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Research / Araştırma Makalesi

The Influence of Adhesive Systems on Microshear Bond Strength in Bur or Laser-Prepared Enamel

Adeziv Sistemlerin Lazer veya Frezle Hazırlanan Minede Mikrokesme Bağlanma Dayanımına Etkisi

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ABSTRACT

Background: The aim of this study was to assess the microshear bond strength(µSBS) of various adhesive systems on enamel surfaces prepared using either an Er, Cr:YSGG laser or a conventional diamond bur.

Methods: Twenty-eight caries-free human molars were longitudinally sectioned, resulting in 56 samples. Buccal or lingual surfaces were embedded in acrylic blocks. Enamel surfaces were prepared using either an Er, Cr: YSGG laser (Biolase Technologies, USA) or a traditional diamond bur (Diatech, Switzerland), referencing the midline of each tooth. Laser treatment was applied to the left side, while the right half underwent bur treatment. The samples were randomly separated into four groups(n=14): [G1] Optibond FL (Kerr, USA), a three-step etch-and-rinse adhesive; [G2] Clearfil SE Bond(Kuraray,Japan), a two-step self-etch adhesive; [G3]Prime&Bond Universal(Dentsply,USA),universal-adhesive/etch-and-rinse-mode; and [G4]Prime&Bond Universal(Dentsply,USA),universal-adhesive/self-etch-mode. Composite cylinders with a diameter of 0.8 mm (Harmonize, Kerr, USA) were affixed to the center of both the laser-prepared and bur-prepared regions of all specimens. The adhesive interface of one randomly chosen representative from each group was analyzed using a Scanning Electron Microscope(SEM). The remaining samples were subjected to µSBS testing. Data were analyzed statistically using Two-Way ANOVA($p<0.05$).

Results: Upon comparing the µSBS data for each adhesive system using both laser and bur preparation processes, no statistically significant differences were noted among the groups($p>0.05$). Regardless of the preparation modalities, the adhesive systems did not exhibit any statistically significant differences($p>0.05$). Furthermore, the correlation between various adhesive systems and preparation techniques did not result in statistically significant variations in µSBS values($p>0.05$).

Conclusion: The measured µSBS values of the adhesive systems examined on enamel surfaces prepared using either an Er, Cr:YSGG laser or a diamond bur showed similarity.

Keywords: Laser preparation, Microshear bond strength, Scanning electron microscopy, Universal adhesive.

ÖZ

Amaç: Bu çalışmanın amacı, Er, Cr: YSGG lazer veya geleneksel elmas frez ile prepare edilen mineye farklı adeziv sistemlerin mikro-kesme bağlanma dayanıklılığının (µKBD) değerlendirilmesidir.

Gereç ve Yöntemler: 28 adet çürüksüz insan molar dişi uzunlamasına kesilerek 56 örnek elde edildi. Bu dişlerin bukkal veya lingual yüzeyleri daha sonra akrilik blokların içine gömüldü. Mine yüzeylerinin preparasyonunda Er, Cr: YSGG lazer(Biolase Technologies, ABD) veya geleneksel elmas frez (Diatech, İsviçre) kullanılarak prepare edildi. Örnekler rastgele dört gruba ayrıldı (n=14): [G1] Üç aşamalı etch-and-rinse adeziv (Optibond FL, Kerr, ABD), [G2] İki aşamalı self-etch adeziv (Clearfil SE Bond, Kuraray, Japonya), [G3] Universal adeziv/Etch-and-rinse modu (Prime&Bond Universal, Dentsply, ABD) ve [G4] Universal-adeziv/Self-etch modu (Prime&Bond Universal, Dentsply, ABD). Örneklerde lazerle ve frezle hazırlanan yüzeylerin merkezine 0,8 mm çapında kompozit silindirler (Harmonize, Kerr, ABD) bağlandı. Her gruptan rastgele seçilen bir örneğin adeziv ara yüzü, Taramalı Elektron Mikroskobu (SEM) altında incelendi. Örneklerin geri kalanı µKBD testine tabi tutuldu. Veriler, İki Yönlü ANOVA kullanılarak değerlendirildi ($p<0.05$).

Bulgular: Her bir adeziv sistemin µKBD verileri, lazerle ve frezle prepare etme yöntemleri açısından karşılaştırıldığında gruplar arasında anlamlı bir farklılık bulunmadı ($p>0.05$). Preparasyon metotlarından bağımsız olarak, adeziv sistemler arasında istatistiksel olarak anlamlı bir fark gözlenmedi ($p>0.05$). Farklı adeziv sistemlerinin farklı preparasyon yöntemleriyle etkileşimi, µKBD değerlerinde önemli bir fark oluşturmadı ($p>0.05$).

