Shear bond strength of orthodontic brackets bonded to porcelain following etching with Er:YAG laser versus hydrofluoric acid

Soghra Yassaei, DDS, MS1
Farshad Moradi, DDS2
Hossein Aghili3
Mohamad Hosein Lotfi Kamran4

Aim: The purpose of the present study was to evaluate the shear bond strength of orthodontic brackets bonded to porcelain following etching with erbium-doped yttrium aluminum garnet (Er:YAG) laser compared with 9.6% hydrofluoric acid (HF). Methods: A total of 100 porcelain disk samples were divided into four groups, and after removing their glazed layer, the first group was etched with 9.6% HF, and the other three groups were etched with Er:YAG lasers of 1.6, 2, and 3.2 W, respectively. After application of silane on the disk surfaces, central incisor brackets were bonded with composite on the disks. The disks were mounted on an acrylic stand for measuring the shear bond strengths. The shear bond strengths were measured by a testing machine. Results: The mean shear bond strength in the laser group with power of 1.6 W (7.88 MPa) was more than that of the HF (7.4 MPa), 2-W power (7.52 MPa), and 3.2-W power (7.45 MPa) groups, but this difference was not statistically significant. Examination with an electron microscope showed different patterns of etching by HF and laser. Also, etching by laser and HF had not resulted in cracks on the porcelain surface. Conclusion: Er:YAG laser can be a suitable method for bonding of orthodontic brackets to porcelain surfaces. ORTHODONTICS (CHIC) 2013;14:e82–e87. doi: 10.11607/ortho.856

Key words: laser, shear bond strength, hydrofluoric acid, Er:YAG

The need for orthodontic treatment in adults is gradually on the rise, and many adults have porcelain crowns, to which orthodontists have problems bonding brackets. Optimal attachment of the bracket to the porcelain surface is important in ensuring that the applied orthodontic forces do not result in breakage of the bond during treatment and that the uniformity of the porcelain surface will be maintained after debonding. Bonding to porcelain is like a double-edged sword for the orthodontist. On one hand, maximum bond strength is required for a minimum detachment of brackets during treatment; on the other hand, debonding at the porcelain-adhesive surface should be avoided.1

From the time of the introduction of laser technology in 1960,2 lasers have been used extensively in medicine and dentistry. In orthodontics, various types of lasers (eg, neodymium-doped yttrium aluminum garnet [Nd:YAG], carbon
dioxide [CO₂], and erbium-doped yttrium aluminum garnet [Er:YAG]) have been proposed for preparation of the enamel surface for bracket bonding. Though certain researchers have reported the advantages of laser etching for bonding brackets to enamel,3–5 others have reported the bond strengths to be insufficient.6,7 There are a very limited number of studies about bracket bonding to porcelain surfaces.

The Er:YAG laser is a solid laser with a wavelength of 2,940 nm in the infrared range. The waves of this laser are easily absorbed by water and hydroxylapatite, thus making its use practicable on hard tissue and bone.8

The aim of present study was to evaluate the effect of the Er:YAG laser on the bond strength of metal brackets to porcelain and compare it with hydrofluoric acid etching.

METHODS

In the present study, a total of 104 samples of feldspatic porcelain disks in the form of porcelain fused to metal (PFM) were used. Each disk was 10 mm in diameter and comprised a layer of 2-mm-thick porcelain attached to a 1-mm nickel-chrome alloy layer. The surface of the blocks was plain and similar to the maxillary central incisor brackets. After preparation of the porcelain samples, they were randomly divided into four groups of 26 samples. Initially the glazed layer of the porcelain was removed using a 0.8 angle round bur.

Group I specimens were etched using 9.6% hydrofluoric acid (HF) (Condac Porcelana, FGM). The acid was applied for a period of 2 minutes to the porcelain surface, then washed with a gentle flow of water for 10 seconds, and later dried by a blower for 10 seconds. Group II, III, and IV samples were etched using an Er:YAG laser (KEY Laser 3+, KaVo Dental). Group II samples were exposed to a 1.6 W laser, while the group III and IV samples were exposed to 2 W and 3.2 W, respectively, at 20 Hz for 15 seconds. The distance of the head of the handpiece was 10 mm from the block surface. The acid was applied by tapping the microbrush on the surface. After preparation of the samples, one from each group was randomly selected, and the pattern of etching was evaluated by an electron microscope (VEGA, TESCAN).

The surface of the samples then was covered completely by silane (Silane Bond Enhancer, Pulpdent) and dried with the help of a blower for 5 seconds. The etched area was then covered with a layer of unfilled resin (Resilience, Ortho Technology), and the brackets were bonded to the porcelain by a bulk of composite resin (Resilience). The brackets were placed at the center of each block and held with a gentle force for a period of 5 seconds. The excess adhesive was filed off. The maxillary central incisor Roth prescription 22-slot brackets (Discovery, Dentaurum) were adapted.

