Evaluating the bond strength between aged composite cores and luting agent

Serdar Polat1*, Fatma Cebe2, Alirıza Tunçdemir3, Caner Öztürk4, Aslıhan Üşümez5

1Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey
2Department of Restorative, Faculty of Dentistry, Abant Izzet Baysal University, Bolu, Turkey
3Department of Prosthodontics, Faculty of Dentistry, Necmettin Erbakan University, Konya, Turkey
4Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Turkey
5Department of Prosthodontics, Faculty of Dentistry, Bezmi Alem University, Istanbul Turkey

PURPOSE. The aim of this study was to evaluate effect of different surface treatment methods on the bond strength between aged composite-resin core and luting agent. MATERIALS AND METHODS. Seventy-five resin composites and also seventy-five zirconia ceramic discs were prepared. 60 composite samples were exposed to thermal aging (10,000 cycles, 5 to 55°C) and different surface treatment. All specimens were separated into 5 groups (n=15): 1) Intact specimens 2) Thermal aging-air polishing 3) Thermal aging- Er:YAG laser irradiation 4) Thermal aging- acid etching 5) Thermal-aging. All specimens were bonded to the zirconia discs with resin cement and fixed to universal testing machine and bond strength testing loaded to failure with a crosshead speed of 0.5 mm/min. The fractured surface was classified as adhesive failure, cohesive failure and adhesive-cohesive failure. The bond strength data was statistically compared by the Kruskal-Wallis method complemented by the Bonferroni correction Mann-Whitney U test. The probability level for statistical significance was set at \( \alpha = .05 \).

RESULTS. Thermal aging and different surface treatment methods have significant effect on the bond strength between composite-resin cores and luting-agent (\( P < .05 \)). The mean baseline bond strength values ranged between 7.07 ± 2.11 and 26.05 ± 6.53 N. The highest bond strength of 26.05 ± 6.53 N was obtained with Group 3. Group 5 showed the lowest value of bond strength. CONCLUSION. Appropriate surface treatment method should be applied to aged composite resin cores or aged-composites restorations should be replaced for the optimal bond strength and the clinical success. [J Adv Prosthodont 2015;7:108-14]

KEY WORDS: Bonding; Composite resin; Er-YAG laser

INTRODUCTION

Composite resin restorative materials are widely used in dentistry. Their exposure to the oral conditions requires significant durability. One of the most important problems is degradation of composite restorations in oral conditions.1 The composite resins are degenerated by the effect of pH, saliva, temperature variance, and a wet environment over time.2,4 This degradation promotes superficial loss, cohesive fractures, color changes, loss of brightness, and restoration staining5,6 and causes long term clinical failure and esthetic dissatisfaction. Removing and replacing the restorations is the traditional treatment method for the failed (defective, discolored) composite restorations, but the disadvantages of this method are the removal and loss of healthy tooth structure, widening the cavity.7 Crown restorations can be an alternative treatment modality for the failed restorations and composites resins can be used as a core or restoration material for large, defected vital or devital teeth8,9 and teeth, with new or aged composite resin restorations, can be used as a base for crown or bridge restorations such as zirconia.

Zirconia (ZrO2) is used as an alternative to traditional dental porcelains and for the fabrication of posterior fixed partial dentures owing to its good mechanical and aesthetic...
properties.\textsuperscript{10,11} It has been widely used in dentistry for fixed partial denture and full crowns, orthodontic brackets, posts, and implant abutments as a core material.\textsuperscript{12,13} Zirconia has high flexural strength (1000 MPa) and also has optical advantage including color adjustment in which it requires a minimum layering porcelain thickness (compared to conventional ceramics) to obtain the required color.\textsuperscript{14,15}

The bond strength between composite core-resin cement and resin cement-zirconia affects the long term success of the restoration.\textsuperscript{16} Although having superior mechanical properties (strength, toughness, and fatigue resistance), there are some basic problems associated with zirconium such as cementation.\textsuperscript{17-19} The cementation technique, cement types and surface characteristics of zirconia are important factors for the successful long-term results\textsuperscript{20} and high bond strength between the zirconia and resin cement is required for better marginal adaptation, retention and high fracture resistance.\textsuperscript{21,22} In previous studies\textsuperscript{12,20,23-25} it was stated that application different priming agents, cement type, cementation technique, surface treatment methods and surface characteristic of zirconia have effect on the bond strength between tooth and zirconia. However, there is no data about the effect of aged direct composite restorations and surface treatments, applied to composite restorations, on the bond strength between core material and resin cements. For these situations, the bond strength between aging composites and resin cement must be investigated.