Sonuç: Er, Cr: YSGG lazer veya elmas frez ile prepare edilen mine yüzeylerine incelenen adeziv sistemler benzer µKBD değerleri göstermiştir.

Anahtar Kelimeler: Lazer Preparasyonu, Mikro Kesme Bağlanma Dayanıklılığı, Taramalı Elektron Mikroskobu, Üniversal Adeziv

INTRODUCTION

In restorative dentistry, the increasing demand for methods that are less invasive and more esthetically pleasing has led to the development of innovative tools and materials, thereby enhancing patients' comfort, and improving the overall standard of dental care. The preparation method is a crucial factor directly linked to patients' acceptance and the longevity of restorations.[1] Hence, new high-technology instruments, such as lasers, have been suggested as alternative modalities to conventional approaches. Among the many types of lasers, erbium lasers have been used to cut dental hard tissues safely and effectively since their approval by the FDA in 1997.[2]

Er,Cr:YSGG lasers (2780 nm) can efficiently prepare tooth tissues without causing thermal damage due to their high absorption of wavelength in both hydroxyapatite and water.[3] Following tooth preparation with Er,Cr:YSGG lasers, an irregular, rough, and clean surface topography is observed, with no smear layer present.[4] In addition to surface characteristics that may contribute to satisfactory bonding strength, utilizing Er,Cr:YSGG lasers in tooth preparation offers distinct advantages compared to traditional handpieces. These include reduced vibration, limited or no requirement for local anesthesia, and antibacterial properties.[5]

One of the main goals of modern dentistry is to restore lost tooth tissue esthetically while also regaining function using reliable restorative materials. Today, with the improvement of resin composites and increasing patient demand for esthetics, the use of these materials in daily dental practice is expanding. Although adhesive systems accompanying composite resins have significantly improved in recent

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years, the resin-tooth interface remains a critical area for the success of tooth-colored restorations.[6] Etch-and-rinse systems have been used to achieve optimal bonding to tooth tissues, especially enamel, and are still considered the gold standard. In the last decade, the use of self-etch adhesives has gained popularity due to their ease of application and a decreased incidence of postoperative sensitivity when compared to etch-and-rinse adhesives.[7] Recently, universal adhesives or multimode adhesives have been introduced as the latest addition to the one-step self-etch adhesive family.[8, 9] These adhesives can be used with total or selective acid etching or in self-etch mode, making them suitable for every restoration procedure.[10]

It is known that laser irradiation can enhance the bond strength to enamel by increasing the mineral content, removing the smear layer, and creating an irregular surface ideal for bonding.[11, 12] Additionally, some studies have shown that the bond strength between tooth tissues and resin composites might increase due to the enhancement in micromechanical retention.[13, 14] However, there is limited data regarding the interaction between universal adhesives and laser-prepared enamel. The objective of the present study was to assess the microshear bond strength (μSBS) of several adhesive procedures on enamel surfaces produced using either conventional bur techniques or the Er, Cr: YSGG laser. The null hypotheses tested were:

1) No difference would exist between the μSBS of the conventional bur preparation and the Er, Cr: YSGG laser preparation methods.

2) No variation would be found in the μSBS across the adhesive systems being tested.

MATERIAL AND METHODS

Approval to conduct the study ethically was granted by the University's Local Ethics Committee (2021/13- 06).

Sample Size Calculation

The calculation of the sample size was performed using G*Power, version 3.1 (Heinrich-Heine Dusseldorf University, Dusseldorf, Germany), with 80% power, a 95% confidence interval, and an effect size of 0.32. For this study, a minimum of 14 samples per group was required for the sample size.[15]

Sample Preparation

The flow chart of the study is presented in **Figure 1**. Twenty-eight freshly extracted human molar teeth without caries were used. Any soft tissue and debris adhering to the tooth surfaces were removed using manual instruments. The teeth were disinfected by immersing them in a 0.5% chloramine T solution at 4ºC for a week. Afterward, the samples were kept in distilled water until they were required for further use. Subsequently, the teeth were examined under a stereomicroscope for any signs of cracks in the enamel, caries, or restorations.

The teeth were then divided mesiodistally under water cooling with a double-sided diamond disc (Finzler, Schrock & Kimmel GmbH, Germany), obtaining two sections (lingual and buccal), and both sections were mounted on self-curing acrylic resin with their buccal or lingual surfaces facing upwards. Once embedded, the teeth were ground using 320-grit carbide polishing papers, with the process carried out under water cooling (n=56).

