laser irradiation with a G-type fiberoptic tip diameter of 400μ It generated photons at a wavelength of 2780nm with 20Hz frequency, 3W output power, energy per pulse 150 mJ, pulse duration 200 µs. The laser tip was used at perpendicular angle of incidence at 1mm distance under 50% water and 60% air spry at 2 bar pressure. The application tip was moved from the center of composite disk to peripheral area with a circular movement for 5 second.

Group 3: The samples were subjected to Nd:YAG dental laser (LambadaScientifica, Srl, Vicenza, Italy) irradiation with a fiber diameter of 400μ. The generated photons had awavelength of 1064nm with 20Hz frequency. The power output of the device was equal to that of group two.

Group 4: The samples were subjected to CO2 surgical laser (LambadaScientifica, Srl, Vicenza, Italy) irradiation with a hallow tubediameter of 400μ.The generated photons had a wavelength of 10.6 µm and 20Hz frequency. The power output of the device was equal to that of group two.

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 manufacture ordering a plastic mold measuring 2mm in height and 4mm in diameter was placed at the center of the surfaces. A layer of composite with 2mm 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 1mm/min vertical to the old-new compositeinterface. The values were recorded in Newton (N) and converted to Megapascals (MPa) using the formula below:

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

In groups 1 to 4, prior to applying the repair composite, two samples were randomly chosen and gold sputter-coated with 150Α° thickness in vacuum conditions (103mbr). The surface topography of these samples wasstudied under a SEM (Tescan Vega-II, Tescan S.RO., LibusiniaTrida, Czech Republic). Moreover, samples 6mm in diameter and 6mm in height were fabricated and Filtek silorane composite was applied to the mold in three 2mm-thick increments. Each layer was light-cured for 40 seconds using Astralis 7 light curing unit. These samples were fabricated to measure the cohesive strength of the material.

The repair shear bond strength data were analyzed using one-way ANOVA and post hoc Tukey’s test at P=0.05 level of significance.

**Results**

Table 1 shows the shear bond strength values of the four groups. As seen in Table 1, the highest and the lowest shear bond strength values were seen in the Er,Cr:YSGG (8.99±1.16MPa) and the control (6.69±1.68MPa) groups. One-way ANOVA revealed a significant difference between the repair bond strength of the four groups (P<0.0001). Pairwise comparison of the groups with the Tukey’s 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). However, no significant differences were noted betweenshear bond strength valuesof the CO2, control and Nd:YAG groups (P>0.05, Table 2).

The SEM micrographs revealed a micro-porous and irregular pattern in the Er,Cr:YSGG laser treated surfaces. In the groups treated with CO2 and Nd:YAG lasers, signs of ablation and increased surface roughness (but with a different pattern from that of Erbium laser group) were seen. (Fig1-4)

**Figure 1.** Er,Cr:YSGG laser treated surface

**Figure 2.** Nd:YAG laser treated surface

**Figure 3.** CO2 laser treated surface

**Figure 4.** Surface topography of the control group

**Discussion**

Repair of aged composites is a minimally invasive and cost-effective technique. Several surface treatment methods have been introduced to enhance micromechanical retention and increase the wettability of the old composite such as acid etching, diamond bur preparation, sandblasting and laser irradiation.21The bond strength of immediate repair of composite is similar to its cohesive strength due to the presence of the oxygen inhibition layer. However, after aging, factors such as decreased amount of active monomers, polishing surface and structural changes affect the repair bond strength of composite.21,23On 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 different lasersirradiations on the repair bond strength of aged silorane-based composites. 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. The results ofthe study were in line with those of Alizadeh et al .26 Erbium lasers enable selective ablation and are used to surface treatment of composite restorations.27,28 Composite resin ablation by erbium laser isdonethrough the mechanism of explosive vaporization followed by hydrodynamic ejection. 27During this process, quick melting and consequently changed volume of the melted material generate strong expansion forces. The generated forces with the composite structure, prominences are formed on the composite surface and melted material leaks out of the composite surface in the form of drops. This type of ablation has also been reported to occur following the application of Er,Cr:YSGGlaser.27-29The SEM micrographs showed round porosities without the smear layer on theEr,Cr:YSGG laser treated surfaces(Fig 1).The micro-retentive patternofthe samples surface can increase the repair bond strength via increasing the surface area and balancing stress distribution 30, 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 theimportant role of surface roughness in achieving optimal repair bond strength.11,31 A noteworthy finding of the current study was that, although the repair bond strength of Nd:YAG and CO2laser groups was higher than that of the control group, the difference values among the three groups did not reach statistical significance; this finding wasin contrast to the results of Alizadeh et al study. Evidence shows that Nd:YAG and CO2 lasers are effective for processing of dental materials32,33 especially for selective ablation and creating porosities in the composite resin.34,35

Evaluation of the SEM micrographs of the surfaces treated with Nd:YAG and CO2 lasers showed degradation of resin matrix, ablation and increased surface roughness with a different pattern from that in the Er,Cr:YSGG laser group(Fig 2 and 3).

