# EVALUATION OF MICROSHEAR BOND STRENGTH OF GLASS CERAMIC VENEERS BONDED TO FLUOROSED TEETH AFTER ER-YAG LASER ENAMEL PRETREATMENT

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## ABSTRACT

**BACKGROUND:** The bonding materials directly affect the clinical success of esthetic indirect restoration on fluorosed enamel. The literature has thoroughly discussed an innovative surface treatment method that varied from the traditional techniques. Yet there is lack of knowledge regarding the erbium-doped yttrium aluminum garnet (Er-YAG) laser effect on the enamel etching before cementation of glass ceramic veneers on fluorosed teeth.
**OBJECTIVES:** Compare microshear bond strengths (μSBS) of glass ceramic veneers bonded to fluorosed teeth after Er:YAG laser and 37% phosphoric acid enamel etching.
**MATERIALS AND METHODS:** Thirty-six CAD lithium disilicate ceramic microdiscs with 1-mm height and 1-mm diameter were cemented to two main groups: fluorosed group (test group n = 18) and non-fluorosed group (control group n = 18). Each group was subdivided into two subgroups (n = 9) according to surface modification method: either Er:YAG laser or 37% phosphoric acid. A universal bonding agent and a resin cement were used for microdiscs bonding. After thermocycling, the microdiscs were subjected to (μSBS) tests at a crosshead speed of 0.5 mm/min until failure. The Kruskal-Wallis test was performed to compare (μSBS) between groups.
**RESULTS:** There was no significant difference in microshear bond strength mean values between groups treated with the Er:YAG laser or 37% phosphoric acid.
**CONCLUSIONS:** The glass ceramic veneers cemented on laser modified fluorosed enamel surface by Er:YAG show higher mean μSBS values than 37% phosphoric acid.
**KEYWORDS:** Er:YAG; Enamel etching; Fluorosed teeth; ceramic veneers; Microshear bond strength.
**RUNNING TITLE:** Bond strength of ceramic veneers to fluorosed teeth.

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## INTRODUCTION

Dental fluorosis is known as a deformity in the tooth structure that results in an external acid-resistant hyper-mineralized layer and internal hypo-mineralization because of the alteration in ameloblasts during the mineralization stage. The hypo-mineralized layer is characterized by its porosity with evenly distributed hypo-mineralization throughout the whole layer (1). Although fluoride has been shown to be anti-cariogenic, ingesting more than 0.5-1.5 mg/l during tooth development may negatively impact the tooth's structure, composition, and appearance as changes in tooth color interfere with a perfect smile (2).

Thylstrup and Fejerskov developed the Thylstrup and Fejerskov index (TFI), which categorizes dental fluorosis into three severities: mild, moderate, and severe (3). In case of mild fluorosis, the tooth's appearance is characterized by white flecking or spotting enamel, or white opacities on the enamel surface; in moderate fluorosis, the enamel has a brown discoloration with scattered white opaque lesions with or without pitting of brownish enamel; and in severe fluorosis, the enamel becomes more susceptible to wear and fracture. Thus, there is a need for a prosthetic intervention. Dental fluorosis becomes an aesthetic issue, especially in anterior teeth (4). Treating such a condition improves the patient's self-esteem as well as its appearance and function (5). Numerous treatment options for fluorosis have been studied in the literature, including composite resins and ceramic veneers (6). However ceramic veneers are the best treatment option for moderate to severe fluorosis with a TFI equal to 5-9 that represents a high survival rate of 98% (5,7,8). Since fluorosed teeth might require restoration, a controversy has been raised over the significance of the bond strength of ceramic veneers to fluorosed enamel (9-11).