The aim of the present study was to evaluate effect of the aged composite restorations and surface treatments, applied to composite restorations, on the bond strength of resin cements. The null hypothesis of the study was that aged composite-resin cores and surface treatment methods do not affect bond strength between the composite resin cores and luting agent.

**MATERIALS AND METHODS**

Seventy-five resin composites were prepared with a micro-hybrid resin composite (Clearfil APX, Kuraray, Kuraray Medical, Osaka, Japan) using a cylindrical mold (diameter: 10mm and thickness: 2 mm). For the 75 specimens, composite material was filled into the mold with one increment of Clearfil APX using a plastic device and composite discs were prepared according to manufacturer’s recommendations. Fifteen resin blocks served as a control (intact specimens) (Group 1) and thermocycling (10000 cycles and 5 to 55° C) was applied to the other 60 composite resin blocks for simulating the thermal aging in the oral cavity. After aging, the 60 samples were divided into 4 groups (Table 1).

| Number | Termal cycling | Surface treatment |
|---|---|---|
| Group 1 | 15 | - | intact specimens | - |
| Group 2 | 15 | + | Air flow |
| Group 3 | 15 | + | Er:YAG laser |
| Group 4 | 15 | + | Acid |
| Group 5 | 15 | + | (control group) | - |

A flexi mold was used for embedding the discs into autopolymerizing acrylic resin (Meliodent, Bayer Dental Ltd; Newbury, UK). After surface treatment, one sample per group was randomly selected and analyzed with a scanning electron microscope (SEM, Noran Instruments JSM 6400; Middleton, USA) at 500× and 2000× magnification.

Seventy-five commercially available zirconium core materials (Cercon, DeguDent, Hanau, Germany) were selected for this study. Zirconium oxide specimens (diameter: 2.5 mm; thickness: 3 mm) were manufactured and sintered. Discs were kept in an enclosed condition. Zirconia discs were cemented to the composites discs (Fig. 1) with a phosphate monomer (MDP) based resin cement (Panavia F2.0, Kuraray, Co. Ltd.; Osaka, Japan) using a cementation jig and 10 N load was applied for 0.5 mm/min.\textsuperscript{26,27} The curing
The data was submitted to Levene Statistics ($P < .05$) and Shapiro-Wilk Statistics. These tests showed that there was no variance in homogeneity. Therefore, non-parametric tests Kruskal-Wallis and Bonferroni correction Mann-Whitney U test ($P < .05$) were used to comparison of data. The comparison of failure modes among groups was made with Chi-square test was used to analyzing data. SPSS 20 (IBM, Armonk, NY, USA) for Mac statistical program software was used for data analysis.

RESULTS

Statistical analysis revealed significant differences in the bond strength values of the groups ($P < .05$). The mean baseline bond strength values were between 7.07 ± 2.11 and 26.05 ± 6.53 N (mean ± SD). The mean SBS values of the groups and results of multiple comparisons are listed in Table 2. The highest bond strength of 26.05 ± 6.53 N was obtained with Group 3. Group 5 showed the lowest value of bond strength (7.078 ± 2.11 N).

Specimens’ failure modes were evaluated. Table 3 shows the distribution of failure mode for the different adhesive systems. Groups 1, 3, and 5 specimens showed cohesive failures. Groups 2 and 4 specimens showed adhesive failures. There were no significant different modes among the groups ($P > .05$).

SEM images (500 and 2000 magnification) of all composite samples are presented in Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7. Composite surfaces treated by air polishing, acid etching, and Er-YAG laser are shown in Fig. 2, Fig. 3, Fig. 4. The surfaces treated with Er-YAG laser and acid etching showed irregularities which may provide mechanical retention. The control group (Group 5) has the same surface irregularities and air polishing surfaces the shallow pits remained.

DISCUSSION

The null hypothesis of this study, aged composite-resin cores and surface treatment methods have no effect on the bond strength between the composite resin cores and luting agent, was rejected. Statistically significant changes occurred in the bond strength of the resin-composite cores with aged composites. Different surface treatments of the composite restorations influenced adhesive bonding that occurs between the aged/new composite and luting agent.

