Bond Strength in Composite Resin Repairs: Preliminary Results of Surface Treatment with Different Techniques

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Purpose: This study evaluated the shear bond strength of repaired new and old composite resin restorations after surface treatment with diamond bur, aluminum oxide jet, and Er:YAG laser, with the aim of developing a new ultraconservative technique to repair unsatisfactory composite resin restorations.

Materials and Methods: Thirty-six hybrid composite resin blocks were made. The blocks were repaired with nanohybrid composite resin and then subjected to shear bond strength testing of the repair interfacial bond strength. ANOVA and the Tukey test were used at a significance level of 5%.

Results: The highest average bond strength values were found when the old composite resin restorations were repaired with the diamond bur and the surface ablated with Er:YAG laser (2.15 W/cm^2).

Conclusion: The results of this study suggest that the Er:YAG laser system can be used effectively for composite resin repair.

Keywords: ablation, diamond bur, Er:YAG laser, jet abrasion.

J Oral Laser Applications 2005; 5: 219-224. *Submitted for publication: 09.12.04; accepted for publication: 09.06.05.*

Defective composite resin restorations do not necessarily require complete removal. According to the minimally invasive restorative concept,[1] repair may be considered the indicated treatment if one or more of the following exist: discoloration of the restoration, small cavity spots along the margins, inadequate contour, marginal irregularities, cracks and fractures, and if the complete removal of large restorations would be harmful to the tooth's health. Repair makes it possible to preserve dental structure, reduce serious jeopardy to the pulp tissue, and lower costs.[1-4] There are several repair techniques that use acid etching,[2] air abrasion (abrasive particles applied with compressed air),[5-8] burs,[2,4,9,10] or chemical agents (adhesives, silanes).[2-6,8,11] Blum[12] described clinical procedures that may be carried out exclusively with laser, among them the re-

Table 1 Composite resin composition

Composite resin	Matrix	Filler
Z100 (3M) – hybrid	Bis-GMA and TEG-DMA	Silica and zircon particles (0.01 to 3.5 m)
Point4 (Kerr) – hybrid and microparticles	Bis-GMA, TEGDMA and EBADM	Disperse silica and barium glass particles (0.4 µm)

moval of old restorations followed by the repair procedure.

When composite resin restorations are repaired in clinical situations, the conventional instruments cannot remove only the old restoration material or damaged composite resin without compromising the sound dental tissue. The advantage of Er:YAG laser application over other mechanical treatments is the possibility to achieve an ultraconservative preparation where the composite resin material may be selectively ablated, while at the same time preserving the sound dental tissue. The purpose of this in vitro study was to evaluate the bond strength in new and aged composite resin repairs after the ablation of the surface with Er:YAG laser and compare these values with those obtained by diamond bur and aluminum oxide jet, with the intent of developing a new ultraconservative technique for composite resin repair.

MATERIALS AND METHODS

Thirty-six composite resin blocks (5 x 6 mm^2) were prepared using a square metallic matrix band (6 x 9 mm^2). Z100 hybrid composite resin (3M, St Paul, MN, USA), A2 shade (batch: 3EK 2006-02) was used for the repair procedure of the blocks (Table 1). Each 1.7-mm increment was cured for 40 s at a power setting of 450 mW/cm^2 using the Light XL 3000 (3M, St Paul, MN, USA) halogen lamp. After this, the blocks were polished using Sof-lex polishing disks (3M, SP, Brazil). Half of the blocks were randomly selected and repaired 24 h after the finishing and polishing procedure, and the other half underwent an artificial physical aging procedure as proposed by Davis[14] and Doray.[15] After storage in saline solution for 15 days at 37°C, the samples were placed in a chamber (47.0 x 9.3 x 16.5 cm^3) where they were exposed to an ultraviolet lamp (S15T8/GL) at 5 W. The blocks were submitted to 4 cycles of 16.6 hours each, with a total ultraviolet irradiation dosage of 60 KJ/m^2, and a 7.4-h interval between each cycle.