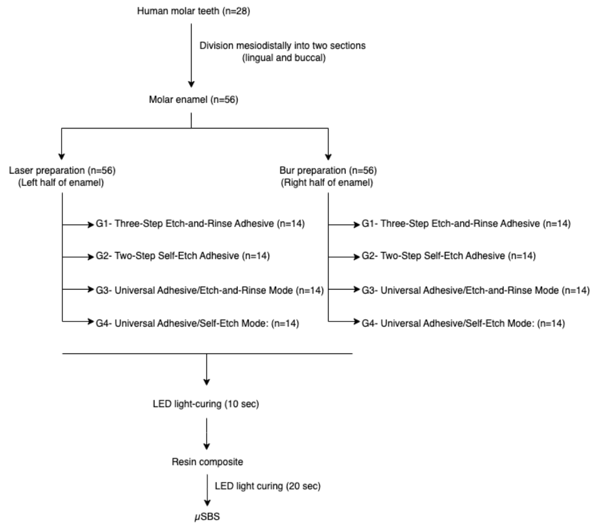


Figure 1. Flow chart of the study

Tooth preparation

Using the midline of each tooth as a reference, the left halves of the samples were prepared with an Er, Cr: YSGG laser, while the right halves were prepared using a conventional diamond bur. In the laser group, the samples were prepared using an Er, Cr: YSGG laser (Biolase Millennium II; Biolase Technologies, San Clemente, CA, USA), employing a Waterlase MD TURBO handpiece. This was combined with an MX5 fiber tip in focus mode, positioned at a distance of 3–5 mm from the target tissue, and produced a spot diameter of 500 μm.[1] The preparations for the laser group were conducted in a sweeping motion, adhering to the manufacturer's specifications, with settings at 5 W, 20 Hz, 140 μs, 60% water, and 70% air.[1] In the bur group, a cylindrical diamond fissure bur with standard grit size (Diatech, Heerbrugg, Switzerland) was used, connected to a high-speed handpiece, and cooled with water. After every 5 preparations, the bur was exchanged for a new one, each possessing a head diameter of 1 mm and a head length of 6 mm **(Figure 2).**

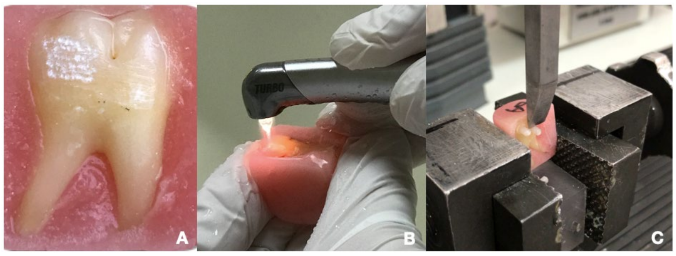


Figure 2. A) Image of the enamel surface prepared with the Er, Cr: YSGG laser and bur, B) Preparation of the enamel surface with the Er, Cr: YSGG laser, C) Application of the μSBS test.

Adhesive Applications

Table 1 illustrates the materials utilized in this study. The laser- and bur-prepared samples were then subdivided into four groups, and one of the following adhesives was applied to both laser- and bur-prepared halves as follows:

Table 1. Materials used in the study.

MATERIAL	MANUFACTURER	COMPOSITION
CLEARFIL SE BOND	Kuraray Medical Inc., Tokyo, Japan	Primer: 10-MDP, HEMA, hydrophilic dimethacrylate, di-camphorquinone, N,N-diethanol-p-toluidine, water. Bond: 10-MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, dicamphorquinone, N,N-diethanol-ptoluidine, silanated colloidal silica
PRIME&BOND UNIVERSAI	Dentsply Sirona, York, PA, USA	Mono-, Di- And Trimethacrylate Resins, Penta, Diketone, Stabilizers, Organic Phosphine Oxide, Cetylamine Hydrofluoride, Acetone, Water, And Selfcure Activator
OPTIBOND FL	Kerr Corp., Orange, CA, USA	Etching: 37.5% phosphoric acid. Primer: HEMA, 2-[2-(methacryloyloxy) ethoxycarbonyl] benzoic acid, GPDM, ethanol, water, photoinitiator Bond: HEMA, 3-trimethoxysilylpropyl methacrylate, 2-hydroxy-1,3-propanediyl bismethacrylate, alkali fluorosilicates (Na), photoinitiator.
HARMONIZE	Kerr Corp., Orange, CA, USA	2,2'-ethylenedioxydiethyl dimethacrylate, 3-trimethoxysilylpropyl methacrylate, Poly(oxy-1,2 ethanediyl), α,α'-[(1- methylethylidene)di-4,1-phenylene]bis[ω-[(2- methyl-1-oxo-2-propen-1-yl)oxy].

