10.5005/jp-journals-10024-2252

ORIGINAL RESEARCH

the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com

Does Erbium:Yttrium–Aluminum–Garnet Laser to Enamel improve the Performance of Etch-and-rinse and Universal Adhesives?

[1]Rudys R De Jesus Tavarez, [2]Lorrany LC Rodrigues, [3]Ana C Diniz, [4]Lucas M Lage, [5]Carlos RG Torres
[6]Matheus C Bandeca, [7]Leily M Firoozmand

ABSTRACT

Aim: This study aims to evaluate the effect of erbium: Yttrium–aluminum–garnet (Er:YAG) laser irradiation on the enamel microshear bond strength (μSBS), followed by the utilization of etch-and-rinse and universal adhesive systems.

Materials and methods: A total of 32 molars were sectioned in the mesiodistal direction producing 64 samples that were randomized into two groups (n = 32): single bond 2 (SB2) (etch-and-rinse system; 3M), SB universal (SBU) (universal etching system; The SB2 and SBU groups were then divided into two subgroups (n = 16): (i) enamel was irradiated with an Er:YAG laser (λ = 2.94 μm, 60 mJ, 10 Hz), and (ii) enamel served as a control. The samples were restored with TPH3 (Dentsply), stored in artificial saliva for 24 hours, and subjected to a microshear test.

Results: Kruskal–Wallis ($p < 0.05$) and Mann–Whitney U tests indicated no significant differences in μSBS between the groups, and the fractures were predominately at the resin–enamel interface.

Conclusion: The previous irradiation of enamel with Er:YAG laser does not interfere with the performance of simplified two-step etch-and-rinse and universal adhesive systems.

Clinical significance: The increasing use of Er:YAG laser is important to evaluate the influence of this irradiation on the adhesion of restorative materials. Thus, to obtain the longevity of the restorative procedures, it is necessary to know the result of the association of the present adhesive systems to the irradiated substrate.

Keywords: Dental composite, Enamel, Laser, Shear strength.

How to cite this article: De Jesus Tavarez RR, Rodrigues LLC, Diniz AC, Lage LM, Torres CRG, Bandeca MC, Firoozmand LM. Does Erbium:Yttrium–Aluminum–Garnet Laser to Enamel improve the Performance of Etch-and-rinse and Universal Adhesives? J Contemp Dent Pract 2018;19(3):278-282.

Source of support: Nil

Conflict of interest: None

[1,4,6]Department of Restorative Dentistry, Ceuma University São Luís, Maranhão, Brazil

[2,3,7]Department of Dentistry, University Federal of Maranhão São Luís, Maranhão, Brazil

[5]Department of Restorative Dentistry, ICT UNESP University São José dos Campos, São Paulo, Brazil

Corresponding Author: Rudys R De Jesus Tavarez, R. Josue Montello No. 01, Renascença II 65075-120, São Luís Maranhão, Brazil, Phone: +559832144127, e-mail: rudysd@uol.com.br

INTRODUCTION

Adhesive systems have been widely used in dentistry, especially because they are used for a large number of direct and indirect restorations. The clinical success of restorations depends on the quality and durability of the bonding interface (restoration tooth structure) and requires knowledge of the dental substrate to which the adhesive system is applied.[1] Bonding strength is influenced by the time, the dental substrate treated, and the type of adhesive system utilized.[2,3]

Advancements in the understanding of adhesive systems have prompted the development of a well-known simplified etch-and-rinse system (conventional), comprising two clinical steps: Total etching and washing/drying, followed by the application of a primer/bond. A previous study reported that the development of the simplified adhesive system is attractive for clinical use because it seems to reduce the number of clinical steps.[4]

To reduce the number of clinical steps, more versatile adhesive systems have been developed including the etch-and-rinse system (two steps) and the self-etching system (one or two steps). These novel adhesive systems can be classified as "multipurpose", "multimode", or "universal".[5]

The applicability and effectiveness of these materials on dental substrates have been recently assessed, whereas the universal systems appear to be material dependent.[5-7]

