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Micro Shear Bond Strength of Resin Composite Restorations to Er,Cr: YSGG Laser Treated Enamel Versus Conventional Acid Etching (An In Vitro Study)

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ABSTRACT

Background: The introduction of adhesive dentistry has spurred research into finding solutions for the facilitation of daily dental adhesive workflow to achieve a durable and reliable adhesive junction using newly introduced instruments & techniques in the dental field. ***Aim of the study:*** to evaluate the μSBS to enamel surfaces treated using conventional acid etching compared to Er,Cr:YSGG laser at two average power outputs as well as in combination with each other. ***Materials and Methods:*** 50 human molars were used. The molars were embedded in acrylic blocks with their buccal surfaces facing upwards. Enamel was removed using an Isomet 4000 exposing superficial dentin and a surrounding enamel rim. The specimens were divided into five equal groups with ten samples in each group GI:Acid Etching, GII:3.5 watt Er,Cr:YSGG Laser, GIII:3.5 watt Er,Cr:YSGG + AE Laser, GIV:4.5 watt Er,Cr:YSGG Laser and GV:4.5 watt Er,Cr: YSGG Laser + AE. Universal microhybrid composite microcylinders were then bonded to the enamel rim using Tygon tubes which were then subjected to microshear bond testing using a universal testing machine and the μSBS were recorded and tabulated. One-way ANOVA followed by Duncan's Post-hoc tests were used to compare between the different groups. ***Results:*** The μSBS values showed that values of GIV were similar to those obtained from GII and showed no statistical significance. Both groups, however, showed higher significant values than the remaining groups. ***Conclusion:*** Low average power output Er,Cr: YSGG laser has a beneficial effect in enhancing the bonding of etch and rinse adhesives to enamel.

Keywords: acid etching, laser, erbium laser, surface treatment and micro-shear bond strength.

INTRODUCTION

The past forty years of dental adhesive development have seen bounds and leaps in the transformations seen in the chemistry and composition of dental adhesives in attempts to produce a durable adhesive bond. Adhesion to enamel has remained consistently reliable since the introduction of the concept of enamel acid etching by

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Michael Buonocore in the 1950s. Dr Michael Buonocore knew very well then that he had established the foundation for the future of adhesive and preventive dentistry.[1]

Recently, the integration of laser therapy into routine clinical practices has opened many fields of application and has pushed researchers to solve clinical and procedural deficits with the use of lasers. Several studies have explored multiple variables in the surface treatment of enamel for adhesion to composite resin restorations as power outputs, time and distance with varying degrees of success. Laser etching, however, presented a tempting alternative to acid etching owing to its commercial availability in dental clinical practices, with it being painless to the patient, eliminating the need for anesthesia.[2–8]

To this date, no studies have produced a definitive clinical recommendation for the use of laser etching as a clinical substitute to conventional acid etching. This research attempted to explore the effect of Er, Cr: YSGG laser surface treatment of tooth surfaces on the strength of the adhesive junction between resin composites and enamel surfaces represented in the microshear bond strength (μSBS) values of the previously mentioned surface treatment compared to conventional acid etching at two different power outputs and in combination with acid etching to observe whether they exhibit a synergistic effect when implemented together or not.

The null hypothesis tested is that there is no difference in the microshear bond strength values between enamel specimens pretreated with Er,Cr: YSGG laser at average power outputs of 3.5 & 4.5 watts, acid etched enamel and the combination of both laser and conventional acid etching.

MATERIALS & METHODS

***Sample Preparation*:**

A total of fifty human molars were used in this study. The molars were obtained from Misr International University teeth bank. The teeth selected were free of caries, exhibited no fractures and were of the permanent dentition.