Abbreviations: MDP, Methacryloyloxydecyl dihydrogen phosphate; HEMA, Hydroxyethyl methacrylate; Bis-GMA, Bisphenol A-Glycidyl Dimethacrylate; PENTA, dipentaerythritol penta acrylate monophosphate; GPDM, glycerol phosphate dimethacrylate.

G1- Three-Step Etch-and-Rinse Adhesive: The enamel surfaces were etched with an etchant containing orthophosphoric acid at a ratio of 37.5% (Gel Etchant, Kerr Corp., Orange, CA, USA) for 15 s, rinsed with water for 15 s, and air-dried. Optibond FL primer (Kerr Corp., Orange, CA, USA) was administered to the enamel surfaces using a slight scrubbing motion for 15 s and air-dried for 5 s. The Optibond FL adhesive (Kerr Corp., Orange, CA, USA) was gently spread using slight scrubbing motions for 15 s and then thinned with a gentle burst of air. A cordless curing light with an output of over 1200mW/cm^2 (Henry Schein, HS-LED Light 1200, NY, USA) was used to cure the bonding agent for a duration of 10 s in standard curing mode.

G2- Two-Step Self-Etch Adhesive: Clearfil SE primer (Kuraray, Tokyo, Japan) was applied to the enamel surfaces using a disposable applicator brush and left for 20 s. After 20 s, the evaporation of volatile ingredients was ensured by a mild air blow. Once the Clearfil SE bond (Kuraray, Tokyo, Japan) was applied to the surfaces, a uniform bond layer was achieved by directing a gentle stream of air over it. The bond was then cured with a light-curing device for a period of 10 s.

G3- Universal Adhesive/Etch-and-Rinse Mode: The enamel surfaces were conditioned using 34% phosphoric acid (Caulk tooth conditioner gel, Dentsply Sirona, York, PA, USA) for 15 s, rinsed for 15 s, and air-dried. Prime&Bond Universal (Dentsply Sirona, York, PA, USA) was applied to the surfaces with a rubbing motion for 20 s using a disposable brush. The excess solvent was removed by a gentle air stream for 5 s, and the adhesive layer was light-cured using a curing light.

G4- Universal Adhesive/Self-Etch Mode: Prime&Bond Universal was applied to the surfaces with a rubbing motion for 20 s using a disposable brush. The adhesive layer was then air-dried to remove the excess solvent for 5 s and light-cured using a curing light.

Specimen preparation and μSBS testing

Cylindrical translucent molds (Tygon tubing, Akron, OH, USA) with a height of 2 mm and an inner diameter of 0.8 mm were prepared.[16] The molds were filled with composite resin (Harmonize, Kerr Corp., Orange, CA, USA) using a condenser and then placed on both laser- and bur-prepared sides of all specimens. After positioning, the molds were light cured from the top surface using an LED light curing device for 20 s. All samples were immersed in water at 37˚C for 24 hours. Representative samples from each group had their adhesive interfaces inspected under a Scanning Electron Microscope (SEM) (Tescan Gaia 3, Brno, Czech Republic) at 2000x magnification. Following the removal of the tubes using a scalpel, the μSBS testing (LR50K, Lloyd Instruments Ltd., Fareham, Hants, UK) was carried out. The shear load was administered at the adhesive interface, and it was applied at a crosshead speed of 1mm/s until failure was observed. The bond strength was quantified in megapascals (MPa) by calculating the ratio between the fracture load and the bonding area.[17] The failure types of the samples were analyzed using a stereomicroscope at a magnification of 10x. Each failure was classified as adhesive (at the adhesive-enamel interface), cohesive (within the composite resin or enamel), or mixed (involving both adhesive and cohesive characteristics).

The data underwent evaluation through a Two-Way Analysis of Variance (ANOVA) with a significance level set at $p<0.05$ (IBM SPSS ver. 23.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Pre-test failures were observed in one sample each in the Laser-G1, Bur-G1, Laser-G2, Bur-G2, and Laser-G4 groups, and in two samples in the Bur-G4 group. There was no discernible difference among the groups when comparing the μSBS data of each adhesive system in terms of the laser and bur preparation processes ($p>0.05$). However, all groups except G4 showed higher μSBS values in bur-prepared samples, whereas in G4, laser-prepared samples exhibited higher μSBS ($p>0.05$). Regardless of the preparation methods, no statistically meaningful variations were seen between the adhesive systems ($p>0.05$). However, the greatest μSBS values were found in G2, followed by G3, G1, and G4, respectively, in bur-prepared samples. In laser-prepared samples, the highest μSBS values were seen in G3, followed by G2, G1, and G4, respectively. The interaction of different adhesive systems with different preparation methods did not result in a significant difference in μSBS values ($p>0.05$) (**Table 2**).