Previous studies evaluated the effect of enamel pretreatment before the application of self-etching adhesive systems in order to determine optimal adhesive conditions.[8,9] Enamel pretreatment with phosphoric acid increases the bonding strength and results in the formation of longer resin tags and greater adhesive penetration depth in the intact enamel.[6,8] However, the adhesive penetration depth does not necessarily lead to an increase in bonding strength.[10]

At present, lasers are utilized in dentistry for tooth cavity preparations, cavity tissue removal, oral cavity decontamination, and enamel etching.[11] The Er:YAG laser is one of the most widely utilized techniques for hard dental tissue etching because it produces surfaces with a greater roughness, without a smear layer.[12]

Furthermore, irradiation with an Er:YAG laser can promote structural and morphological changes in hard dental tissues.[13] However, further studies are required to evaluate the effects of Er:YAG laser application on dental substrates with respect to the bonding technique utilized.

Adhesive systems should be tested *in vitro* and compared with previously established parameters and outcomes before clinical application.[10] Novel materials are constantly introduced into the market and their effectiveness requires both *in vitro* and *in vivo* evaluation.

The aim of this *in vitro* study was to evaluate the effect of Er:YAG laser application on tooth enamel before the utilization of etch-and-rinse and universal adhesive systems.

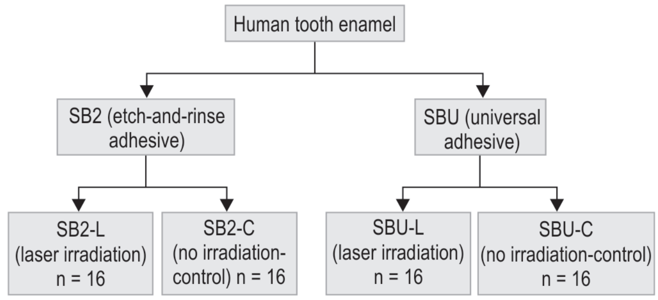
MATERIALS AND METHODS

A total of 32 human permanent molars were extracted from dental clinic patients involved in the undergraduate dentistry course at Ceuma University. The Human Research Ethics Committee under protocol n. 543.409 approved the research.

Healthy teeth free from caries, cervical lesions, cracks, enamel defects, and restorations were selected, cleaned, immersed in 0.1% thymol solution, and stored in distilled water at 37 ± 1°C. These samples were sectioned in the mesiodistal direction, producing 64 vestibular and lingual halves. Following this, the samples were embedded in polyvinyl chloride tubes using chemically activated acrylic resin (JET-CLÁSSICO, São Paulo, Brazil) so that the vestibular and lingual surfaces of each sample were exposed on a flat level, facing up.

The vestibular and lingual halves of each sample were randomized into two groups (n = 32) (Flow Chart 1) to receive application of either an etch-and-rinse bonding (SB2; total-etching Single Bond 2 adhesive system (SB2) (3M ESPE, Saint Paul, Minnesota, USA) adhesive system, or a universal adhesive system (SBU) (3M ESPE, Saint Paul, Minnesota, USA) (Table 1). Before the application of a universal or etch-and-rinse adhesive system, phosphoric acid (37%) was applied to the tooth enamel. Samples in the SB2 and SBU groups were subdivided into either subgroup L (n = 16), in which the enamel surfaces were irradiated with an Er:YAG laser (SBU-L and SBU-L) or subgroup C (control group, n = 16) in which the enamel surfaces were not irradiated (SB2-C and SB2-C).

Flow Chart 1: Experimental design study



The irradiated area corresponded to the central area of the molar surface, delimited by the mesial and distal faces of the vestibular or lingual surfaces, while the remaining tooth surface was used as a control. Irradiation was administered using an Er:YAG laser (KaVo Key Laser 2; Kavo Co, Biberach, Germany) for enamel etching at an energy of 60 mJ per pulse and at a frequency of 10 Hz. The laser emitted a wavelength of 2.94 µm through a handpiece (#2051) with a spot diameter of 0.63 mm. The handpiece was positioned perpendicularly to the tooth surface and the distance was calibrated at 12 mm (focused mode). Irradiation was performed manually in the scan mode under constant water cooling; the entire tooth surface was irradiated. Care was taken to avoid area overlapping in order to obtain a homogeneously irradiated surface.