Regarding the histopathology of the fluorosed enamel, the bonding mechanism depends on the surface treatment procedure and the type of bonding agent (12,13). Surface treatment options have been controversial in the literature, so there is a constant need to find one that increases bond strength, especially when dealing with acid resistant layer in such fluorosed enamel (14). Shear and microshear bond strength tests were used to evaluate the bond formed between tooth substrate and restorative material (15,16). To improve the shear bond strength of the dental restorative material, either micromechanical or chemical preparation should be performed. The traditional method of enamel surface conditioning involves etching with 37% phosphoric acid in different application periods to enhance the surface roughness and, consequently, increase the shear bond strength (17,18). Literature suggests that fluorosed teeth with 37% phosphoric acid may have lower μSBS than non-fluorosed teeth (19,20), and may need more acid etching time to raise the bond strength (21). Recently, lasers have been introduced into the dental field as a revolutionary treatment method with many advantages, such as minimizing swelling, bleeding, and pain. It is used in minimally invasive dentistry; it works on both enamel and dentin, altering the prismatic configuration of enamel (22-24). The Er:YAG wavelength works on different depths of enamel depending on the energy, frequency, and time of exposure used (25-28). Using Er:YAG causes more surface roughness than etching with 37% phosphoric acid (27). Meanwhile, a study has concluded that Er:YAG laser-treated enamel developed subsurface fissuring, thus impairing the bonding ability of the used adhesive system (28). A study on the proportion of microleakage using Er:YAG and conventional acid etch and bur before sealant resin application on teeth with fluorosis has shown equal results between both methods (29). Studies were done over many areas in Egypt, found that people among the population had dental fluorosis ranging from mild to severe (30,31). Lack of data on bond strength of glass ceramic veneers bonded to fluorosed enamel requires further research. Hence, this current study aims to assess the micro-shear bond strength (μSBS) of glass ceramic veneers bonded to a fluorosed enamel surface after Er:YAG laser surface modification.

The null hypothesis stated that the μSBS of bonded glass ceramic veneer to fluorosed enamel after Er:YAG laser surface modification would be similar to the usage of 37% phosphoric acid etchant.

## MATERIALS AND METHODS

A sample size of 36 was calculated based on a study by Farag et al (32), by using statistical software (G*Power v3.1.9.2; Heinrich-Heine-Universität Düsseldorf), where α value was set at 0.05 and the power was set at 80%. The minimum sample size was determined to be 8 per group, which increased to 9 per group to accommodate laboratory processing errors. Four groups were examined in this parallel controlled in-vitro study to measure μSBS using statistical software (IBM SPSS, version 23; Armonk).

**1. Collection and grouping of experimental teeth**

Twelve anterior teeth previously extracted due to periodontal disease were randomly collected (33) from general hospitals in fluorosis-endemic areas of Egypt, six of them have fluorosis: group (F) fluorosed teeth with (TFI = 4–6) and the other six teeth are free of fluorosis: group (NF) normal non-fluorosed teeth. The classification was done by two investigators independently; Cohen's kappa was 0.965 for inter-examiner reliability.

**2. Tooth specimen preparation**

The teeth were cleaned by soaking them in 0.2 percent thymol. They were submerged in self-curing acrylic resin in a custom-made copper mold. The teeth were removed from the acrylic blocks, roots were coated with polyether adhesive (Polyether Adhesive, 3M ESPE, GmbH) until they were completely dry, then coated with polyether (Impregum Penta DuoSoft HB; 3M ESPE GmbH; Permadyne Penta L; 3M ESPE GmbH) to mimic the periodontal ligaments, teeth returned back on their acrylic block. The buccal surface of the enamel in all samples was prepared up to 0.5 mm using a high-speed handpiece (WK-99LT; W&H GmbH) on an electric motor and depth limiting bur (ISO 834; Komet, Gebr. Brasseler GmbH & Co), tapered diamond bur at a constant speed of 200,000 rpm and polished with #600 silicon carbide abrasive disc, to ensure that the entire preparation remained in enamel, a stereomicroscope (SZ114STR; Olympus) was used (34).