**Table 2. The bond strength values (in Newton)**

|          | N  | Mean (N) | SD  | Surface treatment |
|----------|----|----------|-----|-------------------|
| Group 1  | 15 | 18.0980  | 7.25| -                 |
| Group 2  | 15 | 7.9600   | 2.87| Air flow          |
| Group 3  | 15 | 26.0527  | 6.53| Er-yag laser      |
| Group 4  | 15 | 14.4913  | 3.18| Acid              |
| Group 5  | 15 | 7.0786   | 2.11| -                 |

Same uppercase letters denote an insignificant difference within the same column ($P > .05$).

**Table 3. Specimen failure modes**

| Cement type | Adhesive: composite/cement | Cohesive: in cement | Adhesive: cement/zirconia |
|-------------|---------------------------|---------------------|--------------------------|
| Group 1     | 3                         | 9                   | 3                        |
| Group 2     | 10                        | 3                   | 2                        |
| Group 3     | 2                         | 10                  | 3                        |
| Group 4     | 4                         | 7                   | 4                        |
| Group 5     | 12                        | 1                   | 2                        |
| Total       | 31                        | 30                  | 14                       |

The in-vitro bonding testing, after long-term oral simulation, is necessary to provide clinical recommendations. In laboratory studies, different methods can be applied for the aging of composite resins. Thermal cycling is the commonly used method for artificial aging in-vitro studies. Therefore, in this study, the effects of thermal cycling on the bond strength between the composite-resin cores and luting agent were evaluated. Thermal aging period is controversial.
Evaluation of the bond strength between aged composite cores and luting agent

Fig. 3. SEM image of the renovated composite specimen surface.

Fig. 4. SEM image of the air polishing applied composite specimen surface.

Fig. 5. SEM image of the acid etched composite specimen surface.

Fig. 6. SEM image of the Er:YAG laser irradiated composite specimen surface.

Fig. 7. SEM image of the aged control group composite specimen surface.
in the literature and number of thermal cycles which must be used is unclear.\textsuperscript{29} In this study, 10,000 cycles were applied for aging of the composite specimens.

The bond strengths were evaluated using a \( \mu \)SBS because it provides a common and simple measurement of the maximum possible stress at the bonding interface.\textsuperscript{30} The \( \mu \)SBS test performed without sectioning procedure, which may have induced early micro-cracking, so that this method have advantages over the microtensile bond strength.\textsuperscript{26}

Various factors affect the bonding of the aged composite resin including surface roughness, cement type, repair material, and also time after repairing.\textsuperscript{31}

Various surface treatment methods have been applied before cementation and repairing to obtain higher bond strength of the restoration. The more surface roughness results in the better mechanical interlocking. In addition, it is more probable to observe residual free carbon bonds throughout the surface area by increasing the surface roughness.\textsuperscript{32} In the current study, aged composite + laser surface treatment applied specimens exhibited the highest bond strength compared with the other groups. At the same time, the intact composite restoration exhibited higher bond strength than air polished or acid etched specimens. The specimens which were aged but had no surface treatment exhibited the lowest bond strength. Aged composite + laser surface treatment applied specimens and intact specimens showed more cohesive failure. These results may indicate that with surface treatment adhesive bonding (composite/cement) were improved.

Aged resin composites have a minimum number of free carbon bonds to adhere to a new layer of resin.\textsuperscript{30} This indicates that surface treatments should be applied on aged composites for optimum bond strength. The bond strength between aged and new composites reduced about 25-80\%.\textsuperscript{33} In our study, the bond strength of the new composite (Group 1) and aged composite (group 5) showed a 60\% reduction.

A smear layer has a negative effect on the bond strength of the restorations. Kimyai et al.\textsuperscript{34} reported that laser applications do not create smear layer and laser irradiation also provides a higher bonding strength after roughening of the substrate surface in which the surface energy and wettability of the adhesive increase. At the end of the laser irradiation, morphological alterations occurred on the surface of the material. These surface alterations can be varied by laser energy, structure, and chemical composition of the composite.\textsuperscript{35} Furthermore, Cho et al.\textsuperscript{36} reported that the Er,Cr: YSGG laser did not increase SBS. The differences in the results might be attributed to the differences in the type and mechanism of the lasers used in the two studies. In our study, the laser treatment significantly improved the bond strength of the specimens when compared to the control group. This may result from the increased surface roughness after laser irradiation.