Three transparent cylindrical matrices (Tygon Tubing, TYG-030, Saint-Gobain Performance Plastic, Maime Lakes, Florida, USA) were placed on the vestibular surface of each sample. The TPH spectrum composite resin (Dentsply Caulk, Milford, Delaware, USA) was applied to each matrix, filling the internal volume. All photoactivation procedures were performed using a fast-curing cordless LED photopolymerizer (3M ESPE dental, Landsberg am Lech, Germany) under a light intensity of approximately 800 mW/cm^2, measured with a radiometer (GNATUS, Ribeirão Preto, São Paulo, Brazil). After enamel bonding, the matrices were removed to expose the small cylinders of composite resin to the areas intended to be treated.

To perform the microshear test, a 0.2-mm diameter stainless steel wire was positioned around the cylinder and aligned with the bonding interface of the adhesive

Table 1: Materials, their composition, and the application methods utilized in this study

Adhesive system	Adper™ SB (3M) (SB2)	Dimethacrylate resins HEMA Vitrebond™ Copolymer Filler Ethanol Water Initiators	Acid etching: 30s on the enamel; washing for 30s, followed by complete drying Adhesive application for 15s vigorously Duration of photopolymerization: Adhesive 20s;
	SB universal (3M) (SBU)	MDP phosphate monomer Dimethacrylate resins HEMA Vitrebond™ Copolymer Filler Ethanol Water Initiator, silano	Acid etching: 30s on the enamel; washing for 30s, followed by complete drying Adhesive application for 20s vigorously Duration of photopolymerization: 20s
Composite resin	TPH3 Dentsply	Barium aluminum borosilicate silanized glass, barium fluoride aluminum borosilicate silanized glass, Bis-GMA dimethacrylate, silica, and EDAB	Duration of photopolymerization: 40s;

SB2: Single bond; SBU: Single bond universal; TPH: Bis-GMA: Bisphenol A glycidyl methacrylate; HEMA: Hydroxyethyl methacrylate; MDP: Methacryloyloxydecyl dihydrogen phosphate; EDAB: Ethyl-4-dimethylamino benzoate

system. The test was conducted using a universal testing machine EMIC (DL 2000-EMIC, São José dos Pinhais, Paraná, Brazil) at a speed of 0.5 mm/min until fracture was achieved. The mean fracture values of the three composite resin cylinders were then calculated.

After the bonding strength tests, the surface of each sample was examined under a microscope to determine the type of fracture that occurred in the region of rupture between the enamel and the composite resin. Fractures were classified as follows: (1) Adhesive fractures: fractures in the resin–adhesive interface; (2) cohesive enamel fractures: fractures in the tooth enamel; (3) cohesive fractures in the composite resin: fractures in the body of the composite resin cylinder; and (4) mixed fractures: fractures involving resin, adhesive, and tooth structure (combination of the fracture types).

Statistical Analysis

Bonding strength data were not normally distributed in the same groups (Shapiro Wilk; $p < 0.05$). Therefore, bonding strength values were compared with the amount of adhesive material remaining using the nonparametric Kruskal–Wallis and Mann–Whitney tests. For non-normally distributed data or for groups without homogeneity of variance, the median and interquartile ranges of the values obtained were calculated (Table 2). A value of α = 0.05 using the Bonferroni correction was used for multiple comparisons, resulting in an α = 0.012 for each of the four comparisons. Statistical analyses were performed using both PAWS Statistics software (version 17; SPSS Inc., Chicago, USA) and GraphPad Prism software (version 5-2007, release 17.0.2.2009; San Diego, USA).