**3. Ceramic microdiscs fabrication and cementation**

The ceramic microdiscs were fabricated using lithium disilicate CAD blocks (e.max CAD; Ivoclar AG). The design of the microdiscs was created using Exocad Dental CAD software (Exocad; GmbH), each disc was 1-mm in height and 1-mm in diameter. The milling process was performed using a 4-axis milling unit (inLab MC XL; Sirona Dental Systems), then fired (Programat P310; Ivoclar Vivadent AG) according to the manufacturer's instructions. The microdisc's intaglio surfaces were etched with 9.5 percent hydrofluoric acid gel (Porcelain Etchant; Bisco) using a tweezer under a light microscope (CJ-Optik GmbH & Co. KG) for 60 seconds, as directed by the manufacturer. The disc was then rinsed and left to dry in the air until it looked chalky-white. The chalky-white layer formed by mineralized salts after HF etching was removed by thorough rinsing with distilled water and ultrasonic cleaning to prevent any interference with the adhesive bonding quality. Using a microbrush, a porcelain primer (Bis-Silane; Bisco) was applied according manufacturer instructions (35), a thin layer of self-etch adhesive (Prime and Bond Universal, Dentsply Sirona) was applied to

the micro-discs, and then dried with air for five seconds.
The teeth of the two groups were further subdivided into two groups based on surface modification: laser surface etching (L) and chemical 37% phosphoric acid etching (Ph), to form total of 4 sub-groups, fluorosed Laser (FL), fluorosed acid etch (FPh), non fluorosed laser (NFL), and non fluorosed acid etch (NFPh).

**4. Surface treatment of prepared enamel**

Etching of the labial surface of FL and NFL groups using Er:YAG laser system (Fotona LightWalker; Fotona) with enamel etch mode at the following settings: 300 mJ, 6 W, 20 Hz, water 8,140 s, air 4, R14 handpiece (100-degree), MSP mode (pulse duration 100 microseconds), 0.8 mm fiber tip, and 1 to 2 mm distance for 10 seconds (29). The groups FPh and NFPh were etched with 37% phosphoric acid etch (N-etch gel; Ivoclar Vivadent) for 30 seconds, followed by a ten-second water rinse (Figure 1).

**5. Luting procedure**

For all teeth, two layers of self-etch adhesive bond (Prime and Bond Universal, Dentsply Sirona) were coated on enamel surfaces with a microbrush, agitated for 20 seconds, and dispersed with water- and oil-free compressed air until a uniform and glossy layer developed (34). The micro-discs were cemented using light cure resin cement (Calibra Veneer I Light Cure Syringe; Dentsply Sirona) by the aid of a customized holding acrylic guide to verify all the micro-discs were firmly adapted in its corresponding locations on the labial surface: cervical third, middle third, and occlusal third of the labial surface. A static load of 700 grams was applied (36) using a copper bar in a specially designed loading device for 5 minutes to standardize the forces applied to the micro-discs (Figure 2). Excess cement was removed, followed by light-curing for 20 seconds by a light-emitting diode unit using a light intensity of 1200 mW/cm2 e (Elipar Freelight 2; 3M ESPE) (34).

**6. Thermocycling loading**

All specimens were aged in water baths that ranged in temperature from 5 to 55°C and thermocycled for 2,000 cycles with 15-second dwells in each bath, followed by a 5-second rinse transfer period in order to mimic 6 months of clinical day usage (37).

**7. Microshear test**

For microshear bond strength test, a universal testing machine (5ST, Tinius Olsen, England) with a mono-beveled chisel of 0.3 mm tip fell at the tooth and disc interface (Figure 3), load was applied with a crosshead speed of 0.5 mm/min until debonding or fracture of the specimen occurred. The µSBS is calculated in MPa by dividing the applied force (N) by the bonded area (mm²) using software (IBM SPSS, version 23; Armonk) (34). The tests were conducted according to ISO 11405:2015 standards, which provide guidelines for testing adhesion to tooth structure.(38)

Statistical analysis

Normality of SBS was checked using Shapiro Wilk test, descriptive and Q-Q plots and non-normal distribution was confirmed. SBS values were presented using median, inter quartile range (IQR), minimum and maximum in addition to mean and standard deviation (SD). The Kruskal Wallis test was performed to compare µSBS between groups. All tests were two tailed and the significance level was set at p value ≤ 0.05. Data were analyzed using IBM SPSS, version 23, Armonk, NY, USA.

