Surface treatment comparison by application of diamond bur and Er,Cr:YSGG at different powers: morphological and mechanical evaluation

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Purpose: This study evaluated the micro-tensile bond strength of new and previous composite resin restorations after surface treatment with diamond bur and Er,Cr:YSGG laser at different power settings (2,3 and 4 W).

Materials and methods: Micro-hybride composite resin was inserted in metallic mold 5 ×5 ×15 mm and cured for 40 sec according to manufacturer's instruction. 12 blocks were made. The bonded surfaces of the 12 blocks so obtained were subsequently ground using Silicon Carbide papers 1200 grit, for 15 seconds under running water.

Then the samples randomly were divided into 4 groups: (G1) Bur-treated, (G2) Er,Cr:YSGG laser with power of 2 W and energy of 100 mJ, (G3) Er,Cr:YSGG laser with power of 3 W and energy of 150 mJ, (G4) Er,Cr:YSGG laser with power of 4 W and energy of 200 mJ.

One sample of each group was analyzed by SEM while, after cutting the blocks to 1 mm² of area samples, the others samples were mechanically tested by Universal testing machine with the speed of 0.5 mm per minute till fracture point. Data were analysed using One-Way ANOVA and Tukey Test.

Results: T-test showed no significantly differences between G2 and G4(P=0.064) while G3 demonstrated significant differences than G2 (P=0.001) and G4(P=0.000) and also between samples treated with bur (G1) and G2 (P=0.242), G3 (P=0.000), G4 (P=0.829); G1 didn't significantly differ to G2 and G4(P>0.05), while G1 and G3(P<0.05).

Conclusion: On surface treatment of repaired composite, samples treated by laser at 3W power showed better condition of micro-tensile bond strength.

Keywords: Microhybride composite · Er,Cr:YSGG laser · Bond strength

Introduction

Resin composite is a widely used material in direct restorative procedures. After a period of service, most resin restorations develop defects resulting from wear, fracture, or discoloration ¹⁾. Defective composite resin

restorations do not necessarily require complete removal. According to the minimally invasive restorative concept ²⁾, repairing may be considered to be the best choice for treatment. The repairing technique has some advantages like preservation of dental structures, inhibition of serious damage to the pulp tissues and lower costs ³⁾.

Several techniques using mechanical and/or chemical treatments have been proposed to improve bonding quality. Examples of mechanical treatments to improve bonding area are bur abrasion, air abrasion

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and laser application, while examples of chemical treatments are tribochemical silica coating with 30 μm aluminum oxide, hydrofluoric acid, phosphoric acid, silane application, and application of a bonding agent 4, 5).

Nowadays, the laser application in restorative dentistry causes less pain and reduce the need for anesthesia, increase bond strength.

The laser has many applications and much research has been done on it. Among different lasers using in dentistry, Erbium lasers are considered as the best option for caries removal and cavity preparation. This family has two wavelengths including Er:YAG laser (2940 nm) and Erbium, Chromium doped Yttrium Scandium Gallium Garnet (Er,Cr:YSGG) laser (2780 nm) 6, 7).

Since there is not sufficient information regarding the effect of Er,Cr:YSGG laser as a surface treatment method on composite repair, the objectives of this study were to evaluate the surface treatment on the composite by application of different powers of Er,Cr:YSGG laser on its bond strength with microhybrid composite resin.

Materials and methods

Sample preparation

12 blocks of a micro-hybride (DiaFil TM, DiaDent, Korea), were made using a metallic mold with 5 $\times$ 5 $\times$ 15 mm dimensions. The composite resin was prepared with layering 1-mm-thick increments and each increment was cured for 40 sec with a light curing device (Woodpecker, China), following manufacturer's instructions. The last increment compressed with a glass slide in order to obtain a flat surface for the specimen after light-curing. Subsequent to curing of the second layer, the specimens were removed from the mold. The bonding surface of these blocks were polished using 1200 grit silicon sandpaper for 15 seconds under running water to make an even surface. Then the samples were randomly divided into 4 groups:

- Group 1 (GI): Bur-treated
- Group 2 (GII): Er,Cr:YSGG Laser irradiation with Power: 2 W, Energy:100mJ
- Group 3 (GIII): Er,Cr:YSGG Laser irradiation with power: 3 W, Energy:150mJ
- Group 4 (GIV): Er,Cr:YSGG Laser irradiation with power: 4 W, Energy:200mJ

In group 1, the composite surface was roughened by

diamond fissure bur (D &Z, Diamant, Germany) and rotating high speed handpiece with constant water spray, sweeping motion perpendicular to the surface with depth of 0.5 mm. Then, the specimens were rinsed with distilled water and air-dried.