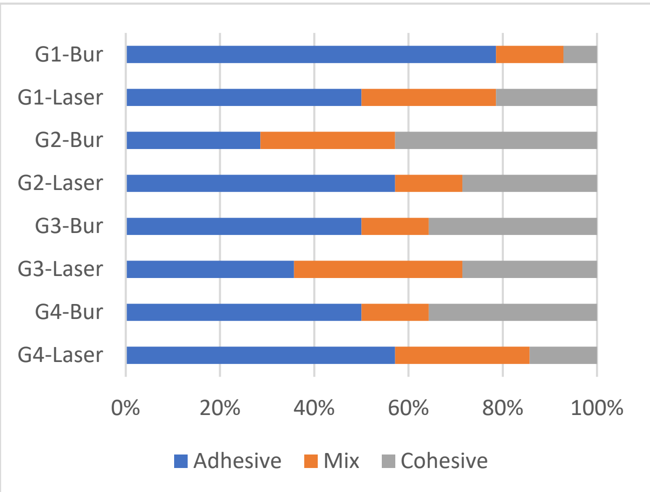
Table 2. Mean and standart deviations μSBS values (MPa) of all groups.

	BUR (MEAN μSBS±SD)	LASER (MEAN μSBS±SD)	P
G1 (ETCH-AND-RINSE)	14.29 ± 6.37 ^{Aa}	13.57 ± 5.81 ^{Ba}	0.883
G2 (SELF-ETCH)	15.86 ± 7.80 ^{Ab}	14.68 ± 5.30 ^{Bb}	0.904
G3 (UNIVERSAL ADHESIVE/ETCH-AND-RINSE MODE)	15.22 ± 8.01 ^{Ac}	15.10 ± 7.03 ^{Bc}	1.000
G4 (UNIVERSAL ADHESIVE/SELF ETCH MODE)	10.59 ± 6.69 ^{Ad}	12.57± 4.83 ^{Bd}	0.203

Two-Way ANOVA **p<0.05*
Different lowercase in the same row indicates significant difference.
Different capital letters within the same column indicates significant differences.

According to the failure type analysis, adhesive failure was predominantly noted in the G1-bur group, while cohesive failures were mostly identified in the G2-bur group ($p<0.05$). In the laser groups, adhesive failures were predominant, except in G3-Laser, which revealed adhesive and mixed failures equally ($p>0.05$) (**Table 3**).

Table 3. Distribution of the failure modes



SEM evaluations showed that the G1-Bur group exhibited an intact adhesive interface without any gap formation between the restoration and the prepared surface, whereas the G1-laser group showed significant gap formation between the surface and the restoration. Both laser- and bur-prepared samples in G2 and G3 exhibited an intact adhesive interface without any gaps between the prepared surface and the material. However, crack lines were observed within the enamel tissue in laser-prepared samples. In G4, bur-prepared specimens showed continuous integrity between the prepared surface and restorative material, whereas laser-prepared samples showed distinct spacing between the restoration and prepared surface (Figure 3).