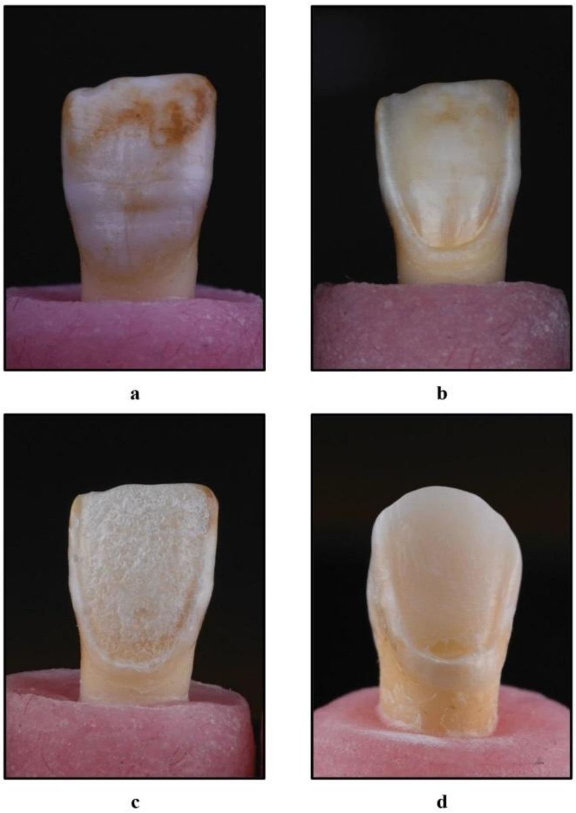


**Figure (1):** Different surface treatments of fluorosed teeth in acrylic blocks **(a)** Fluorosed tooth, enamel surface without preparation. **(b)** Non-etched prepared enamel. **(c)** Laser-etched enamel. **(d)** 37% phosphoric acid etched enamel

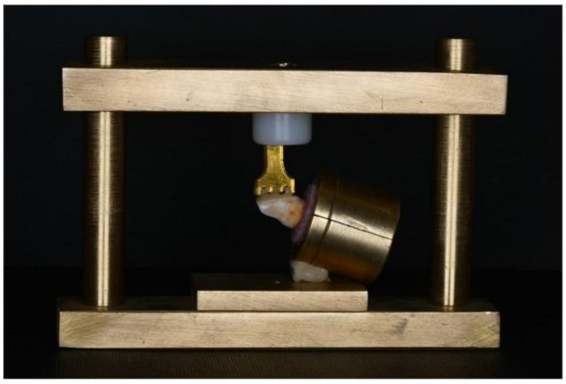

**Figure (2):** Specially designed static loading device used to holding the specimens and apply a static load during micro-disc cementation.

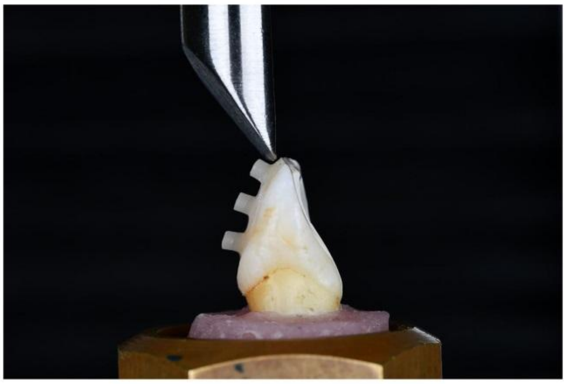

**Figure (3):** Mono-beveled chisel tip fell at the tooth and micro-disc interface.

## RESULTS

The highest mean value of µSBS was recorded in group NFPh (171.68 ±53.05 MPa), followed by group FL (153.94 ±41.51 MPa), and then the NFL group (150.35 ±39.16 MPa). The lowest mean µSBS value was recorded in the group FPh (135.76 ±67.7 MPa). The Kruskal-Wallis test revealed that there was no statistically significant difference in µSBS values among the groups (*p =0.587*) (Table 1 and Figure 4)