In the next stage, a halogen light-curing machine with a power of 700 mW (Faraz Dentine, Isfahan Farazmehr) was used to bond the brackets to the porcelain surface. Each side of the bracket was cured for 10 seconds. The tip of the curing machine was placed as close as possible to the bracket base at a 45-degree angle. After curing, the samples were immersed in 37°C water for a period of 24 hours. They were then exposed 500 times to thermocycling baths of 5°C and 55°C for 30 seconds each with a period of transfer of 15 seconds.

After thermocycling, the disks were mounted on an acrylic stand. The samples were placed in the machine (Dartec, Zwick Roell) and fixed in their place. The tip of the machine was moved forward at the rate of 1mm/minute until the attachment of the bracket was detached. The maximum force applied by the machine on the bracket was divided into area units of the bracket base (12 mm²) and reported in megapascal units (MPa).
The samples selected for examination with the electron microscope were evaluated for etching pattern and possible damage due to etching. After preparation of the samples for evaluation by scanning electron microscopy (SEM), they were filmed at a magnification of 1,000 to 2,000 times by an SEM machine (VEGA) and compared with each other.

The gathered data was coded and entered in a computer using SPSS 16 software program (IBM). Analysis of variance (ANOVA) test was used to compare the groups.

RESULTS

The mean, standard deviation, and minimum and maximum bond strengths of the groups are shown in Table 1. The laser group with power of 1.6 W had the highest mean bond strength (7.88 ± 1.18) followed by the laser group with power of 2 W (7.52 ± 1.09), 3.2 W (7.45 ± 1.53), and the HF group (7.4 ± 1.27). Because there was no statistical difference between the groups (P = .53), there was no need for post hoc analysis (Table 2).

The results of the analysis by the electron microscope showed that the etching pattern by HF (Fig 1) was different from that of the laser groups (Fig 2). The HF-etched surface pattern was uniform with more porosity in comparison to surface destructions visualized in the samples etched with laser.

DISCUSSION

At present in almost all of the cases that require bracket bonding on porcelain restorations, the only method for preparation of the porcelain surface is to use HF. Though this preparation method resulted in appropriate bonding between the bracket and porcelain surface, the acid’s potential for causing damage to oral soft tissue has led to the need for more accurate isolation procedures. Many researchers...
Yassaei et al have studied the effects of various methods for preparation of the dental porcelain surface on bracket and bond strength. In short, only a few studies have been done in the orthodontic field regarding bonding with laser etching (especially orthodontic brackets to porcelain), and the studies by Li et al9 and Akova et al2 are two of the index studies in this field.

In the present study, the effects of an Er:YAG laser with three powers of 1.6, 2, and 3.2 W, a frequency of 20 Hz, and use for 15 seconds were studied on dental porcelain. The data were compared with etching with 9.6% HF with regard to etching pattern and shear bond strength. The reason for using the Er:YAG laser was the specific use of this laser in dentistry.

In evaluating shear bond strength, there was no significant difference between the four groups. The mean bond strength in the HF group was 7.4 MPa, while the mean bond strengths in the 3 laser groups were 7.88, 7.52 and 7.45 MPa respectively. Though the mean bond strength in the HF group was lower than the 3 laser groups (highest mean bond strength was with the power of 1.6 W that decreased with an increase in power), but this difference was not statistically significant (P = .53).

On the basis of their results, Lee et al10 declared that the Er:YAG laser can be used as an alternative to the acid-etch process. Other studies also have evaluated the use of lasers for etching, and all have declared that the laser can be an appropriate alternative to the acid-etch process.11,12 The results of these studies are in line with the results of the present study, ie, there was no statistically significant difference between the bond strengths of the acid and laser etching groups. In this study we prepared porcelain surfaces, in contrast to Lee et al,10 who evaluated the bond strength of enamel surface preparation. Another difference was the different power setting of laser etching in the Lee et al study10 and others.11,12

Li et al9 studied the strength of composite resin bonded to porcelain by Nd:YAG laser in 2000. They compared three different laser powers with 8% HF for etching the porcelain surface and concluded that the Nd:YAG laser can be used as an etching process for bonding composite to porcelain. The result of the study by Li et al9 is in line with that of the present study, ie, that the laser can be used as an alternative to HF etching. The difference between the two studies is that first, Li et al9 used an Nd:YAG laser and compared it with 8% HF, while in the present study, an Er:YAG laser was used and compared with 9.6% HF. Secondly, the power settings of the lasers used in the two studies were different.