With the occlusal surface facing upwards (**Figure 1)**, the buccal enamel was then peeled off using the Buehler Isomet 4000 to expose an enamel rim at the level of the superficial dentin.[9] **Figure (2, 3)**

The teeth were then sectioned mesiodistally at the level of the cervical line to separate the roots. Sectioned specimens were embedded in sectioned Poly Vinyl Chloride (PVC) pipes of 25 mm cross sectional diameter into which self-cured acrylic resin (Acrostone ™) was poured and

Figure 1: Mounting of samples on Isomet 4000 Clamp.

Figure 2: Peeling of buccal enamel of mounted samples.

the prepared specimen was placed with the sectioned surface facing upwards. After setting of the self-cured acrylic resin, the samples were removed from the PVC pipe

Figure 3: Sample after peeling off of buccal enamel.

mould. The samples were then finished using Soflex Discs (3M ESPE, Minnesota, USA) in a descending order of abrasiveness. The samples were then ready for the surface treatment (**Figure 4, 5).**

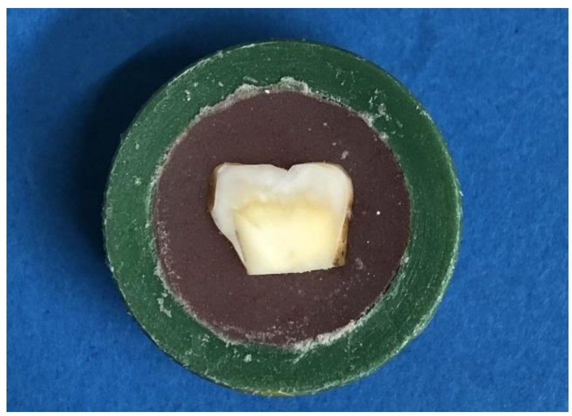

Figure 4: Sectioned specimens embedded in poly vinyl chloride sectioned pipe.

The samples were each numbered at the bottom of the resin block and randomly allocated using online randomizing software (www.randomizer.org) into five equal groups. Ten samples in each group according to the method of surface treatment.

Figure 5: Cold cure acrylic resin containing specimen with enamel peeled off after removal of sectioned PVC pipes.

Surface Treatment of Test Groups:

Group (I):

The enamel surfaces of the samples were etched with Meta Etchant 37% phosphoric acid gel for 15 seconds and then rinsed with air/water spray for 10 seconds then blot dried with cotton pellet. This was followed by the application of a two-step etch and rinse adhesive resin (Single Adper 2, 3M ESPE, Minnesota, USA), according to the manufacturer's instructions.

The mode of application was in two coats using vigorous active brushing. This was followed by spreading in air for 5 seconds. Finally, the adhesive was light cured for 10 seconds using an Elipar™ FreeLight 2 LED of power output $500mW/m^2$. The light cure power output was calibrated using a radiometer to ensure proper curing and consistency throughout the test process.

Group (II):

Surface treatment with Er, Cr: YSGG laser at an output of 3.5 Watt in a 20-second pulse was done followed by the procedure of application of the adhesive resin as in group I.

Group (III):

Surface treatment with Er, Cr: YSGG laser was used at an output of 3.5 Watt in a 20- second pulse followed by the procedure of application of Meta Etchant - 37% phosphoric acid gel for 15 seconds. The acid was then rinsed with air/water spray for 10 seconds and blot dried with cotton pellet. The adhesive resin was then applied as in group I.

Group (IV):

Surface treatment with Er, Cr: YSGG laser at an output of 4.5 Watt in a 20-second pulse was done followed by the procedure of application of the adhesive resin as in group I.

Group (V):

Surface treatment with Er, Cr: YSGG laser was used at an output of 4.5 Watt in a 20- second pulse followed by the procedure of application of Meta Etchant - 37% phosphoric acid gel for 15 seconds. The acid was then rinsed with air/water spray for 10 seconds and blot dried with cotton pellet. The adhesive resin was then applied as in group I.