**Table (1):** Comparison of shear bond strength (MPa) among the study groups

| | **FL (n=9)** | **FPh (n=9)** | **NFL (n=9)** | **NFPh (n=9)** |
|---|---|---|---|---|
| Mean ±SD | 153.94 ±41.51 | 135.76 ±67.7 | 150.35 ±39.16 | 171.68 ±53.05 |
| Min | 109.04 | 42.68 | 101.02 | 70.83 |
| Max | 223.53 | 223.95 | 215.24 | 255.20 |
| H test (*p value*) | 1.931 (0.587*) | | | |

H test: Kruskal Wallis test
SD: Standard deviation
p: p value for comparing between the studied groups
*: Statistically significant at $p \leq 0.05$

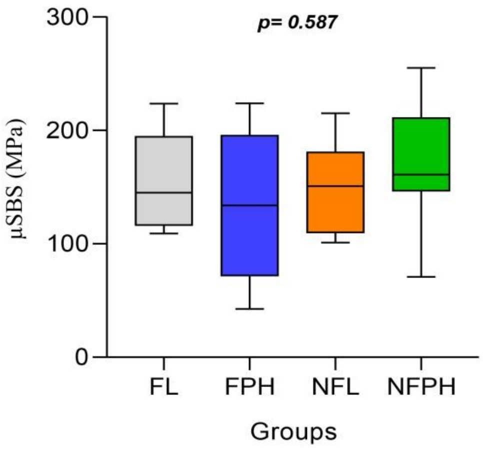


**Figure (4):** Comparison between the different studied groups according to shear bond strength.

## DISCUSSION

This study was designed to assess microshear bond strength of glass ceramic veneers bonded to fluorosed enamel after surface modification by Er:YAG laser.

Treatment modalities of dental fluorosis are subjected to the severity of the condition. Because the TFI Index is more corresponding to the histopathological changes in fluorosed enamel, Akapata (6) preferred using it over Dean's Index as it is highly reproducible and allows for useful determination of various clinical management options for fluorosed teeth. Rotoli (7) reported that glass ceramic veneers were superior to composite veneer restorations, due to its maintainability, wear resistance, and biocompatibility.

A 10 years clinical follow up study done by Demirekin et al (5) recommended that dentists consider ceramic veneers instead of crown restorations. The success of ceramic veneers is largely determined by the durability and strength of the bond formed among the three components of veneer complex; the ceramic veneer, the tooth surface, and the luting resin (10).

Researchers depend on different means to evaluate the bond strength of adhesive systems to tooth substrates (14), the micro-shear bond strength µSBS test was used in the conducted research. As minor bonding areas are used in this test, it is considered superior to the conventional shear test, which has a main complication regarding stress distribution (15). In this study, we assessed the µSBS of lithium disilicate CAD micro-discs to fluorosed ground enamel after surface treatments. The use of self-etching systems on enamel has been debated. Hara et al observed that the adhesion between ground enamel and self-etching adhesives was inferior in comparison to systems that used phosphoric acid as an independent conditioner (11). Conversely, additional research indicated that self-etching systems could serve as a suitable substitute for 37% phosphoric acid in preparing ground fluorotic enamel (12). In literature, the optimum acid-etching time for non-fluorosed enamel is 15 seconds (16). Moreover, Al-Sugair and Akpata said that etching time at least has to be doubled for moderately fluorosed teeth (17). Ravindranath et al & Ioannidis et al suggested that increasing etching time on fluorosed teeth has provided better outcomes (20). Toman et al found that there was not a statistically significant difference between self-etch and etch-and-rinse bonding systems when compared to bond strength when the outer hypermineralized layer of fluorotic enamel was removed (13). Consequently, this study used double etching time (30s) followed by the use of a self-etch bonding system to achieve the optimum results. The fact that the preparation of 0.5 mm of fluorotic enamel contains the superficial acid-resistant layer may increase the effect of acid etch, Opinya and Pameijer (8) found that grinding the outer