Although micromorphological properties following laser ablation depend on the structure of composite and laser-related parameters28, it seems that the main reason explaining the differences between our results and those of Alizadeh et al, is the type of composite samples.

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.21,23among the in vitro Aging that simulated by storaging in water or citric acid or by thermocycling, waterstorageis the most efficient due to its hydrolytic effect on the matrix and filler interface.21 In the current study, water storage was performed for aging of composite samples. 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

Evidence shows that due to the presence of siloxane groups 36, water sorption and solubility of silorane-based composites are lower than those of methacrylate-based composite resins.37. Therefore, water storage was expected to have insignificant effect on the repair bond strength of Filtek silorane composites. However, Ozcan and Brandake reported that storage of the samples in distilled water for two months decreased their repair bond strength.23Similarly in our study, storage of silorane-based composite samples in distilled water for two months significantly decreased their repair bond strength. It was showed that aging in water affected the strength of hydrophobic silorane-based composites.26Fernande et al, revealed that accelerated artificial aging of silorane-based composite samples caused detachment of filler particles from the resin matrix.38 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 Last but not least, the mean repair bond strength of laser-treated groups was less than 50% of the cohesive strength of Filtek silorane composite. According to Beyer et al32, the optimal repair bond strength in terms of clinical service 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**

Within the limitations of this study, Surface treatment of aged silorane-based composites using to Er,Cr:YSGG laser provide sufficiently high repair bond strength between the repair composite and the aged composite but Nd:YAG and CO2 lasers cannot.

**Acknowledgments:**

 The authors thank the Dental Research Center and the Vice Chancellor of Research of Tabriz University of Medical Sciences for supporting this study.

**Ethical considerations:**

This study has been approved by 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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| Table 1. The properties of the materials and lasers used in this study |
| Material | Description & Composition | Manufactured by |
| FiltekTMSilorane, low shrink posterior Restorative | A light curing radiopaque silorane –based composite The monomer matrix is composed of siloxane and oxirane (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 Product, St. Paul, MN, USA |
| FiltekSilorane Bond | A filled, light –curing component bonding agent for enamel and dentin bonding. It contains a 3M ESPE hydrophobic bifunctional monomer, camphor quinine/ a silane- treated silicofillers and stabilizer. | 3M ESPE Dental Product U.S.A |
|  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, Paintweg 10, 92685 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 |

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| Table 2**.**Comparisons of the mean shear bond strength (MPa) values in the study groups |
| Groups | Mean ± SD | 95%confidence interval for the Mean | P=0001 |
| 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 |
| \* One-way ANOVA |

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| Table 3. Pairwise comparisons of studied groups using the Tukey’s test |
| group | group | Mean Differences | \*P-Value | group | group | Mean Differences | \*P-Value |
| Er:YAG | Control | 2.29 | 0.000 | Er:YAG | Co2 | 1.78 | 0.001 |
| Co2 | Control | 0.50 | 0.693 | Er:YAG | Nd:YAG | 1.66 | 0.003 |
| Nd:YAG | Control | 0.64 | 0.508 | Nd:YAG | Co2 | 0.46 | 0.991 |
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| \*Tukey HSD |

**References**

1. Gregory WA , Berry S , Duke E and Dennison JB.Physical properties and repair bond strength of direct and indirect composite resins .J Prosthet Dent 1992;68:406-11.

2. Lucena-Martin C , Gonzalez-Lopez S , Navajas Rodriguez de MondeloJM.The effects of various surface treatments and bonding agents on the repaired strength of heat-treated composites. J Prosthet Dent 2001;86:481-8.

3. OztasN ,Alacam A , BardakeyY.The effect of air abrasion with two new bonding agents on composite repair . Oper Dent2003; 28:149-54.

4. Rodrigues SA Jr, Ferracane JL, Della Bona A. Influence of surface treatments on the bond strength of repaired resin composite restorative materials. Dent Mater 2009;25:442-51.

5. Ferracane JL. Hygroscopic and hydrolytic effects in Dental polymer networks.Dent Mater2006; 22:211-22.

6. Sideridou I, Tserki V, PapanastasiouG.Study of water sorption, solubility and modulus of elasticity of light-cured dimethacrylate-based dental resins. Biomaterials2003;24:655-65.

7. Kalachandra S. Influence of fillers on the water sorption of composites. Dent Mater1989;5: 283-8.

8. Gordan VV, Mjør IA, Blum IR, Wilson N.Teaching students the repair of resin-based composite restorations: a survey of North American dental schools. J Am Dent Assoc2003;134: 317-323.

9. Brosh T, Pilo R, Bichacho N, Blutstein R. Effect of combinations of surface treatments and bonding agents on the bond strength of repaired composites.JProsthet Dent 1997;77:122-6.

10. Bouschlicher MR, Reinhardt JW, Vargas MA.Surface treatment techniques for resin composite repair. Am J Dent1997;10:279-83.

11. Bonstein T, Garlapo D, Donarummo J Jr, Bush PJ. Evaluation of varied repair protocols applied to aged composite resin.JAdhes Dent2005; 7:41-9.