Laser Procedures:

In order to ensure consistent spot size with the laser hand irradiation used in the current study, a distance of 7 mm from the substrate surface was kept constant during the procedures. This 7 mm distance was maintained and standardized using a premade clamp and stand apparatus consisting of a clamp attached to a main metal rod attached to a metallic base onto which the sample is placed and moved around on.[10] **Figure (6, 7, & 8)**

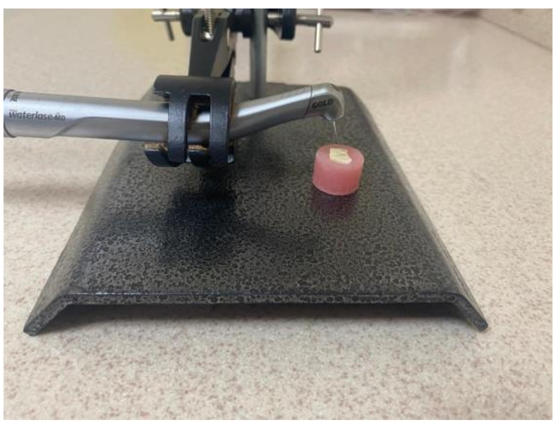

Figure 6: Clamp component holding laser handpiece at the standardized distance.

The following parameters were used in the administration of the laser beam: a repetition rate of 50 Hz frequency, 80% H_20, 20% air using a 600-micron MZ6 tip in non-contact mode. The only variable was the laser beam with an average power output which in G2 & G4 were set at 3.5 Watts, and groups G3 and G5 were set at 4.5 Watts.

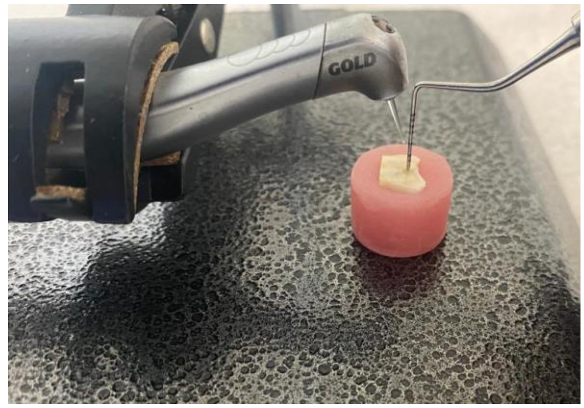

Figure 7: Clamp component holding laser handpiece at the standardized distance.

Figure 8: Clamp & stand assembly.

In order to ensure the depth of the etching was standardized as well, the surfaces of the prepared samples were marked using a permanent felt-tip marker[10]. Subsequently, the laser administration was arrested when the marked surfaces were clear of the markings.

Application of Composite Microcylinders:

Nanohybrid 3M ESPE Z350 composite was applied using a plugger of 1 mm diameter by packing it into micro-cylinders of 0.9 mm diameter and 0.5 mm height cut from US Plastics Tygon® ND 100-80 Microbore tubing polymer tubing. The micro-cylinder was mounted perpendicular to the vertical axis of the tooth on the enamel surface. It was then light cured for 20 seconds using a light curing unit of power output of 500mW/m^2 which was previously calibrated using a radiometer. The Tygon® polymer tubing was then split using a sharp thin lancet and carefully peeled off after 24 hours, exposing the cured composite rods producing samples ready for micro shear bond testing. The samples were kept for 24 hours prior to microshear bond testing to allow for the maturation of the hybrid layer.[11]

Micro Shear Bond (μSBS) Testing:

The acrylic block with the specimen was attached to the lower fixed head of the universal testing machine (Instron model 3345, England). Each composite cylinder was subjected to a (μSBS) test using a stainless-steel wire 0.14-inch diameter attached to the upper movable head of the testing machine, which was placed as close as possible to the composite/enamel or dentin interface. Tensile mode of force was applied at a crosshead speed of 1.0 mm/min up to specimen failure. The force required for failure (Newton) was divided by the surface area (mm^2) to calculate the shear bond strength in MPa by machine software (BlueHill 3, Instron, England). **Figure (9)**