Laser preparation was performed with an Er,Cr:YSGG laser device (WaterLase iPlus 2.0, Biolase CO, USA). All samples were prepared by MZ6 laser tip, a repetition rate of 20 Hz, at 60% air and 30% water level. The output power of this device was 2, 3, 4 W (energy density of 35.368, 53.052, 70.736) in group 2, 3, 4, respectively. The beam was aligned to be perpendicular to the target area, and was applied at a 1mm distance during an exposure time of 10 sec; subsequently, the specimens were rinsed and air-dried.

One block of each group were analyzed with a scanning electron microscope at $\times 500$, $\times 1000$, $\times 2000$ and $\times 5000$ magnification in order to evaluate the surface texture created by the different powers of laser.

After surface treatment, in all of the groups, single-bottle adhesive resin (Adper TM Single Bond, 3M ESPE, Dental Products, St. Paul, MN, USA) was applied for 15 s, then compressed with air for 5s from 5cm distances and cured for 10 s according to manufacturer's instructions. Then, the increment of 1mm thickness of the same resin composite was applied to the treated resin composite blocks and light cured for 40 s, composite layers were added till each block reached a height of 15 mm. Next, the samples stored in incubator for 24 h at 37°C and 100% humidity.

Micro-tensile bond strength test

All of blocks mounted in Teflon mold with acrylic resin (Meliodent, Bayer, UK). Then, the blocks were sectioned using cutting machine (CNC, pars, Iran), so that 14 slabs in each group with cross section of about 1 mm were prepared.

The specimens were fixed on special jig of the micro-tensile bond strength device (Zwick, Germany). A crosshead speed of 0.5 mm/min was used to debond the repaired surface interface. Micro-tensile bond strengths were recorded in Newtons and converted to mega pascals (MPa). In order to determine failure modes, a stereomicroscope (Olympus SZX9; Olympus, Tokyo, Japan) was used at magnification $\times 30$. Failure mode was classified as follows: within composite area, within bonding area or interface between bonding and composite (mixed).

Statistical analysis

The data for bond strength were analyzed using one-way ANOVA. Pairwise comparisons were made by

Tukey test. Statistical significance was set at $p < 0.05$.

Result

Repair bond strength

Repair bond strengths in MPa (means and standard deviations) for the groups are shown in **Table 1**. The GIII (58.47±17.37) showed the highest bond strength and GIV (24.69±7.31) showed the lowest one.

There were statistically significant differences in bond strength among the groups ($p < 0.001$). Multiple comparisons by Tukey's post-hoc tests (**Table 2**) showed no significant differences in bond strengths between G1, G2 and G4 ($p > 0.05$). Furthermore, significant difference were observed between G3 and the other groups ($p < 0.05$).

The Mode of Failure

The mode of failure in all groups was shown in **table 3**.

Table 1: means and standard deviations of all groups

group	Mean ± Std. Deviation
Bur (GI)	27.4857 ± 5.15794
2 W (GII)	34.4357 ± 10.94311
3 W (GIII)	58.4714 ± 17.37272
4 W (GIV)	24.6929 ± 7.31547

The Chi-Square test showed no significant difference between the groups ($p = 0.23$).

Scanning Electron Microscopic (SEM) Findings

Under SEM evaluation in the laser groups, cleaned ablated surfaces with no smear layer production could be seen. The surfaces treated by Er,Cr:YSGG laser showed irregular and micro porous surfaces that by

Table 2: Multiple comparisons of all groups

Groups		Sig.
bur	2 w	.242
	3 w	.000
	4 w	.829
2 W	bur	.242
	3 w	.001
	4w	.064
3 W	bur	.000
	2 w	.001
	4 w	.000
4 W	bur	.829
	2 w	.064
	3 w	.000