After the restoration, polishing, and – for half the blocks – aging procedures, each group was subdivided into 6 subgroups, for a total of 12 subgroups. Then the experimental surfaces were submitted to different treatments: diamond bur (G1); 60 µm-aluminum oxide particle jet (air abrasion) (G2); Er:YAG laser ablation with different energy per pulse parameters: 100 mJ (G3), 200 mJ (G4), and 300 mJ (G5). Group 6 was the control, receiving no mechanical treatment. Each surface to be repaired was abraded to a depth of ca 0.2 mm ± 0.1 mm, which was standardized with a digital caliper (Digimatic, Caliper, Mitutoyo, Japan).

Diamond Bur Abrasion

The composite resin block surfaces were abraded with a high-speed, air/water cooled cylindrical diamond bur (#3145, KG Sorensen, Alphaville, São Paulo, Brazil) with the long axis parallel to the composite resin block surface. The block was abraded with moderate pressure for 20 s.

Aluminum Oxide Jet Abrasion

The surfaces were abraded with a 60-µm aluminum oxide particle jet from an intraoral device (Microjet, Bio-art, SN 10558, SP, Brazil) for 10 s at a distance of 10 mm from the sample.

Er:YAG Laser Ablation

An Er:YAG laser system (Twin Light, Fotona Medical Lasers, Ljubljana, Slovenia) was used with 200- and 450-µs pulse duration, a wavelength of 2940 nm, maximum energy per pulse of 500 mJ, repetition rate or pulse frequency from 2 to 15 Hz, and a spot area of approximately 0.38 mm^2. The parameters chosen were: 10 Hz; focused (13 mm from the target tissue); exposition time of 35 s; pulse energies of 100, 200 and 300 mJ; fluences of 26.32, 52.63, and 78.95 J/cm^2 and pulse intensity of 8.1×10^4, 16.2×10^4, and 24.3×10^4 W/cm^2, respectively. Each composite resin block was ablated for 35 s, using a device to hold the laser fiber stable while the operator moved the table to scan all the exposed surfaces with an average speed and constant acceleration, uniformly irradiating the surface to be repaired.[16,17] All the ablation procedures were conducted under an air/water cooling spray from the laser device at a water flow of 0.14 ml/s. After the treatment, the surfaces were rinsed with air/water spray and dried with an air jet. Then, a thin layer of Single Bond adhesive system (3M, St Paul, MN, USA) was applied, and another thin layer was re-applied and cured for 20 s at 450 mW/cm^2 with the halogen lamp (curing light XL 3000). The composite resin blocks were repositioned in the matrix and the hybrid microparticle Point4 composite resin (Kerr, Orange, CA, USA), A3 shade (batch # 303457) (Table 1) was inserted using the incremental technique. Each increment was 1.7 mm thick and was light cured for 40 s at a power setting of 450 mW/cm^2 with the XL 3000. After the composite resin blocks repair procedures were complete, the repaired blocks were finished using sequential Sof-lex polishing disks (3M, SP, Brazil) and stored in saline solution at 37°C. Twenty-four hours after the finishing and polishing procedure, the blocks were sectioned in a precision hard-tissue cutting machine (Isomet-1000 Precision Saw, Buehler, Lake Buff, IL, USA) with a diamond disk, series 15 LC, # 11-4254 (Buehler) under water cooling at a speed of 400 rpm. The samples were vertically sectioned in multiple series of 1.0 mm resulting in rectangular samples with a cross section of 1.0 $mm^2 \pm 0.1$ mm^2.[2,18] These samples were stored at 37°C for 24 h before the shear bond strength test.[19]

The shear bond strength test was performed using a universal testing machine MTS (Material Test System 810, MTS Systems, Minneapolis, MN, USA) at a speed of 0.5 mm/min[6,20] with a load transducer of 10 KN (Load Transducer, model 66118 D-01) and a force of 1 N. The samples were affixed to a special apparatus in the universal testing machine with a cyanoacrylate-based glue (Super bond gel and catalyst; Zapit Accelerator, Dental Ventures of America, Anaheim, CA, USA), with the adhesion area placed perpendicular to the load traction long axis. At the moment of fracture, force application was stopped and the data collected for statistical analysis. The final bond strength values were calculated dividing the rupture load values in Newton (N) by the transversal sections (in mm^2) of the sticks obtained, being expressed in MPa. After the shear bond strength test the fractured surfaces were evaluated under optical microscopy (Stereozoom, Bausch & Lomb, Rochester, NY, USA) at 100X magnification to classify failure types: adhesive (A), cohesive (C), and mixed (M).