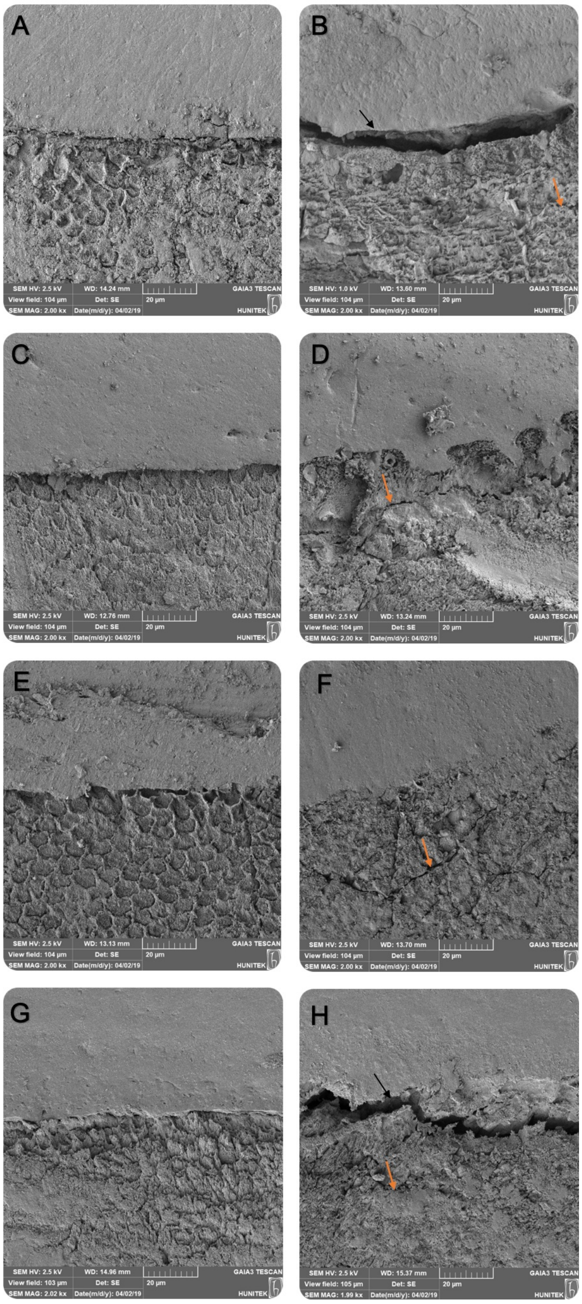


Figure 3. SEM images of laser- and bur-prepared enamel and the interface with different adhesive systems. Subsurface enamel cracks were observed in all laser-prepared groups (orange arrows). In groups G1 and G4, distinct spacing between the enamel and adhesive was evident (black arrows). In all bur-prepared groups, a typical honeycomb pattern created by phosphoric acid etching was observed.

A: G1 (Etch-and-rinse)-Bur, B: G1 (Etch-and-rinse)-Laser, C: G2 (Self-etch)-Bur, D: G2 (Self-etch)-Laser, E: G3 (Universal Adhesive/Etch-and-rinse mode)-Bur, F: G3 (Universal adhesive/Etch-and-rinse mode)-Laser, G: G4 (Universal adhesive/Self-etch mode)-Bur, H: G4 (Universal adhesive/Self-etch mode)-Laser.

DISCUSSION

The success of a composite resin restoration hinges on the bonding strength it achieves with the tooth's hard tissues. The stresses that may result in failure at the restoration interface are mainly shear and tensile stresses caused by horizontal or vertical forces generated during the mastication process.[18] Therefore, the ability to resist shear stresses has a vital impact on the retention of an adhesive restoration.[18] The μSBS test can be defined as a SBS test with a bonded cross-sectional area of 1 mm^2 or less.[19] The μSBS test has recently become popular for obtaining multiple specimens per tooth compared to the macroshear bond strength test.[20] Based on these findings, the current study sought to determine the μSBS of a universal adhesive in comparison to a gold standard two-step self-etch adhesive system and a gold standard three-step etch-and-rinse adhesive to determine the best adhesive strategy for laser-prepared enamel.

The use of lasers in operative dentistry has been widely researched since their introduction to dental practice, owing to their ability to reduce sensitivity and preserve sound tissues.[21-23] Based on the authors' knowledge, there is not much data available regarding the μSBS of various adhesives to laser-prepared enamel. Likewise, the performance of universal adhesives on laser-prepared enamel is partially unknown, leading to the need for further studies on this subject. Therefore, in this study, the μSBS of different adhesive systems used with different strategies on enamel prepared conventionally or with a laser was evaluated. In previous studies, the laser preparation method was shown to create longitudinal exposure of enamel rods and microcracks throughout the laser-irradiated enamel area, which was interpreted as a possible cause for weak bonding.[21, 24] In an *in vitro* study,[25] it was noted that the restorations prepared with a bur demonstrated enhanced marginal adaptations when contrasted with those prepared using laser techniques. In a study carried out by Cardoso et al.,[21] the impact of the Er,Cr:YSGG laser on the microtensile bond strength of four distinct adhesives to enamel was examined. Their findings revealed that all the adhesives, except for Clearfill S3, demonstrated reduced bond strengths when utilized on enamel treated with the laser.[21] According to Anton et al.,[26] the group prepared with a bur using the selective-etch technique demonstrated superior marginal adaptation compared to both the self-etch group prepared with an Er:YAG laser and the selective-etch group prepared with a CO2 laser. However, another study[1] reported that different preparation techniques did not influence the durability of restorations and achieved similar clinical success. Heyder et al.[27] found that the optimal marginal integrity and minimal marginal discoloration in fillings were achieved when laser preparation was supplemented with additional acid conditioning. In the present investigation, it was shown that there were no statistically meaningful disparities among the μSBS values of the specimens prepared either using Er,Cr:YSGG laser or conventional diamond bur. Therefore, the first null hypothesis had to be accepted. Some of the adhesives used in Cardoso et al.'s[21] study were also used in the present study (Optibond FL and Clearfil SE), and although they reported significantly lower bond strength values with laser-prepared groups, no significant differences were observed in this study. Shakya et al.[28] demonstrated that utilizing an Er:YAG laser for cavity preparation leads to diminished SBS to adhesive restorative materials compared to the usage of conventional burs. Similarly, Dunn et al.[29] also demonstrated in their study that laser-prepared specimens presented lower SBS values than bur-prepared specimens. In this study, although the differences between the preparation methods were not significant, bur-prepared groups (except for the universal adhesive used in self-etch mode) demonstrated greater mean μSBS values. Therefore, it may be speculated that, with larger groups, a significant difference might have been observed between bur- and laser-prepared samples.