hypermineralized surface layer can lead to increased bond strength to composite resin. It is stated in the literature that in many instances, fluorosed teeth should have lower µSBS than non-fluorosed teeth with the use of 37% phosphoric acid (18,19), which was consistent with our results in the research was that the µSBS mean values of the FPh group were insignificantly lower than those of group NFPh.
One of the alternative methods introduced in the literature for changing the enamel prismatic configuration was using Er:YAG lasers. Laser irradiation's influence on dental substrate morphology is unclear and contentious. It can be used to roughen the enamel surface, which creates small pores and uneven areas. This allows adhesive resin to seep into these areas and form resin tags, which in turn increases the mechanical grip of the resin. This process is referred to as the laser irradiation effect (22). The micro-abrasive action of the Er:YAG laser also leads to evaporation of organic substances and water, causing micro explosions that destroy inorganic compounds. De Munck (24) suggests that Er:YAG laser irradiation on dental surfaces results in topographic modifications, such as removing smear layers and preventing enamel melting or carbonization, consequently, increase bonding.
Several studies (10,18, 21,26) have been conducted to examine laser etching using various irradiation settings. The settings selected for enamel etching in this study were adjusted at an energy output of 300 mJ with a power of 6 W and a pulse duration rate of 100 microseconds. These values were recommended based on findings from a previous study (25).
In this study, the mean µSBS values of fluorosed teeth treated with Er:YAG laser (group FL) were insignificantly greater compared to those treated with 37% phosphoric acid (group FPh). These results supported the null hypothesis. The findings were in agreement with the results of previous studies (26,27). With the same energy output and time of exposure on non fluorosed teeth, Lee et al (39) stated that, debonding occurs when a crack forms, spreads, and eventually leads a bond to failure. Furthermore, there is a correlation between surface energy and wetting capacity. The combined effect of these variables may not necessarily lead to a decrease in bond strength for the group that had laser treatment. Raji et al (26) compared the SBS of different groups, laser 100 mJ, 150 mJ and acid etch, However, there was no statistically significant difference in the mean SBS between the acid etch group and the group exposed to 150 mJ. While the SBS of the 100 mJ, group was significantly lower than the control group, it still above the minimum threshold of SBS recommended for clinical use. Jiang et al (40) concluded that the combined analysis of shear bond strength indicated no significant differences between erbium family lasers and acid etching. On the other hand, Martínez-Insua et al (35) reported that enamel etched using Er:YAG laser at 20 mJ showed lower significant mean tensile bond strength values compared to that etched with conventional acid etch.
One of the study's limitations was the significant challenge in milling the micro-discs, which was attributed to the discs' thickness and small size (1-mm x 1-mm). Furthermore, manual laser etching of the enamel surface might cause an uneven distribution of the laser beam, leaving non etched enamel patches. Further studies should be conducted, using various types of lasers and different Er:YAG laser parameters, and also to study the effect of laser on the elimination of colored fluorosed teeth and shade selection.

## CONCLUSION

Based on the findings of this in vitro study, we conclude that:

1. Glass ceramic veneers cemented on laser modified fluorosed enamel surface by Er:YAG show higher mean µSBS values than 37% phosphoric acid .
2. Er:YAG laser may be used as an alternative way of surface treatment of fluorosed enamel for glass ceramic veneers in dental clinics.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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