12. Hossain M, Nakamura Y, Yamada Y, Suzuki N, Murakami Y, Matsumoto K. Analysis of surface roughness of enamel and dentin after Er,Cr:YSGG laser irradiation.JClin Laser Med Surg2001;19:297-303.

13. Usumez A, Aykent F. Bond strengths of porcelain laminate veneers to tooth surfaces prepared with acid and Er,Cr:YSGG .J Prosthet Dent2003 ;90:24-30.

14. Dumore T, Fried D.Selective ablation of orthodontic composite by using sub-microsecond IR laser pulses with optical feedback.LaserSurg Med2000;27:103-10.

15. Chan KH, Hirasuna K, Fried D.Rapid and selective removal of composite from tooth surfaces with a 9.3 µm CO2 laser using spectral feed back.Lasers Surg Med2011;43:824-32.

16. Alexander R, Xie J, Fried D.Selective removal of residual composite from dental enamel surfaces using the third harmonic of a Q-switched Nd:YAGlaser.LasersSurg Med2002;30:240-5.

17. Weinmann W, Thalacker C, GuggenbergerR.Siloranes in dental composites.Dent Mater2005;21:68-74.

18. Guggenberger R, WeinmannW.Exploring beyondmethacrylates. Am J Dent2000 ;13:82-84.

19. Søderholm KJ, Roberts MJ.Variables influencing the repair strength of dental composites .Scand J Dent Res1991; 99: 173-180.

20.Yap AU, Sau CW, Lye KW .Effects of aging on repair bond strengths of a polyacid-modified composite resin. Oper Dent1991; 24:371-376.

 21. Özcan M, Barbosa SH, Melo RM, Galhano GP, BottinoMA.Effect of surface conditioning methods on microtensile bond strength of resin composite to composite after aging conditions. Dent Mater2007;23:1276-1282.

22.Shiau JY, Rasmussen ST, Phelps AE et al.Analysis of shear bond strength of pretreated aged composites used in some indirect bonding techniques. J Dent Res1993; 72:1291-1297.

23. Brendeke J, Ozcan M.Effect of physicochemical aging conditions on the composite-composite repair bond strength. J Adhes Dent2007;9:399-406.

24. Denehy G, Bouschlicher M, Vargas M. Intraoral repair of cosmetic restorations. Dent Clin North Am 1998;42: 719-37.

25. Ramoglu SI, Usumez S, Buyukyilmaz T. Accelerated aging effects on surface hardness and roughness of lingual retainer adhesives. Angle Orthod 2008;78: 140-4.

26. Alizadehoskoee P , et al.Effect of Suerface Treatment with Er,Cr;YSGG,Nd:YAG,and Co2 Lasers on Repair Bond strength of a Silorane-based composite resin. J Dent Res Dent Clin Dent Prospects2013;7:61-66.

27. Correa-AfonsoAM, Palma-Dibb RG, Pécora JD. Composite filling removal with erbium:yttrium-aluminum-garnet laser: morphological analyses.Lasers Med Sci 2010;25:1-7.

28. LizarelliRde F, Moriyama LT, Bagnato VS. Ablation of composite resins using Er: YAG laser--comparison with enamel and dentin. Lasers Surg Med2003; 33:132-9.

29. Lizarelli RFZ, Moriyama LT, BagnatoVS.Ultraconservative ablation in operative and esthetic dentistry. J Oral Laser Applic 2003;3:73-78.

30. Fawzy AS, El-Askary FS, AmerMA.Effect of surface treatments on the tensile bond strength of repaired water-aged anterior restorative micro-fine hybrid resin composite. A.J Dent2008;36 :969-76.

31. Hannig C, Laubach S, Hahn P, Attin T. Shear bond strength of repaired adhesive filling materials using different repair procedures. J Adhes Dent 2006;8:35-40.

32. Beyer E, Behter K, PetschkeSchweissenmit U. Lasers in Dentistry, 1st ed.Chicago, Quintessence1989;231-45.

33. Akova T, Yoldas O, Toroglu MS, Uysal H. Porcelain surface treatment by laser for bracket-porcelain bonding.Am J OrthodDentofacialOrthop2005;128:630-7.

34. Türkmen C, Sazak H, Günday M. Effects of the Nd:YAG laser, air-abrasion, and acid-etchant on filling materials. J Oral Rehabil2006 ;33:64-9.

35. Chan KH, Fr Chan KH, Fried D .Selective Removal of Dental Composite using a Rapidly Scanned Carbon Dioxide Laser . ProcSoc Photo Opt InstrumEng2011.7884.

36.Weinmann W et al .Polymerizable compositions based on epoxides. ESPE Dental AG 2011

37.Boaro LC etal.Sorption,Solubility,Shrinkageand mechanical properties of low shrinkage commercial resin composites.Dent Mater2013;29:398-404.

38. Pires-de-Souza fde C, Garcia Lda F, RoselinoLde M, Naves LZ. Color stability of silorane-based composites submitted to accelerated artificial aging—an in situ study.J Dent2011;39:18-24.