The analysis of variance (ANOVA) was used to check the significance of the effects of two factors and their interaction at the significance level of 5%. This analysis was complemented by the Tukey test, also at the significance level of 5%, for a two-by-two average multiple comparison.

RESULTS

Table 2 summarizes the ANOVA of the factors affecting bond strength. All p values were lower than 0.05, meaning that there are differences among the group average values and these differences depend on whether the composite resin is new or old. The Tukey test was used to highlight these differences to compare the bond strength average values two by two.

In the groups with new composite resin restorations, it was observed that all the p values are higher than 0.05; therefore, the average values obtained are not statistically significantly different. This result is illustrated by Fig 1. The error bars represent the 95% confidence interval for the real bond strength average values of the groups with the new composite resin. Regarding the old composite resin group, the G1 average value is not significantly higher than the average values of G3. However, the G3 average value is only significantly higher than the G2 and G6 (control) average values. On the other hand, the G2 and G6 average values are significantly lower than the ones from all the other groups with the old composite resin. The G4 and G5 average values constitute equivalent intermediate values, significantly lower than the G1 average value and higher than the G2 and G6 average values. These results are presented in Table 2. It is also evident that the average values of the new composite resin groups are significantly different from all the average values from

Table 2 Summary of the ANOVA for the evaluation of the composite resin effects, group and interaction

Variation factors and interaction	Degrees of freedom	Square average	F	Probability of H0
Composite resin	1	1215.18	18.21	< 0.0001
Group	5	708.25	10.61	< 0.0002
Composite resin x group	5	934.40	14.00	< 0.0003
Residue		228	66.74	

Table 3 Fracture type frequency distribution

Composite resin	Group (n=20)	Adhesive	Cohesive	Mixed	Not evaluated
New	G1	12	7	1	0
	G2	13	6	1	0
	G3	13	2	4	1
	G4	15	1	3	1
	G5	13	2	2	3
	G6	13	5	0	2
Old	G1	18	2	0	0
	G2	19	1	0	0
	G3	17	1	2	0
	G4	15	2	3	0
	G5	17	2	1	0
	G6	18	1	1	0

the old composite resin groups. Thus, the G2 and G6 average values for the old composite resin are significantly lower than all the new composite resin average values.

Table 3 shows the types of failure found in all groups.

DISCUSSION

There are three possible adhesion mechanisms between the resin to be repaired and the adhesive system: chemical adhesion between the adhesive and the composite resin matrix, chemical adhesion to the exposed load particles, and mechanical retention caused by monomer penetration into the matrix microcracks.[5] The presence of water on the surface to be repaired with a composite resin without any adhesive allows a chemical reaction, which optimizes the adaptation between the composites and is thus important for the development of a high bond strength.[13]

In the present study, some of the composite resin samples were repaired 24 h after restoration procedures. There was no statistically significant difference in the bond strengths between the different treatments of these surfaces. When the composite resin was aged, simulating the real clinical situation when the replacement or repair is necessary, the highest bond strength values were achieved when the resin was abraded with a diamond bur or ablated with the Er:YAG laser at a pulse energy of 100 mJ. The lowest values were achieved in the group where the surface was treated with the aluminum oxide jet and in the group without any mechanical surface treatment (control).

In contrast to our study, the literature contains other reports showing that the highest bond strength

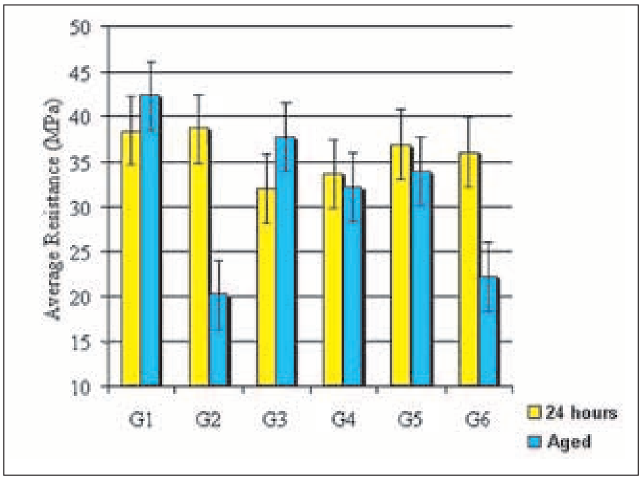

Fig 1 Bond strength average values according to the groups (new or old composite resin) and subgroups. The vertical bar represents the 95% confidence interval for the real average value.