Table 3: Mode of Failure of all groups

		mode of failure			Total	
		composite	bonding	mixed		
group	bur	Count	8	5	1	14
		% within group	57.1%	35.7%	7.1%	100.0%
	2 W	Count	11	3	0	14
		% within group	78.6%	21.4%	0.0%	100.0%
	3 W	Count	13	1	0	14
		% within group	92.9%	7.1%	0.0%	100.0%
	4 W	Count	10	2	2	14
		% within group	71.4%	14.3%	14.3%	100.0%
Total	Count	42	11	3	56	
	% within group	75.0%	19.6%	5.4%	100.0%	

increasing the laser power, these changes also increased. (**Figure 1-3**). On the other hand, in group IV that prepared by bur, the noticeable smear layer was seen. (**Figure 4**)

Discussion

An ideal adhesive material should present no shrinkage during polymerization and have physicochemical properties similar to dental hard tissues ⁸⁾. Some studies have shown that laboratory processed composites showed 25-80% decrease in bond strength ⁹⁾.

Previous researchers ^{10, 11, 12)} reported that mechanical interlocking is the most significant factor

contributing to repair strength. Increasing surface roughness provides better mechanical interlocking and enhances the probability of finding residual free carbon bonds throughout the surface area ¹³⁾.

Bonstein et al. ¹⁴⁾ found that surface treatment with diamond burs resulted in higher bond strength compared to other surface treatments. However, several composite repair studies have shown that grinding of the composite resin surfaces leads to the formation of the smear layer ^{10, 15)}.

In contrast to the bur, lasers ablate the restorative materials without smear layer formation ¹⁶⁾. Due to the negative effect of smear layer on bonding, lasing is thought to provide a higher bonding strength than

Figure 1: Surface treated by Er,Cr:YSGG laser with output power of 2 W (Original magnification $\times 5000$)

Figure 2: Surface treated by Er,Cr:YSGG laser with output power of 3 W (Original magnification $\times 5000$)

Figure 3: Surface treated by Er,Cr:YSGG laser with output power of 4 W (Original magnification $\times 5000$)

Figure 4: Surface treated by Bur (Original magnification $\times 5000$)

grinding with bur ¹⁰⁾.

Rosatto et al. ¹⁷⁾, compared the effect of diamond bur, air abrasion, and lasing on repair bond strength, found no significant difference between laser- and bur-treated groups. These findings can be attributed to the acid etching procedure used in this study. The use of the acid etch on ground surfaces removes the smear debris, exposing the underlying surface and fillers ¹⁵⁾.

Kimyai et al. ¹⁰⁾ reported that Er,Cr:YSGG laser treated laboratory composite resulted in higher repair bond strength compared to diamond bur. The differences in findings of this study might be related to the type of composites used, given that the composition of composite resin can affect the efficacy of mechanical surface treatments ^{18, 19)}.

Lizarelli et al. ²⁰⁾ investigated the ablation rate and morphological aspects of an Er:YAG laser on different types of composite resin, including microfiller, hybrid, and condensable. They found that the surface of ablated region was smoother for the hybrid composite than for others. The authors also claimed that the micro-morphological aspects, rate of penetration, and overall ablation rate were dependent upon the chemical composition and structure of the composite resin as well as the laser parameters.

An important point for laser studies is irradiation parameters. Previous researchers evaluated different energy parameters (200 mJ, 300 mJ, 400 mJ) in order to determine the best surface treatment in terms of com-

posite repair bond strength ¹⁷⁾. Despite the fact that there was no statistically significant difference among the experimental groups, 400 mJ of energy showed the lowest value of bonding strength. The authors reported that increasing energy in laser pulse did not seem to promote general aspects of change, but a larger modification occurred in the polymer. Additionally, higher laser power settings (400 and 600 mJ) caused excessive material deterioration, making them unsuitable as surface treatments for dental materials surfaces ²¹⁾.

Hence, in the present study, a lower power setting for the Er,Cr:YSGG laser was selected in accordance with the results of the preliminary investigation. In addition, the surfaces were irradiated with constant water cooling.

However, further investigations focusing on the effect of different laser parameters and clinical studies are necessary to develop guidelines for the repair of composite restorations with Er,Cr:YSGG laser or diamond bur.

Conclusion

Er,Cr:YSGG laser with output power of 3W can be used as an alternative technique for surface treatment of unsatisfactory composite restorations. There is still need to do more researches to find the best protocol for achieving to the best bonding surface.

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