Fig 2 SEM image of 1.6-W laser (a), 2-W laser (b), and 3.2-W laser (c) samples (original magnification ×2,000).
In 2003, Akova et al\textsuperscript{2} studied the tensile strength of bracket and porcelain attachment by CO\textsubscript{2} laser and concluded that a power of 2 W of this laser is the most appropriate setting for etching porcelain, while powers above 2 W can be destructive to its surface. The result of this study is somewhat different from that of the present study, in which powers of 1.6 and 2 W had better etching patterns as compared to 3.2 W, but in regard to bond strength, there was no significant difference between them. In the present study, the Er:YAG laser was used, and there was no difference between the bond strengths of 1.6, 2, and 3.2 W. Only the etching pattern of the 3.2-W laser showed more destruction of the porcelain surface (in the electron microscope evaluation). In the present study, because the Er:YAG laser was used along with a water spray, a part of the energy of the laser was absorbed by water flow, thus decreasing the thermal effects of the Er:YAG laser.

In 2009, da Silva Ferreira et al\textsuperscript{11} studied the strength of the bond of composite resin to the porcelain surface after preparation by several methods. They compared the sandblast etching with 10% HF etching and sandblasting with etching by Er:YAG laser. Their conclusion was that the bond strength created by the Er:YAG laser is the same as that of HF, which is in line with the present study. The difference between the two studies is that in the da Silva Ferreira et al\textsuperscript{11} study, sandblasting was used along with acid and laser during the preparation stage, while sandblasting was not used in the present study.

Cavalcanti et al\textsuperscript{13} compared the pulp temperature increase during cavity preparation with Er:YAG laser (2.94 μm, 350 mJ/10 Hz, with water cooling) and high-speed handpiece (with and without water spray). They found that the mean pulp temperature increase using a handpiece was 11.64°C and 0.96°C with and without application of cooling, respectively, and this mean in the laser group was 2.69°C. They did not find a significant difference between the high-speed handpiece with water cooling and the Er:Yag laser with water cooling.

Armengol et al\textsuperscript{14} studied pulp temperature increase with three different methods of cavity preparation: high-speed handpiece, Er:YAG laser (140 mJ, 4 Hz), and Nd:YAG laser (240 mJ, 10 Hz). They concluded that during cavity preparation with the Er:YAG laser, temperature increase is minimal and similar to that found with the high-speed handpiece.

Therefore, the laser powers used in each group of the present study (1.6, 2, and 3.2 W) could not exert harmful damage on the pulp and are similar to cavity preparation using a high-speed handpiece with application of water. Since a great deal of laser energy is absorbed by water, as shown by the Attrill et al study,\textsuperscript{15} water spray is an effective way to control thermal effects of pulp preparation by laser. Hence, in the present study, water spray was used in all groups. The results of the electron microscope analysis showed that although the etching pattern by HF was uniform, the surface damage was greater. In the three laser groups, the etching pattern had a peeling state, and in certain areas damage to the porcelain surface was seen.

In the laser group with the power of 3.2 W, the damage was more severe in the areas of destruction, which could be due to the increased energy applied in this group. This difference in the destruction pattern in the three laser groups could explain the higher mean bond strength in the 1.6-W laser group. With an increase in the power of the laser, melting of the porcelain surface also increased, leading to weakening of the porcelain surface and a weaker bond. The etching mechanism by laser is such that the laser results in heating of the porcelain surface and formation of pearls that are responsible for mechanical retention between the porcelain surface and resin composite.\textsuperscript{2} The pattern observed in the present study was similar to this view.

In the study by Akova et al,\textsuperscript{2} wherein an electron microscope was used to study the etched porcelain surface, cracks were reported in the group etched
with laser, and they concluded that with an increase in laser power, the possibility of formation of cracks also increased. In the present study, under the electron microscope, the samples etched with HF showed cracks that were absent in the samples etched with laser. The HF samples were examined again by the electron microscope to confirm the findings, but these cracks were not observed. This could be due to artifacts or damage that had occurred during removal of the glaze layer, which also may be the cause in the Akova et al study.

CONCLUSION

The results of the present study showed that etching with the Er:YAG laser can be an appropriate alternative to HF for bonding orthodontic brackets to porcelain. Of the three powers of laser used in the study, the lowest power (1.6 W) was the most effective and created the strongest bonds. Evaluation of the etch pattern on the porcelain surface studied with an electron microscope showed a difference between the HF and laser etching patterns. The etch pattern in the three laser groups was the same except that with an increase in power of the laser, more destruction of the porcelain surface was seen. The results of the study showed that there is no linear relation between increase in power of laser and shear strength of bonds.

REFERENCES