Shimizu et al.\textsuperscript{37} reported that air polishing causes increasing the surface roughness of the composite. In a previous study, Rinaudo et al.\textsuperscript{37} concluded that air polishing cannot remove the smear layer; therefore, the bond strength of the restorations decreases. Structure of the powder particles also has an effect (positive or negative) on the adhesion surface. In the present study, the air polishing treatment has no significant effect on the SBS. Spraying time, distance, and type of abrasive powder can have an effect on the surface treatment and surface characteristics.\textsuperscript{38}

Acid etching is a commonly used method for surface treatment of composite resins. However, its effectiveness is controversial. Swift et al.\textsuperscript{39} stated that acid etching treatment has no effect on the bond strength of composite. Acids with different concentrations and types have been used in studies and various result have been obtained.\textsuperscript{31-41} Surface treatment with acid alone did not produce remarkable changes in the superficial texture of the composite compared with that of an untreated sample; it seemed to only have a cleaning effect.\textsuperscript{30} In the present study, acid etching of the surface increased the bond strength of the aged composite. Application method and type of composite resin may affect this result. Burnett et al.\textsuperscript{40} investigated the effects of laser, air abrasion, acid etching, and silane application surface treatments on the bond strength of composite restorations and concluded that the laser was the most effective for the improving bond strength.

It was stated that the repair of aged and defective composites is a more conservative and economic treatment option.\textsuperscript{41,42} In addition, Gordan\textsuperscript{35} reported that replacing composite restorations caused a loss of the tooth structure and widened the cavity. In the present study, the bond strength value of the renewed composite is the highest after laser roughening. However, it is not desired to renew the composite because of the reasons described above. In the clinic, the worst bond strength results from including the composite to the restoration without any surface treatment.

The Er:YAG laser is a conservative treatments option in dentistry\textsuperscript{35,40,43,44} and laser treatment may be used as surface treatment methods for composite restoration.\textsuperscript{39} Lizzarelli et al.\textsuperscript{43} reported in their study that composite resins treated with a laser had their polymeric matrix removed, leaving behind an area occupied by the reinforcement particles. Increasing the energy of the laser pulse does not promote general aspect changes, but a bigger alteration occurs in the polymer. In laser applications, the type of the composite influences the outcome of the surface treatment. Hybrid composites are reported to be more convenient for laser application and bond strength than others.\textsuperscript{44} In the current study, Er:YAG laser-treated specimens and renovated composite specimens mostly cohesive failure, in aged composite and air polishing treated specimens adhesive failures were occurred.

Few laboratory studies evaluating the bond strength between tooth-luting agent and zirconia-luting agent were performed under clinical conditions.\textsuperscript{18,20-24} Using \textit{in vitro} tests to evaluate the bond strength of restorative materials is one way to assess their effectiveness. However, shear bond strength test has limitations with regard to obtaining information on the internal behavior of the tooth-restoration
complex before failure. The test standards and conditions are not identical to the clinical situation; they allow for comparison of different materials within a given standard. The clinical significance of these findings remains to be determined. Additional in vitro and in vivo studies are required to demonstrate long-term results.

CONCLUSION

Within the limitations of the study, it can be concluded that aged composite restorations and different surface treatment methods have effect on the bond strength between composite-resin cores and luting agent. Surface characteristics of core material are important factors for the successful long-term results and high bond strength between the composite-resin cores and resin cement is required for better marginal adaptation, retention and high fracture resistance. Improved bond strength could be achieved by the different surface treatments and the highest bond strength was achieved with laser surface treatment which applied on aged composite surface. Appropriate surface treatment method should be applied to composite restorations or aged-composites restorations should be replaced for the optimal bond strength and the clinical success.