Table 2: Descriptive and inferential statistics of the bonding strength (MPa)

Variables	*Mean (SD)**	*Median*	*95% CI*
SB2-L	22.83 (4.0) A	24.00	20.25–25.42
SB2-C	19.67 (2.4) A	19.00	18.10–21.23
SBU-L	21.50 (3.2) A	21.00	19.43–23.57
SBU-C	20.58 (4.5) A	19.00	17.72–23.44

CI: Confidence interval; SD: Standard deviation; *Similar uppercase letters denote no statistically significant difference within each group of teeth

RESULTS

Adhesive Strength (MPa)

Descriptive and inferential statistics of bonding strength for the study groups are shown in Table 2. Kruskal–Wallis and Mann–Whitney tests showed that there was no statistically significant difference in bonding strength between the groups evaluated (Table 2).

Fracture Mode

The absolute and relative frequencies of the variable type of fracture are presented in Table 3. Adhesive fractures were the predominant fracture type in groups SB2-C, SBU-L, and SBU-C.

Table 3: Distribution of the absolute and relative frequencies of the variable type of fracture in the groups evaluated

Groups	*1 n (%)*	*2 n (%)*	*3 n (%)*	*4 n (%)*	*Total*
SB2-L	3 (25.0)	0	4 (33.3)	5 (41.6)	12 (100)
SB2-C	9 (75.0)	0	3 (25.9)	0 (0)	12 (100)
SBU-L	8 (66.6)	0	1 (8.3)	3 (25.0)	12 (100)
SBU-C	9 (75.0)	0	3 (25.9)	0 (0)	12 (100)

DISCUSSION

In this study, there was no significant difference in tooth enamel bonding strength between the utilization of a universal adhesive system and a etch-and-rinse bonding system following Er:YAG laser irradiation.

Enamel treatment with phosphoric acid before adhesive system application results in greater bonding strength compared with unetched enamel.[6,9,14] Phosphoric acid creates microporosities and more pronounced bonding patterns in the enamel.[4] With regard to novel universal adhesive materials, McLean et al[6] found that etching significantly increased the bonding strength of these materials. In the present study, before the application of a universal or etch-and-rinse adhesive system, phosphoric acid (37%) was applied to the tooth enamel, independent of the use of Er:YAG laser. This is because acid etching increases the bonding strength of different adhesive systems.[15]

The analysis of the composition of the adhesive materials used in this study indicated that, in addition to the components present in the etch-and-rinse adhesive system, the universal adhesive material also contains methacryloyl oxide decamethylene phosphoric acid, methacryloyloxydecyl dihydrogen phosphate (MDP), and silane (Table 1). Self-etching adhesive systems are known to cause a partial demineralization of the tooth substrate and studies investigating the Clearfil SE Bond have demonstrated that 10-MDP forms a stable chemical bond with the tooth substrate. This knowledge led to the development of the "universal," "multipurpose," and "multimode" adhesive systems that contain 10-MDP, in addition to other components. Accordingly, the bonding mechanism occurs through micromechanical and chemical nanointeractions. Nanolayers of 10-MDP molecules result in the formation of a stable salt, MDP-calcium, which increases the resistance of the adhesive interface to biodegradation. This may explain the improved interfaces obtained with the use of 10-MDP-based adhesive systems.[16]

Some studies utilizing universal adhesive systems containing 10-MDP have been recently conducted because these systems have previously been shown to yield greater and more stable bonding strengths, with reduced nanoleakage.[6,7,17]

Although previous studies have shown that acid etching improves the penetration of universal adhesives in the dentin, it should be noted that total etching could remove the inorganic content, leaving the organic matrix exposed.[18] Therefore, the formation of the MDP-calcium salt, which facilitates the chemical interaction with nanomaterials, becomes restricted.