In a study conducted *in vitro* comparing the SBS of enamel prepared with either a bur or Er,Cr:YSGG laser, it was found that the laser-prepared and acid-etched samples exhibited higher SBS values than the bur-prepared and acid-etched samples; however, the difference was not significant.[30] These findings align with the results of the present study, where no statistically significant differences were observed between the preparation methods in terms of μSBS, although the bur-prepared groups did show higher μSBS values. In the present study, a power output of 5 W was employed for the preparation process, whereas the aforementioned study utilized a power output of 4 W. This difference in power output could lead to distinct variations in tooth tissues. Furthermore, another study reported that laser preparation with lower power outputs, when combined with higher frequencies, resulted in higher immediate enamel SBS.[31] This finding may help to explain the differences between the outcomes of the two studies.

In a previous *in vitro* study, it was noted that the combination of the acid etching procedure with either laser or bur preparation methods did not yield a statistically significant change in SBS values[32]. The findings align with the outcomes of this research. In the current investigation, while the observed difference was not statistically significant, it was noted that laser-prepared samples exhibited reduced bond strength in groups G1, G2, and G3; however, in group G4, the laser-prepared samples demonstrated stronger bond strength. In another *in vitro* study, it was similarly observed that using an Er:YAG laser for irradiation could potentially increase the bond strength between an all-in-one adhesive and enamel.[33] The etch-and-rinse technique is often considered the most effective method for achieving optimal bond strength to enamel.[34] Previous research has suggested that laser irradiation could be a viable alternative to the traditional acid etching technique.[35, 36] Within the framework of the current study, the utilization of laser preparation in conjunction with a universal adhesive applied in self-etch mode appears to have positively influenced the enamel bond strength. This could account for the higher mean μSBS values observed with the laser-prepared samples in Group 4.

It is known that achieving an adequate bond strength requires the elimination of the smear layer or the preference for adhesives capable of penetrating beyond it. Self-etch systems can include various acidic primers that modify, solubilize, or disrupt the smear layer, thereby obtaining a clinically acceptable bond strength.[37] However, mild self-etch adhesives can benefit from the absence of the smear layer due to their weak acidity.[21] Cardoso et al.[21] reported that Clearfill S3, a universal adhesive with a similar combination to Prime&Bond Universal, exhibits higher SBS when used with the laser preparation method, in line with the findings of the current research. Similarly, another mild self-etch adhesive, Clearfil SE bond, exhibited lower SBS values with the laser preparation method, also in line with the present study. The reason for this dilemma might be that Clearfil SE is a two-step self-etch adhesive, and the additional primer step might have had an adverse effect on bonding to laser-irradiated enamel.

Ansari et al.[38] revealed that re-etching with phosphoric acid following Er,Cr:YSGG laser preparation is advisable to achieve a sufficient bond strength. Conversely, Türkmen et al.[39] indicated that the Er,Cr:YSGG laser provides superior surface etching than phosphoric acid. In this study, phosphoric acid etching was conducted using etch-and-rinse modes to standardize the conditions, except for the preparation methods.

In the present study, regardless of the preparation methods, no substantial variations were seen among the μSBS of the different adhesives and the application modes. Accordingly, the second null hypothesis was also confirmed. Despite the insignificant difference, the highest mean μSBS values were observed in G2, followed by G3, G1, and G4, respectively, in the bur-prepared groups, and in the laser-prepared groups, the greatest mean μSBS values were noted in G3, followed by G2, G1, and G4, respectively.

Universal adhesives have been shown to exhibit suboptimal performance on enamel when utilized in self-etch mode, leading to inferior marginal adaptation and discoloration.[40] Thus, they are recommended to be used in selective etch mode on enamel.[41] Accordingly, in the present study, both laser- and bur-prepared groups showed lower bond strength values with the application of the universal adhesive in self-etch mode. Peumans et al.[34] revealed in their systematic review that two-step self-etch and three-step etch-and-rinse adhesives both promote dependable clinical performances, whereas one-step self-etch adhesives demonstrate insufficient clinical performances. In this study, two-step self-etch, three-step etch-and-rinse, and universal adhesive performed with etch-and-rinse mode all showed similar μSBS values.