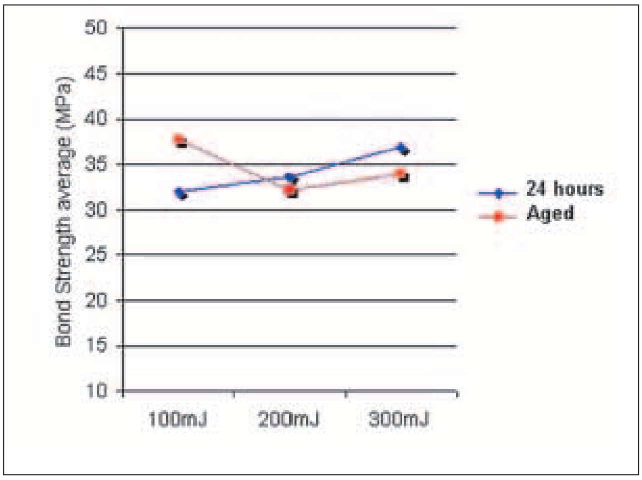

Fig 2 Bond strength average values according to the group and type of composite resin (new and old) for the subgroups ablated with Er:YAG laser.

values were found when the surface was abraded with the aluminum oxide jet,[5-8] or that bond strength was enhanced by both aluminum oxide jet and diamond burs.[4,10] Crumpler et al[9] obtained the highest bond strength values when the surfaces were treated with a diamond bur. Clinically, most of dental practitioners use diamond burs for the mechanical treatment of composite resin surfaces to be repaired.[2]

In the present study, aging the composite resin produced a color change on the surface, accompanied by surface roughness with some oval orifices. Air abrasion of these surfaces with aluminum oxide particles increased the diameter of these orifices, a fact which could facilitate air-bubble inclusion. The persistence of aluminum oxide particles on abraded surfaces decreases the area available for adhesion.[11]

Aged control group specimens (no mechanical treatment) presented the lowest interfacial bond strength values, which is in accordance with the results of other studies.[4-8,10,11,13] Thus, the findings of the present study confirm the importance of mechanical surface treatment when adhesive agents are used. [4-8,10,11,13]

The interfacial strength which is required to meet the in vivo repair demands was not completely investigated. On the other hand, bond strength of the composite resin to enamel has been extensively researched and ranges from 15 to 30 MPa. It is known that composite resins rarely fail mechanically at the junction with enamel, and therefore it is suggested that the repair bond strength – which is similar to that of the enamel and composite resin interface – is clinically adequate.[11]

The selective ablation of composite resin using the Er:YAG laser system was proposed by Lizarelli, Moriyama, and Bagnato.[16,17] It may be applied with little effect on the enamel when the laser is focused and applied for 120 s at 300 mJ and 10 Hz, enabling safe removal of composite resin. Besides the selective capability of the Er:YAG laser, it removes tissue with minimal damage chiefly when cooling is applied. Another advantage of Er:YAG laser over conventional rotating instruments is the absence of vibration duration ablation. Vibration can promote mechanical stress on the composite resin to be repaired, compromising the bond strength with the dental substrate. A microsecond of laser irradiation generates less mechanical stress than a carbide bur or a high-speed diamond bur.

In the subgroups (G3, G4, G5) treated with the Er:YAG laser, it was observed that the interfacial bond strength values of the repair were independent of the energy used (Figs 1 and 2). Thus, high interfacial bond strength values were achieved even with the low energy pulses.

The microscopic surface fracture analysis at 100X magnification classified most of the failures as being adhesive in all the subgroups, independent of the bond strength values. Microfractures and voids observed inside the material may result from the stress of polymerization, weakening the material,[4] which may have contributed to the cohesive or mixed failures.