ORCID

Serdar Polat  http://orcid.org/0000-0003-0442-5789
Fatma Cebe  http://orcid.org/0000-0002-8637-7649
Ali Riza Tunçdemir  http://orcid.org/0000-0002-6114-3369
Caner Öztürk  http://orcid.org/0000-0001-9549-2770
Aslıhan Uşümuz  http://orcid.org/0000-0002-7222-7322

REFERENCES

1. Öilo G. Biodegradation of dental composites/glass-ionomer cements. Adv Dent Res 1992;6:50-4.
2. Bagheri R, Tyas MJ, Burrow MF. Subsurface degradation of resin-based composites. Dent Mater 2007;23:944-51.
3. Jaffer F, Finer Y, Santerre JP. Interactions between resin monomers and commercial composite resins with human saliva derived esterases. Biomaterials 2002;23:1707-19.
4. Gröger G, Rosentritt M, Behr M, Schröder J, Handel G. Dental resin materials in vivo - TEM results after one year: a pilot study. J Mater Sci Mater Med 2006;17:825-8.
5. Ferracane JL, Marker VA. Solvent degradation and reduced fracture toughness in aged composites. J Dent Res 1992;71:13-9.
6. Topcu FT, Sahinences G, Yamanel K, Erdemir U, Oktay EA, Ensahan S. Influence of different drinks on the colour stability of dental resin composites. Eur J Dent 2009;3:50-6.
7. Gordan VV. Clinical evaluation of replacement of class V resin based composite restorations. J Dent 2001;29:485-8.
8. Taha NA, Palamara JE, Messer HH. Fracture strength and fracture patterns of root-filled teeth restored with direct resin composite restorations under static and fatigue loading. Oper Dent 2014;39:181-8.
9. Asensio Acevedo R, Suarez-Feito JM, Suarez Tuoer C, Jané L, Roig M. The use of indirect composite veneers to rehabilitate patients with dental erosion: a case report. Eur J Esthet Dent 2013;8:414-31.
10. Christel P, Meunier A, Heller M, Torre JP, Peille CN. Mechanical properties and short-term in-vivo evaluation of yttrium-oxide-partially-stabilized zirconia. J Biomed Mater Res 1989;23:45-61.
11. Tinschert J, Zwez D, Marx R, Anusavice KJ. Structural reliability of alumina-, feldspar-, leucite-, mica- and zirconia-based ceramics. J Dent 2000;28:529-35.
12. Wolfart M, Lehmann F, Wolfart S, Kern M. Durability of the resin bond strength to zirconia ceramic after using different surface conditioning methods. Dent Mater 2007;23:45-50.
13. Ozcan M, Kerkdijk S, Valandro LF. Comparison of resin cement adhesion to Y-TZP ceramic following manufacturers' instructions of the cements only. Clin Oral Investig 2008;12:279-82.
14. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. Biomaterials 1999;20:1-25.
15. Blatz MB, Sadan A, Kern M. Resin-ceramic bonding: a review of the literature. J Prosthet Dent 2003;89:268-74.
16. Fazi G, Vichi A, Ferrari M. Influence of surface pretreatment on the short-term bond strength of resin composite to a zirconia-based material. Am J Dent 2012;25:73-8.
17. Blatz MB, Sadan A, Arch GH Jr, Lang BR. In vitro evaluation of long-term bonding of Procera AllCeram alumina restorations with a modified resin luting agent. J Prosthet Dent 2003;89:381-7.
18. Blatz MB, Chiche G, Holst S, Sadan A. Influence of surface treatment and simulated aging on bond strengths of luting agents to zirconia. Quintessence Int 2007;38:745-53.
19. Thompson JY, Rapp MM, Parker AJ. Microscopic and energy dispersive x-ray analysis of surface adaptation of dental cements to dental ceramic surfaces. J Prosthet Dent 1998;79:378-83.
20. Derand T, Molin M, Kvam K. Bond strength of composite luting cement to zirconia ceramic surfaces. Dent Mater 2005;21:1158-62.
21. Atsu SS, Kilicaslan MA, Kucukesmen HC, Aka PS. Effect of zirconium-oxide ceramic surface treatments on the bond strength to adhesive resin. J Prosthet Dent 2006;95:340-6.
22. Burke FJ, Fleming GJ, Nathanson D, Marquis PM. Are adhesive technologies needed to support ceramics? An assessment of the current evidence. J Adhes Dent 2002;4:7-22.
23. Kobayashi K, Komine F, Blatz MB, Saito A, Koizumi H, Matsumura H. Influence of priming agents on the short-term bond strength of an indirect composite veneering material to zirconium dioxide ceramic. Quintessence Int 2009;40:545-51.
24. Komine F, Kobayashi K, Saito A, Fushiki R, Koizumi H, Matsumura H. Shear bond strength between an indirect composite veneering material and zirconia ceramics. Quintessence Int 2009;40:545-51.
26. Armstrong S, Geraldeli S, Maia R, Raposo LH, Soares CJ, Yamagawa J. Adhesion to tooth structure: a critical review of “micro” bond strength test methods. Dent Mater 2010;26: e50-62.