Earlier studies have indicated that employing an Er,Cr:YSGG laser for enamel preparation results in a smear-free and retentive surface, which is favorable for bonding.[32, 42] AlQussie et al.[43] observed that while higher gap formation occurred on the dentin surface prepared with a laser, there was no meaningful distinction in gap formation between laser and bur preparation on the enamel surface. However, Martinez-Insua et al.[44] stated that laser preparation on enamel negatively impacted SBS, creating "extensive subsurface fissuring". They observed deep vertical and shallow horizontal fissures from the surface in SEM evaluations, akin to the recent study. In accordance with the present study's findings, micro-crack formation on the laser-irradiated tooth tissues has been broadly reported in the literature.[21, 24, 45-48]

The universal adhesive utilized in the current study, Prime&Bond Universal, contains MDP and Penta, and it also incorporates a novel technology known as "Active Guard". Allegedly, this technology reinforces the adhesive interface against water contamination while imparting low viscosity characteristics to the adhesive, allowing it to form a thin film layer. Due to the adhesive's low viscosity, the authors hypothesized that it would achieve a more durable bond by penetrating deeply into the enamel defects created by the laser. Consequently, in this research, when this adhesive was utilized in the etch-and-rinse mode on laser-prepared samples, it exhibited the highest mean μSBS values among all the adhesive systems. Similarly, when used in self-etch mode, laser-prepared samples demonstrated higher μSBS values than bur-prepared samples. While these findings might be beneficial, additional universal adhesive systems with varying pH values and compositions should be evaluated to gain a more accurate understanding of the most advantageous adhesive system to be used with laser preparation methods.

Although laser preparation offers benefits, it is crucial to analyze the impact of the parameters used and their effects on the tissue, as well as the interaction between the tissue and the material. Although no statistically significant variations were detected in the present study, laser-prepared samples in most of the groups exhibited lower μSBS values, indicating the necessity for additional investigations with increased sample sizes to fully comprehend the interaction between laser-irradiated enamel and different adhesives.

This study has certain limitations, including a limited number of specimens and adhesives examined, along with the lack of utilization of diverse parameters for laser preparation, which should be acknowledged when interpreting the findings. Additionally, no aging procedures were performed in this study, so the results provide information about the immediate performance of the laser on the enamel surface rather than long-term effects. Future studies should consider incorporating aging processes to evaluate the durability and long-term performance of adhesive systems on bur- and laser-prepared enamel. It may also be advisable to evaluate numerous adhesives with diverse chemical properties and compositions on tooth tissues prepared with various laser parameters, employing a range of testing methodologies.

CONCLUSION

In conclusion, all the tested adhesives showed similar μSBS values regardless of the preparation methods, and both preparation methods presented similar μSBS values irrespective of the adhesive resins used. However, it appears that laser preparation damages the enamel tissue, creating subsurface cracks, which might lead to decreased bond strength.

Clinical Significance: All adhesive systems and strategies exhibited similar bond strength values in laser- and bur-prepared enamel surfaces. It might be beneficial to use the laser preparation method, especially in circumstances where universal adhesives must be used in self-etch mode on enamel.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu makale, Hacettepe Üniversitesi Diş Hekimliği Fakültesi 1. Uluslararası Diş Hekimliği Öğrenci Kongresi'nde sözlü olarak sunulan ancak tam metni yayımlanmayan "Er, Cr: YSGG Lazer veya Frezle Prepare Edilen Mineye Mikro-Kesme Bağlanma Dayanıklılığı" adlı tebliğin içeriği geliştirilerek ve kısmen değiştirilerek üretilmiş hâlidir.

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

This article is the version of the presentation named "Micro-Shear Bond Strength of Different Adhesive Systems on Enamel Prepared with Er, Cr: YSGG Laser or Conventional Diamond Bur", which was presented orally at the Hacettepe University Faculty of Dentistry 1st International Dentistry Student Congress, but whose full text was not published, by improving and partially changing the content.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: EM (%10), MNP (%10), AÖ (%10), EE (%70)
Veri Toplanması | Data Acquisition: EM (%20), MNP (%20), AÖ (%50), EE (%10)
Veri Analizi | Data Analysis: EM (%30), MNP (%20), AÖ (%20), EE (%30)
Makalenin Yazımı | Writing up: EM (%70), MNP (%10), AÖ (%10), EE (%10)
Makale Gönderimi ve Revizyonu | Submission and Revision: EM (%10), MNP (%70), AÖ (%5), EE (%15)

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