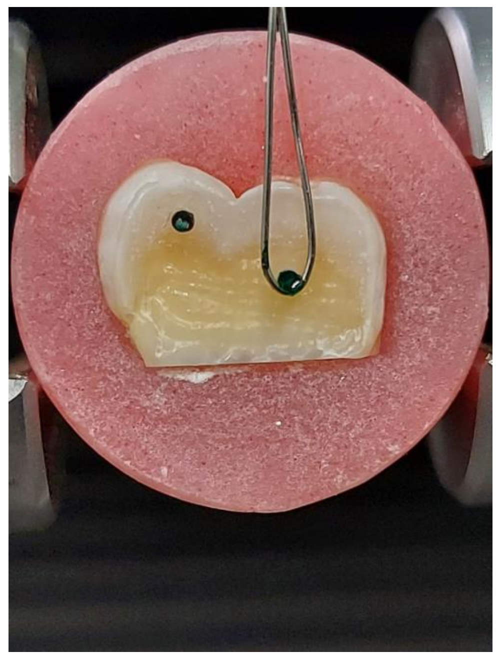

Figure 9: Wire Component around composite microcylinder for μSBS testing.

Statistical Analysis:

The (μSBS) values were recorded, tabulated, and statistically analyzed. μSBS data showed parametric (normal) distribution. Data was presented as mean and standard deviation values. One-way ANOVA test was used to compare between surface treatments. Duncan's Post-hoc test was used for pair-wise comparisons when One-way

ANOVA test was significant. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY:IBM Corp.

RESULTS

Microshear Bond Strength Testing:

Comparison between surface treatments:

Data in **table (1)** shows descriptive statistics and results of one-way ANOVA test for comparison of enamel μSBS at different power outputs using various surface treatment protocols. There was a statistically significant effect for surface treatment on microshear bond strength with an F-value of 3.976 and a p-value of 0.008.

Table (1): Descriptive statistics & Duncan post hoc test between the groups for enamel surface treatments.

Groups	Mean & Sig.	Standard Deviation	F value	P value
Control	15.6115 ^{b}	5.89	3.976	0.008
3.5 Watt	16.8950 ^{ab}	4.2		
3.5 + Acid Etching	23.0046 ^{a}	11.54		
4.5 Watt	13.9667 ^{b}	3.03		
4.5 + Acid Etching	11.2803 ^{b}	5.4		

**Different lower-case letters mean significant difference.*

Duncan post-hoc test showed that the samples treated with 3.5 watt Er,Cr:YSGG in combination with phosphoric acid etching showed the highest significant μSBS 23 ± 11.54 MPa followed by the samples that were treated with 3.5 watt Er,Cr:YSGG laser etching 16.89 ± 4.2 MPa with no significant difference in between.

Significant difference was not detected between the enamel samples treated with 3.5 watt Er,Cr:YSGG laser etching, acid etching only (Control Group) , 4.5 watt Er,Cr:YSGG & 4.5 watt Er,Cr:YSGG in combination with acid etching with values of mean and standard deviation: 16.89 ± (4.2) MPa, 15.61 ± (5.9) MPa, 13.96 ± (3.03) MPa & 11.28 ± (5.4) MPa respectively.

DISCUSSION

From the development of the first working laser device by Theodore Mainman in the 1960s, lasers have slowly but surely integrated themselves into the modern daily dental practice. From soft tissue lasers capable of performing painless soft tissue surgeries such as crown lengthening and gingivectomies with minimal bleeding to the use of erbium lasers for caries excavation and enamel and dentin surface treatment in an attempt to further facilitate the bonding process.

Dental researchers would be at fault if attempts at streamlining the bonding process using modern dental lasers were neglected, especially with the modern-day literature bursting with studies attempting to use Erbium lasers – and especially Er, Cr:YSGG Laser – as a modern substitute to the conventional 37% phosphoric acid etching.