The results obtained in this study indicate that enamel etching using Er:YAG laser prior to the use of the phosphoric acid did not significantly change the bonding strength in the groups treated with a conventional or a universal adhesive system. Ciucchi et al[19] by employing the Er:YAG in dental pits before etching, for applying sealants, also found no significant changes in the microscopic images obtained. A previous study has demonstrated that enamel etching with Er:YAG laser produces less stress traction and demineralization compared with phosphoric acid.[20] In the present study, a low-energy Er:YAG laser (60 mJ) was utilized for enamel etching, as previously described because low-energy levels (60–80 mJ) can promote demineralization without causing major changes in the enamel.[21]

However, it is difficult to compare the findings of previously published studies due to the variation in the experimental techniques employed: some studies combined the use of laser and acid etching, while others used laser alone to promote etching.[13,20,22] The previous study has proposed the application of enamel etching using laser parameters similar to those used in cavity preparations. In these cases, despite an adequate bonding strength, severe and permanent damage to the tooth enamel has been recorded.[22]

In contrast to acid etching, the application of a tooth enamel laser has been shown to produce a region comprising fissures and debris in the subsurface layer of the enamel in 80% of the irradiated samples.[23] Accordingly, Ceballos et al[24] highlighted that the enamel laser irradiation is a nonviable alternative to acid etching pretreatment for the composite resin. These results provided the rationale for the current study; to perform acid etching after irradiating the tooth enamel with Er:YAG laser.

Yung et al[25] showed that the lower bonding strength values obtained after laser etching may be due to thermal damage, unfavorable changes in the enamel surface by excessive laser energy, composition of the adhesive system utilized, or due to differences in the laser parameters.

The most frequent fractures in the SB2-C, SBU-L, and SBU-C groups were observed at the adhesive–enamel interface. The SB2-L group presented homogeneous adhesive, cohesion, and mixed fractures. In contrast, McLean et al[6] performed a microtensile assessment and recorded a higher frequency of mixed fractures (adhesive and cohesive fractures in the enamel) with acid etching followed by the application of the universal adhesive system.

Therefore, there was no statistically significant difference in the tooth enamel bonding strength between a universal adhesive system and a two-step etch-and-rinse adhesive system following application of Er:YAG laser irradiation.

CONCLUSION

According to the data and statistical analysis applied to the results, it is concluded that the previous irradiation of enamel with Er:YAG laser does not interfere with the performance of simplified two-step etch-and-rinse and universal adhesive systems.

ACKNOWLEDGMENT

The authors are grateful for the assistance granted by FAPEMA, Assistance Foundation of Research of Maranhão.