27. Román-Rodríguez JL, Fons-Font A, Amigó-Borrás V, Granell-Ruiz M, Busquets-Mataix D, Panadero RA, Solà-Ruiz MF. Bond strength of selected composite resin-cements to zirconium-oxide ceramic. Med Oral Patol Oral Cir Bucal 2013;18:e115-23.

28. Ozen M, Barbosa SH, Melo RM, Galhano GA, Bottino MA. Effect of surface conditioning methods on the microtensile bond strength of resin composite to composite after aging conditions. Dent Mater 2007;23:1276-82.

29. Özel Bektas O, Eren D, Herguner Siso S, Akin GE. Effect of thermocycling on the bond strength of composite resin to bur and laser treated composite resin. Lasers Med Sci 2012; 27:723-8.

30. Cho SD, Rajitragson P, Matis BA, Platt JA. Effect of Er,Cr:YSGG laser, air abrasion, and silane application on repaired shear bond strength of composites. Oper Dent 2013; 38:E1-9.

31. Shahdad SA, Kennedy JG. Bond strength of repaired anterior composite resins: an in vitro study. J Dent 1998;26:685-94.

32. Nilsson E, Alaeddin S, Karlsson S, Milleding P, Wennerberg A. Factors affecting the shear bond strength of bonded composite inlays. Int J Prosthodont 2000;13:52-8.

33. Lewis G, Johnson W, Martin W, Canerdy A, Claburn C, Collier M. Shear bond strength of immediately repaired light-cured composite resin restorations. Oper Dent 1998;23:121-7.

34. Kimyai S, Mohammadi N, Navimipour EJ, Rikhtegaran S. Comparison of the effect of three mechanical surface treatments on the repair bond strength of a laboratory composite. Photomed Laser Surg 2010;28:825-30.

35. Lizarelli Rde F, Moriyama LT, Bagnato VS. Ablation of composite resins using Er:YAG laser-comparison with enamel and dentin. Lasers Surg Med 2003;33:132-9.

36. Shimizu Y, Tada K, Seki H, Kakuta K, Miyagawa Y, Shen JF, Morozumi Y, Kamoi H, Sato S. Effects of air polishing on the resin composite-dentin interface. Odontology 2014;102: 279-83.

37. Rinaudo PJ, Cochran MA, Moore BK. The effect of air abrasion on shear bond strength to dentin with dental adhesives. Oper Dent 1997;22:254-9.

38. Salerno M, Giacomelli L, Derchi G, Patra N, Diaspro A. Atomic force microscopy in vitro study of surface roughness and fractal character of a dental restoration composite after air-polishing. Biomed Eng Online 2010;9:59.

39. Swift EJ Jr, Cloe BC, Boyer DB. Effect of a silane coupling agent on composite repair strengths. Am J Dent 1994;7:200-2.

40. Burnett LH Jr, Shinkai RS, Eduardo Cde P. Tensile bond strength of a one-bottle adhesive system to indirect composites treated with Er:YAG laser, air abrasion, or fluoridric acid. Photomed Laser Surg 2004;22:351-6.

41. Lucena-Martín C, González-López S, Navajas-Rodríguez de Mondelo JM. The effect of various surface treatments and bonding agents on the repaired strength of heat-treated composites. J Prosthet Dent 2001;86:481-8.

42. Keski-Nikkola MS, Alander PM, Lassila LV, Vallittu PK. Bond strength of Gradia veneering composite to fibre-reinforced composite. J Oral Rehabil 2004;31:1178-83.

43. Lizarelli RFZ, Moriyama LT, Jorge JRP, Bagnato VS. Comparative ablation rate from an Er:YAG laser on enamel and dentin of primary and permanent teeth. Laser Phys 2006;16:849-58.

44. Lizarelli RFZ, Moriyama LT, Pelino JEP, Bagnato VS. Ablation rate and morphological aspects of composite resins exposed to Er:YAG laser. J Oral Laser App 2005;5:151-60.