However, the data regarding this topic has been in essence conflicting with the research spectrum extending from papers recommending its use and boasting its benefits, especially in enamel surface etching to studies and finite element analyses revoking that recommendation, and insisting on adhering to the gold standard etch and rinse adhesives.[12–18]

Its of importance to note that the attempt at finding an alternative to acid etching stems not from a question of its efficacy. Quite the contrary, as research has proved the merits and high bond strength values achieved with etch & rinse adhesives. Rather its efficiency in terms of clinical work flow that remains a contest of improving the clinical process currently in use owing to its technique sensitivity.[19-22]

The variability in recommendations stems mainly from the variability of laser energy average power outputs. Some papers used low level lasers and produced favorable results and recommendations for the use of low-level laser from 1.5 watts to 3 watt.[15–17] Other papers, however, used higher values of average laser power outputs and did not produce favorable results and as such did not recommend the use of dental lasers as adjunctive aids to the bonding process.[14]

This study attempted to find and utilize the middle ground that appeared to have presented itself as a gap of knowledge in terms of use of intermediate level dental lasers and even using them in combination with conventional 37% phosphoric acid etching and comparing its outcomes in terms of microshear bond strength values to a control group utilizing 37% phosphoric acid etching and a two-step etch and rinse adhesive system.

μSBS testing was used to evaluate the strength of the adhesive interface of the respective surface treatments used. This mode of bond strength testing provides an advantage over microtensile bond testing due to its ability for testing of small areas and the preparation of multiple specimens from a single tooth.[23] In addition to producing a significantly less amount of stress or damage during the preparation of the specimen prior to testing compared to the microtensile testing procedures.[24]

Although the preparation of multiple specimens from a single tooth provides a major advantage of μSBS testing, however this was not done within this study procedures in order to ensure the absence of bias within the study design parameters.

The results of this study found that combination between laser and acid etching revealed a statistically significant difference in shear bond strength values compared to other groups in the study. The highest μSBS value was recorded at the groups that received 3.5-watt average laser power output in combination with acid etching although the effect was not statistically significant compared to the group that received 3.5 watt Er,Cr: YSGG laser only. However, it was significant compared to other groups. This observation denotes that low power Er,Cr: YSGG laser had statistically enhanced the bond strength values to enamel. The lowest microshear bond strength values were recorded in the group that received 4.5-watt laser followed by acid etching. This is in agreement with Gulec et al (2018),[15] and Labunet et al (2022)[16] and can be interpreted according to Gulec et al (2018)[15] that laser energy absorbed by the water molecules. This causes their rapid evaporation and creates micro-explosions of the tooth particles during tissue ablation resulting in microscopic and macroscopic roughness.[25]

This in combination with the effect of conventional acid etching is responsible for yielding the statistically significant increase in μSBS values. This could also be further interpreted by the occurrence of a melting and recrystallization process that creates a porous surface similar to the type III pattern produced by phosphoric acid etching. The combination of both acid and laser etching – in fact – was found to increase the etching depth and causing an eventual greater penetration of acid.[16,25,26]

This study's findings; however, were in contradiction with various studies that do not recommend the use of Er,Cr: YSGG laser etching such as the studies conducted by Ustunkul et al (2016) [27], Shafiei et al (2018)[28] and Al Habdan et al (2021).[17]

The results obtained by Ustunkul et al (2013) can be interpreted by the fact that the study utilized a silorane system adhesive which relies on a cationic polymerization reaction that is completely different from the adhesive system used in this study which relies on free radical polymerization.[27]

Shafiei et al (2018) produced results that were in partial contradiction with the current study owing to the fact that the previous study utilized a Universal adhesive in self etch mode while the current study utilized a two-step etch and rinse adhesive system.[28]

