Dentin Bond Strength: Influence of Er:YAG and Nd:YAG Lasers

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The aim of this study was to investigate the effects of Er:YAG and Nd:YAG lasers on the shear bond strength of composite resin to dentin. The coronal portion of 56 human molars was divided into three parts, and the dentin thickness was standardized at 2 mm. A 3-mm hole was marked in the center of each tooth with sealing tape paper. The specimens (n = 14) were then divided into four groups: (1) acid etching + Single Bond (SB) (control), (2) acid etching + SB + Nd:YAG laser irradiation (before adhesive curing), (3) thermal etching with the Er:YAG laser + SB, and (4) thermal etching with the Er:YAG laser + SB + Nd:YAG laser irradiation (before adhesive curing). A composite resin cylinder was built into the delimited area for conducting the shear bond strength test on the universal testing machine. The means ± standard deviations were: group 1, 17.05 ± 4.15 MPa; group 2, 16.90 ± 3.36 MPa; group 3, 12.12 ± 3.85 MPa; and group 4, 12.92 ± 2.73 MPa. Groups 1 and 2 presented significantly higher values than groups 3 and 4. It was concluded that conventional etching with 37% phosphoric acid yielded significantly higher bond strength values compared to thermal etching with the Er:YAG laser. The Nd:YAG laser did not significantly influence the bond strength. (Int J Periodontics Restorative Dent 2013;33:373–377. doi: 10.11607/prd.1096)

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forming); characteristics that are ideal for bonding. This suggests the use of the Er:YAG laser as an alternative technique for etching of the dentin surface.4,5

Application of the Nd:YAG laser on dentin previously impregnated by an adhesive provides fusion and recrystallization of dentin hydroxyapatite in the presence of resin monomers, developing a more resistant substrate with greater chemical affinity to the bonding process.6,7

This study evaluated the shear bond strength to dentin by comparing conventional chemical etching with phosphoric acid, thermomechanical etching with the Er:YAG laser, and the success of dentin treatment with the Nd:YAG laser after application of an adhesive system.

Method and materials

Preparation of teeth

This study was conducted on 56 intact human molars supplied by the Department of Surgery of São José dos Campos Dental School – UNESP, São Paulo, Brazil. The teeth, extracted from adult patients, were cleaned and stored in distilled water in a freezer at –18°C for up to 29 days. With aid of a silicon matrix, the teeth were embedded in acrylic resin with the occlusal surface parallel to the horizontal plane.

The coronal portion of each tooth was cut into three sections parallel to the occlusal plane using the sectioning machine (Labcut 1010, Extec). The sections were separated and the middle section was measured with a thickness meter for standardization of dentin thickness at 2 mm. This section was once again embedded in acrylic resin with the aid of a silicon matrix so the dentin surface was positioned on the horizontal plane. The dentin surface was then polished in a machine with sandpaper of decreasing grit (from 400 to 800).

Surface treatment and fabrication of the specimens

A sealing tape (3M ESPE) was employed, in which a 3-mm orifice was fabricated for standardization of the area to be treated on the dentin surface. The specimens were randomly divided into four experimental conditions, with 14 specimens each, and received the following treatments:

- Group 1 (control): chemical etching with 37% phosphoric acid for 15 seconds, rinsing, drying with cotton pellets, and application of the adhesive system Single Bond (3M ESPE) in two consecutive coats, gentle drying for 2 to 5 seconds, and light curing for 10 seconds
- Group 2: chemical etching with 37% phosphoric acid for 15 seconds, rinsing, drying, and application of the adhesive system Single Bond. Before light curing of the adhesive system, the dental tissue covered by the adhesive was irradiated with the Nd:YAG laser (Pulse Master 600 IQ, American Dental Technologies) set at 140 mJ/pulse, 10 Hz, 1.4 W, 174.1 J/cm², without contact, at an approximate distance of 2 mm, scanning the surface for 60 seconds. Afterwards, the adhesive was light cured for 10 seconds
- Group 3: thermal etching with the Er:YAG laser (Kavo Key Laser) set at 60 mJ, 10 Hz, 20 mJ/cm², without contact, at an approximate distance of 2 mm, scanning the surface for 30 seconds and under cooling with distilled water, application of the adhesive system Single Bond, and light curing of the adhesive for 10 seconds
- Group 4: thermal etching with the Er:YAG laser set at 60 mJ/pulse, 10 Hz, 20 mJ/cm², without contact, at an approximate distance of 2 mm, scanning the surface for 30 seconds and under cooling with distilled water, and application of the adhesive system Single Bond. Before light curing of the adhesive system, the dental tissue covered by the adhesive was irradiated with the Nd:YAG laser set at 140 mJ/pulse, 10 Hz, 1.4 W, 174.1 J/cm², without contact, at an approximate distance of 2 mm, scanning the surface for 60 seconds. Afterwards, the adhesive was light cured for 10 seconds

The specimens were positioned in a metallic matrix for fabrication of composite resin cylinders measuring 3 mm in diameter and 5 mm in height. The hybrid composite resin
Z-100 (3M ESPE), shade B2, was applied in two increments. Each increment was light cured for 40 seconds (Optilight 600, Gnatus Equipamentos Médico-Odontológicos). Next, the specimens were stored in distilled water at 37°C for 7 days.

Shear bond strength testing

Shear bond strength testing was performed in a universal testing machine (Emic) at a crosshead speed of 0.5 mm/min with a load cell of 100 Kgf, using a special device to fixate the specimens. The results were recorded in MPa.

Analysis of fracture type

After shear bond strength testing, all specimens were evaluated under a stereomicroscope (Stemi 2000-C, Carl Zeiss) to identify any type of fracture. For that purpose, the specimens received a coat of hematoxylin-eosin at the central region. The dye does not stain the composite resin, and the composite resin does not stain the dentin or tooth. Therefore, the fractures were classified as (1) cohesive type I: cohesive in composite resin; (2) cohesive type II: cohesive in dentin; (3) adhesive: at the dentin/adhesive or adhesive/resin interfaces; and (4) mixed: a combination of cohesive and adhesive fractures.

For each group, the means were calculated and submitted to two-way analysis of variance (ANOVA) and Tukey tests at a significance level of 5% (P < .05).

Table 1 Mean ± SD shear bond strength (MPa) for the four treatment groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Group</th>
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<tr>
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<td>1</td>
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<tr>
<td>Acid etching</td>
<td>17.05</td>
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<tr>
<td>Acid etching with Nd:YAG</td>
<td>–</td>
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<tr>
<td>Er:YAG etching</td>
<td>–</td>
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<tr>
<td>Er:YAG etching with Nd:YAG</td>
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Results

Means ± standard deviations of shear bond strength are presented in Table 1. The ANOVA showed significant differences for the etching condition (P = .001). The application of the Nd:Yag laser and interaction showed no significant differences.

The results of evaluation of type of fracture are presented in Fig 1. There were no cohesive fractures of composite resin (type I) in any of the groups. Adhesive fractures were predominant in all groups.

Discussion

Penetration of resin monomers into the tooth structure has been accepted as the main mechanism of bonding; however, uniform infiltration of hydrophilic monomers throughout the dentin is rarely observed.1,8-10 It is known that the smear layer reduces the surface energy, decreasing the reactivity of the dentin substrate to the bonding systems and yielding lower bond strength values.2,9,11 Thus, it is believed that its
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absence may provide a physically resistant substrate that is chemically favorable to the adhesive procedure.

Based on the fact that the thermomechanical technique of ablation of hard dental tissue with the Er:YAG laser does not yield formation of a smear layer, this type of laser may be an alternative to acid etching.2,3,11-13

Irradiation of dentin tissue with the Er:YAG laser promotes opening of the dental tubules and formation of an irregular surface, which are advantageous characteristics for adhesion to the dental substrate, providing acceptable microretention to the adhesive system.6,12-15 The studies conducted by these investigators suggest that the Er:YAG laser makes the dentin more receptive to promote strong adhesion with composite resins.