CONCLUSION

Mechanical treatment of the surface to be repaired is necessary to increase the interfacial bond strength values of composite resin repair procedures, mainly with aged composite resin. This study confirms the importance of mechanically treating the composite resin surface when adhesive agents are to be used to repair composite resin restorations.

The diamond bur and Er:YAG laser ablation of the surface were shown here to be the most effective treatments for repairing composite resin restorations. The results of this study show that the Er:YAG laser system has promise as a new ultraconservative technique for reparing composite resin restorations, considering the absence of vibration and the selective removal mechanism.

ACKNOWLEDGMENTS

We acknowledge the financial support of CePOF-FAPESP and CNPq.

REFERENCES

1. Murdock-Kinch CA, McLeam ME. Minimally invasive dentistry. J Am Dent Assoc 2003;134:87-95.
2. Gordan VV, Mjor IA, Blum IR, Wilson N. Teaching students the repair of resin-based composite restorations: a survey of North American dental schools. J Am Dent Assoc 2003;134:317-323.
3. Lewis G, Johnson W, Martin W, Carnerdy A, Claburn C, Collier M. Shear bond strength of immediately repaired light-cured composite resin restorations. Oper Dent 1998;23:121-127.
4. Oztas N, Alaçam A, Bardakcy Y. The effect of air abrasion with two new bonding agents on composite repair. Oper Dent 2003;28:149-154.
5. Brosh T, Pilo R, Bichacho N, Blutstein R. Effect of combinations of surface treatments and bonding agents on the bond strength of repaired composites. J Prosthet Dent 1997;77:122-126.
6. Cesar PF, Faara PMM, Caldart RM, Jaeger RG, Ribeiro FC. Tensile bond strength of composite repairs on artglass using different surface treatments. Am J Dent 2001;14:373-377.
7. Lucena-Martín C, Gonzáles-Lópes S, Mondelo JMNR. The effect of various surface treatments and bonding agents on the repaired strength of heat-treated composites. J Prosthet Dent 2001; 86:481-488.
8. Swift Jr. EJ, Levalley BD, Boyer DB. Evaluation of new methods for composite repair. Dent Mater 1992;8:362-365.
9. Crumpler DC, Bayne SC, Sockell S, Brunson D, Roberson TM. Bonding to resurfaced posterior composites. Dent Mater 1989; 5:417-424.
10. Turner CW, Meiers JC. Repair of an aged, contaminated indirect composite resin with a direct, visible-light-cured composite resin. Oper Dent 1993;18:187-194.
11. Shahdad JA, Kennedy JG. Bond strength of repaired anterior composite resins: an in vitro study. J Dent 1998;26:685-694.
12. Blum R. Restorative dentistry with the Er:YAG laser. J Oral Laser Applic 2001;1:55-58.
13. Boyer DB, Chan KC, Reinhardt JW. Build-up and repair of light-cured composites: bond strength. J Dent Res 1984;63:1241-1244.
14. Davis BA, Friedl K, Powers JM. Color stability of hybrid ionomers after accelerated aging. J Prosthodont 1995;4:111-115.
15. Doray PG, Li D, Powers JM. Color stability of provisional restorative materials after accelerated aging. J Prosthodont 2001; 10:212-216.
16. Lizarelli RFZ, Moriyama LT, Bagnato VS. Ultraconservative ablation in operative and esthetic dentistry. J Oral Laser Applic 2003;3:73-78.
17. Lizarelli RFZ. Laser ablation of dental substrates: enamel, dentin and composite resin. [Ablação a laser de substratos dentais: esmalte, dentina, e resinas compostas] 2002. PhD Thesis. IFSC, University of São Paulo.
18. Pashley DH, Carvalho RM, Sano H, Nakajima M, Yoshiyama M, Shono Y. The microtensile bond test: a review. J Adhes Dent 1999;1:299-309.
19. Sano H, Shono T, Sonoda H, Takatsu T, Ciucchi B, Carvalho R, Pashley DH. Relationship between surface area for adhesion and tensile bond strength: evaluation of a micro-tensile bond test. Dent Mater 1994;10:236-240.
20. Chang JC, Koh SH, Powers JM, Duong JH. Tensile bond strengths of composites to a gold-palladium alloy after thermal cycling. J Prosthet Dent 2002;87:271-276.

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