The findings obtained by Al Habdan et al (2021)[17] were in contradiction with the current study. This can be explained by the use of only 4.5-watt average laser power output which is considered a high value for laser etching and in turn causes a loss of the unique etching pattern that usually appears after acid etching which prevents resin infiltration and consequentially reduces the bond strength values.[17,26,29]

The study findings as such recommend the limiting of the use of Er, Cr:YSGG Laser etching to the use of low to moderate level average output power to ensure the proper development of etching patterns that aid in the bonding process. It should be noted that an inherent risk of enamel damage due to the thermomechanical ablation taking place (especially with higher average power outputs of laser) which can lead to microcracks, and lower bond strength values as exhibited in this study with the use of the 4.5-Watt average laser power output.

CONCLUSION

Within the limitations of the present study, low average power output Er,Cr: YSGG laser has a beneficial effect in enhancing the bonding of etch and rinse adhesives to enamel.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Perdigão J, Araujo E, Ramos RQ, Gomes G, Pizzolotto L. Adhesive dentistry: Current concepts and clinical considerations. J Esthet Restor Den. 2021,33(51–68).
2. Piccioni Marv, Neves T, Kubo C, Saad JRC, Campos EA. Effects of the Er, Cr:YSGG laser irradiation on dentin bond strength. Laser Phys. 2016 Feb 1;26(2).
3. Üşümez S, Orhan M, Üşümez A. Laser etching of enamel for direct bonding with an Er,Cr:YSGG hydrokinetic laser system. Am J Orthod Dentofacial Orthop. 2002;122(6):649–56.
4. Yazici AR, Karaman E, Tuncer D, Berk G, Ertan A. Effect of an Er,Cr: YSGG laser preparation on dentin bond strength of a universal adhesive. J Adhes Sci Technol. 2016 Nov 16;30(22):2477–84.
5. Ansari ZJ, Fekrazad R, Feizi S, Younessian F, Kalhori KA, Gutknecht N. The effect of an Er,Cr:YSGG laser on the

micro-shear bond strength of composite to the enamel and dentin of human permanent teeth. Lasers Med Sci. 2012 Jul;27(4):761–5.

6. Hassoon S. Evaluation of shear bond strength of composite resin to dentin after etching with Er,Cr:YSGG Laser and conventional acid etch. Tikrit J Dent Sci. 2015 1.
7. Carvalho A, Reis AF, De Oliveira M, De Freitas PM, Aranha A, Eduardo CDP, et al. Bond strength of adhesive systems to Er,Cr: YSGG laser-irradiated dentin. Photomed Laser Surg. 2011; 29 (747–52).
8. Obeidi A, Liu PR, Ramp LC, Beck P, Gutknecht N. Acid-etch interval and shear bond strength of Er,Cr:YSGG laser-prepared enamel and dentin. Lasers Med Sci. 2010 May;25(3):363–9.
9. Valinhos Piccioni, Girotto AC, Saad JRC, de Campos EA. Influence of different surface protocols on dentin bond strength irradiated with Er,Cr:YSGG laser. Lasers Dent Sci. 2019 Mar 14;3(1):43–51.
10. El-Sahn N, Elkassas D, Al Quran FA. Bonding of machinable ceramics to laser ablated tooth substrates using different resin cements bonding effectiveness of all-in-one adhesives. Egy Dent J. 2013 July, 59(3): 3165-3175
11. Harnirattisai C, Roengrungreang P, Rangsisiripaiboon U, Senawongse P. Shear and micro-shear bond strengths of four self-etching adhesives measured immediately and 24 hours after application. Dent Mater J. 2012;31(5):779–87.
12. Coluzzi DJ. Fundamentals of dental lasers: Science and instruments. Dental Clinics of North America. 2004, 48: 751–70.
13. Obeidi A, Liu PR, Ramp LC, Beck P, Gutknecht N. Acid-etch interval and shear bond strength of Er,Cr:YSGG laser-prepared enamel and dentin. Lasers Med Sci. 2010 May;25(3):363–9.
14. Valinhos Piccioni MAR, Girotto AC, Saad JRC, de Campos EA. Influence of different surface protocols on dentin bond strength irradiated with Er,Cr:YSGG laser. Lasers Dent Sci. 2019 Mar 14;3(1):43–51.
15. Özer T, Başaran G, Berk N. Laser etching of enamel for orthodontic bonding. American Journal of Orthodontics and Dentofacial Orthopedics. 2008 Aug;134(2):193–7.
16. Labunet A, Tonea A, Kui A, Sava S. The