However, the present study revealed that groups 3 and 4, which were submitted to etching with the Er:YAG laser, presented significantly lower bond strength values compared to the groups submitted to etching with 37% phosphoric acid.

These results corroborate a previous study16 in which the dentin bonding of the adhesive system Single Bond was negatively influenced when laser etching was performed.

This may be related to the fact that Single Bond requires acid etching before its application, which promotes intermingling of its resin component into the intertubular matrix and dental tubules.

This disagreement may also be related to the fact that etching with 37% phosphoric acid promotes demineralization of the peritubular dentin, leading to funnel-shaped opening of the dental tubules and contributing to the formation of tags, whereas irradiation with the Er:YAG laser does not yield demineralization of the peritubular dentin. Thus, there is formation of an irregular surface and opening of tubules, but not a hybrid layer or resin tags.2,3,12,17

In regard to the decreased bond strength when etching is performed by irradiation with the Er:YAG laser, De Munck et al15 and Corona et al18 suggested that diffusion of hydrophilic monomers into the dentin may be impaired by excessive dehydration since the thermomechanical ablation promoted by the laser vaporizes the water in the dentin tissue, thus reducing the bond strength between dentin and composite resin. This may be overcome if the tissue is rehydrated before the adhesive procedure. Also, it is not known whether this occurs in vivo since in this condition there is flow of dentinal fluid that may promote rehydration of the irradiated tissue.

With regard to the use of the Nd:YAG laser for dentin surface treatment, several studies demonstrated that this type of laser is able to promote fusion and recrystallization of the dentin surface, obliterating some dental tubules, depending on the energy density employed.15,19 These alterations in the morphology of the tooth substrate occur due to reduction of the percentage of calcium and phosphate in the dentin structure, causing changes in the organic composition of hydroxyapatite leading to its recrystallization.6,7,19

Thus, Gonçalves et al20 proposed dentin irradiation after application of the adhesive system but before light curing. This promotes the formation of a new layer of dentin tissue from the adhesive system joined by the action of the laser, ie, a mechanically intermingled substrate that is chemically receptive to bonding.

The groups irradiated with the Nd:YAG laser in the present study did not present significant differences in bond strength when compared with the control group. Matos et al21 and Ariyratnam et al22 also found similar results.

Despite the lack of a statistically significant difference between groups 1 and 2, utilization of the Nd:YAG laser in adhesive procedures should be considered, since previous studies revealed that the association of the Nd:YAG laser and an adhesive system promotes a significant reduction in marginal microleakage.23,24

Regarding the type of fracture, no cohesive fractures of composite resin (type I) were observed, which suggests that the shear bond strength testing was well conducted, without the induction of stresses at undesired areas.

There was a higher percentage of cohesive fractures, followed by mixed fractures in groups 1, 3, and 4. Group 2 presented a higher percentage of cohesive fractures of dentin (type II), suggesting that recrystallization may have increased the friability of the dentin tissue,
which corroborates the results reported by Wigdor et al. 25

The present study was designed to investigate the interaction of Er:YAG and Nd:YAG lasers with the tooth substrate to determine whether this type of advanced technology might increase tooth/restoration bonding.

Even though the present results did not reveal relevance of the use of the Nd:YAG laser with regard to bond strength, there was smaller variability as confirmed by the lowest standard deviation. Moreover, the literature reports that use of the Nd:YAG laser significantly reduces marginal microleakage. Best outcomes may be achieved with the advent of new parameters or with the use of other adhesive systems associated with the laser technique.

Conclusion

The results revealed the following: (1) conventional etching with 35% phosphoric acid yielded significantly higher bond strength values compared to thermal etching with the Er:YAG laser, and (2) the application of the Nd:YAG laser after the application of the adhesive system did not significantly influence the bond strength.

Acknowledgment

The authors reported no conflicts of interest related to this study.

References