REFERENCES

1. Manso AP, Marquezini L Jr, Silva SM, Pashley DH, Tay FR, Carvalho RM. Stability of wet versus dry bonding with different solvent-based adhesives. Dent Mater 2008 Apr;24(4): 476-482.
2. Leloup G, D'Hoore W, Bouter D, Degrange M, Vreven J. Meta-analytical review of factors involved in dentin adherence. J Dent Res 2001 Jul;80(7):1605-1614.
3. Cehreli ZC, Kecik D, Kocadereli I. Effect of self-etching primer and adhesive formations on shear Bond strength of orthodontic brackets. Am J Orthod Dentofac Orthop 2005 May;127(5):573-579, quiz 625-626.
4. Ozer F, Blatz MB. Self-etch and etch-and-rinse adhesive systems in clinical dentistry. Compend Contin Educ Dent 2013 Jan;34(1):12-14, 16, 18.
5. Muñoz MA, Luque I, Hass V, Reis A, Loguercio AD, Bombarda NH. Immediate bonding properties of universal adhesives to dentine. J Dent 2013 May;41(5):404-411.
6. McLean DE, Meyers EJ, Guillory VL, Vandewalle KS. Enamel bond strength of new universal adhesive bonding agents. Oper Dent 2015 Jul-Aug;40(4):410-417.
7. Perdigão J, Loguercio AD. Universal or multi-mode adhesives: why and how? J Adhes Dent 2014 Apr;16(2):193-194.
8. Devarasa GM, Subba Reddy VV, Chaitra NL. Self-etching adhesive on intact enamel. J Indian Soc Pedod Prev Dent 2012 Apr-Jun;30(2):133-138.
9. Poggio C, Scribante A, Della Zoppa F, Colombo M, Beltrami R, Chiesa M. Shear bond strength of one-step self-etch adhesives to enamel: effect of acid pretreatment. Dent Traumatol 2014 Feb;30(1):43-48.
10. Heintze SD, Zimmerli B. Relevance of *in vitro* tests of adhesive and composite dental materials. A review in 3 parts. Part 3: *in vitro* tests of adhesive systems. Schweiz Monatsschr Zahnmed 2011;121(11):1024-1040.
11. Usumez A, Aykent F. Bond strengths of porcelain laminate veneers to tooth surfaces prepared with acid and Er,Cr: YSGG laser etching. J Prosthet Dent 2003 Jul;90(1):24-30.
12. Celik EU, Ergücü Z, Türkün LS, Türkün M. Shear bond strength of different adhesives to Er:YAG laser-prepared dentin. J Adhes Dent 2006 Oct;8(5):319-325.
13. Contreras-Bulnes R, Scougall-Vilchis RJ, Rodríguez-Vilchis LE, Centeno-Pedraza C, Olea-Mejía OF, Alcántara-Galena MC. Evaluation of self-etching adhesive and Er:YAG laser conditioning on the shear bond strength of orthodontic brackets. Sci World J 2013 Sep;2013:719182.
14. Sheets JL, Wilcox CW, Barkmeier WW, Nunn ME. The effect of phosphoric acid pre-etching and thermocycling on self-etching adhesive enamel bonding. J Prosthet Dent 2012 Feb;107(2):102-108.
15. Pires PT, Ferreira JC, Oliveira SA, Azevedo AF, Dias WR, Melo PR. Shear bond strength and SEM morphology evaluation of different dental adhesives to enamel prepared with Er:YAG laser. Contemp Clin Dent 2013 Jan;4(1):20-26.
16. Yoshida Y, Yoshihara K, Nagaoka N, Hayakawa S, Torii Y, Ogawa T, Osaka A, Meerbeek BV. Self-assembled nano-layering at the adhesive interface. J Dent Res 2012 Apr;91(4): 376-381.
17. Muñoz MA, Luque-Martinez I, Malaquias P, Hass V, Reis A, Campanha NH, Loguercio A. *In vitro* longevity of bonding properties of universal adhesives to dentin. Oper Dent 2015 May-Jun;40(3):282-292.
18. Wagner A, Wendler M, Petschelt A, Belli R, Lohbauer U. Bonding performance of universal adhesives in different etching modes. J Dent 2014 Jul;42(7):800-807.
19. Ciucchi P, Neuhaus KW, Emerich M, Peutzfeldt A, Lussi A. Evaluation of different types of enamel conditioning before application of a fissure sealant. Lasers Med Sci 2015 Jan;30(1):1-9.
20. Lasmar MF, Reher VG, Lalloo R, Reher P. Enamel demineralization and bracket bond strength when etching with acid and/or Er:YAG laser. Aust Dent J 2012 Jun;57(2):190-195.
21. Cecchini RC, Zezell DM, De Oliveira E, De Freitas PM, Eduardo CP. Effect of Er:YAG laser on enamel acid resistance: Morphological and atomic spectrometry analysis. Lasers Surg Med 2005 Dec;37(5):366-372.
22. Türköz C, Ulusoy C. Evaluation of different enamel conditioning techniques for orthodontic bonding. Korean J Orthod 2012 Feb;42(1):32-38.
23. Frentzen M, Santaella MR, Matson E. Er:YAG laser-assisted fissure sealing. Int Congr Ser 2003 May;1248:197-198.
24. Ceballos L, Osorio R, Toledano M, Marshall GW. Microleakage of composite restorations after acid or Er-YAG laser cavity treatments. Dent Mater 2001 Jul;17(4):340-346.
25. Yung FY, Gutknecht N, Franzen R, Fischer H. Shear strength of composite bonded to Er:YAG laser-prepared enamel: an *in vitro* comparative study. Lasers Med Sci 2013 May;28(3): 879-889.