Use of Laser Energy for Etching Enamel Surfaces in Dentistry—A Scoping Review. 2022 MDPI Vol. 15.

17. Al Habdan AH, Al Rabiah R, al Busayes R. Shear bond strength of acid and laser conditioned enamel and dentine to composite resin restorations: An in vitro study. Clin Exp Dent Res. 2021 Jun 1;7(3):331–7.
18. 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. J Clin Med 2001; 19.
19. Malekipour MR, Shirani F, Tahmourespour S. The Effect of Cutting Efficacy of Diamond Burs on Micro-leakage of Class V Resin Composite Restorations Using Total Etch and Self Etch Adhesive Systems. J of Dent. 2010; 7.
20. Bahrami B, Askari N, Tielemans M, Heysselaer D, Lamard L, Peremans A, et al. Effect of low fluency dentin conditioning on tensile bond strength of composite bonded to Er:YAG laser-prepared dentin. Lasers Med Sci. 2011 Mar;26(2):187–91.
21. Breschi L, Mazzoni A, Ruggeri A, Cadenaro M, di Lenarda R, de Stefano Dorigo E. Dental adhesion review: Aging and stability of the bonded interface. Dental Materials., 2008: 24. 90–101.
22. Sebold M, André CB, Sahadi BO, Breschi L, Giannini M. Chronological history, and current advancements of dental adhesive systems development: a narrative review. J Adhes Sci Technol; 2021;35: 1941–67.
23. Placido E, Meira JBC, Lima RG, Muench A, Souza RM de, Ballester RY. Shear versus micro-shear bond strength test: A finite element stress analysis. Dental Materials. 2007 Sep;23(9):1086–92.
24. Roeder L, Pereira PNR, Yamamoto T, Ilie N, Armstrong S, Ferracane J. Spotlight on bond strength testing - Unraveling the complexities. Dental Materials. 2011;27: 1197–203.
25. Gulec L, Koshi F, Karakaya İ, Yanardag EC, Ulusoy N. Micro-shear bond strength of resin cements to Er,Cr:YSGG laser and/or acid etched enamel. Laser Phys. 2018 Oct 1;28(10).
26. Moslemi M, Nadalizadeh S, Mojahedi M, Javadi F, Iranparvar P. Effect of Enamel Pretreatment Using Er,Cr:YSGG Laser Irradiation on Micro-shear Bond Strength of a Self-etch Fissure Sealant. Photochem Photo biol. 2022
27. Ustunkol I, Yazici AR, Gorucu J, Dayangac B. Influence of laser etching on

enamel and dentin bond strength of Silorane System Adhesive. Lasers Med Sci. 2015 Feb 1;30(2):695–700.

28. Shafiei F, Sardarian A, Fekrazad R, Farjood A. Comparison of shear bond strength of orthodontic brackets bonded with a universal adhesive using different etching methods. Dental Press J Orthod. 2019 Jul 1;24(4):33. 1-33.
29. Golshah A, Bagheri N, Moslem Imani M, Safari-Faramani R. Effects of different types of laser etching versus phosphoric acid etching on shear bond strength of metal brackets to human enamel: A systematic review and meta-analysis of in vitro studies. Vol. 18, Inter Orthodont. 2020;18: 673–83.