Diode laser debonding of ceramic brackets

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Introduction: Our objective was to investigate the effectiveness of debonding ceramic brackets with a diode laser. Methods: Two types of ceramic brackets (monocrystalline and polycrystalline) were bonded to bovine maxillary central incisors. The diode laser was applied to brackets in the experimental groups for 3 seconds. Shear bond strength and thermal effects on the pulp chamber were assessed at 2 laser energy levels: 2 and 5 W per square centimeter. Analysis of variance (ANOVA) was used to determine significant differences in shear bond strength values. Results: The diode laser was ineffective with polycrystalline brackets and effective with monocrystalline brackets in significantly (P < 0.05) lowering the shear bond strength. There were no significant adhesive remnant index score differences between any groups tested. Conclusions: Diode laser use significantly decreased the debonding force required for monocrystalline brackets without increasing the pulp chamber temperature significantly. Diode lasers did not significantly decrease the debonding force required for polycrystalline brackets. (Am J Orthod Dentofacial Orthop 2010;138:458-62)

Ceramic brackets have been the preferred choice for esthetically conscious clinicians and patients since their introduction in the 1980s. Their popularity continues, as evidenced by the recent wave of ceramic self-ligating bracket systems introduced to the specialty. Discussion of the clinical challenges of ceramic bracket use remains an active topic of debate. A major concern is bracket debonding. The increased bond strength in attachment of ceramic brackets to enamel might increase the potential for enamel damage or bracket fractures at debonding.

Various methods have been developed to aid in debonding ceramic brackets. These methods use special pliers for mechanical debonding, degrading the bonding resin with electro-thermal debonding devices and lasers. There are 4 major types of lasers. They are classified mostly by their lasing mediums, defined by their state: gas, liquid, solid, and semiconductor (or laser diode).

A laser diode, also known as an injection laser or a diode laser, is a semiconductor device that produces coherent radiation (in which the waves are all at the same frequency and phase) in the visible or infrared spectrum when current passes through it. Laser diodes are used in optical fiber systems, compact disk players, laser printers, and remote-control devices. Laser diodes differ from other laser types in several important ways: small size and low weight, current, voltage, intensity, and power requirements.

Previous studies have shown that use of carbon dioxide, neodymium: yttrium-aluminum garnet, or xenon chloride excimer lasers can be effective in significantly lowering the shear bond strength (SBS) of ceramic brackets. The purpose of this study was to investigate the effect of diode laser use in debonding 2 types of ceramic brackets.

MATERIAL AND METHODS

Two maxillary left central incisor ceramic brackets were used in this study: Inspire ICE (Ormco, Orange, Calif), a monocrystalline bracket; and Clarity (3M Unitek, Monrovia, Calif), a polycrystalline bracket. A single-paste visible light-cured orthodontic adhesive system, Transbond XT (3M Unitek), was used.

Sixty bovine incisors were obtained from a slaughterhouse. The teeth were stored in distilled water in a freezer at −20°C until used. When needed, the teeth were thawed in warm water and embedded in auto-polymerizing polymethyl methacrylate in molds (25 × 25 × 25 mm) so that the crown was exposed. After polymerization of the polymethyl methacrylate, the teeth were stored for 24 hours in distilled water to which crystals of thymol were added to inhibit bacterial growth. Before bonding, access cavities, 2 mm in diameter, were drilled into the pulp chamber by using
a high-speed hand piece into the center of the cingulum on the lingual surfaces.

The middle third of the labial surface was flattened with sandpaper. The flattened enamel surface was dried with hot air, and Transbond Plus Self Etching Primer (3M Unitek) was prepared for application to the tooth surface according to the manufacturer’s instructions. A saturated applicator tip was rubbed on the tooth surface for 4 seconds followed by a gentle air burst. Transbond XT was then placed on the bracket base, and the bracket was placed on the prepared enamel surface so that the slot was parallel to the incisal edge of the incisor.

The guide pin of a nonadjustable Hanau articulator (Teledyne Water Pik, Fort Collins, Colo), with a stone cylinder of 600 g attached to its upper member, was positioned to engage the bracket slot. This ensured that the brackets were seated under constant pressure and allowed the investigator to remove, with a sharp dental explorer, any surplus cement extruded from the periphery of the base without compromising the onset of the polymerization process. The cement was then cured with a 75-W halogen curing light (3M ESPE, St Paul, Minn) for 40 seconds (10 seconds on each side of the bracket).

The teeth were then stored for 24 hours in distilled water for 4 seconds (10 seconds on each side of the bracket). Transbond XT was then placed on the bracket base, and the bracket was placed on the prepared enamel surface so that the slot was parallel to the incisal edge of the incisor.

Table I. Experimental groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Bracket type</th>
<th>Debonding method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clarity</td>
<td>Force only</td>
</tr>
<tr>
<td>2</td>
<td>Inspire ICE</td>
<td>Force only</td>
</tr>
<tr>
<td>3</td>
<td>Clarity</td>
<td>Diode laser 2 W/cm²/sec and force</td>
</tr>
<tr>
<td>4</td>
<td>Inspire ICE</td>
<td>Diode laser 2 W/cm²/sec and force</td>
</tr>
<tr>
<td>5</td>
<td>Clarity</td>
<td>Diode laser 5 W/cm²/sec and force</td>
</tr>
<tr>
<td>6</td>
<td>Inspire ICE</td>
<td>Diode laser 5 W/cm²/sec and force</td>
</tr>
</tbody>
</table>

Statistical analysis

Statistical analysis of the data was then carried out, including calculating the mean SBS values, ARI scores, and standard deviations for each group. A 1-way analysis of variance (ANOVA) established whether there were any differences in the mean SBS values for each bracket type. If there were differences, the Tukey honestly significant difference test was done to establish which groups differed significantly. A chi-square test was calculated to analyze the mean ARI score for each bracket group. Signed rank tests were used to compare each bracket group’s temperature change against standard increases of 1.8°C and 5.5°C.

RESULTS

The mean SBS values and standard deviations are given in Table II. The data were then used to compare the means of the groups for each bracket type.

No statistically significant differences (P < 0.05) were found when comparing the mean SBS values of the 3 groups of Clarity brackets. There was a statistically significant difference in the mean SBS values of the 3 groups of Inspire ICE brackets. The means of the 2 lased groups were statistically significantly lower (P < 0.05) than those of the nonlased group. However, the difference in the means of the lased groups was not statistically significant (P < 0.05; Fig 1).

There were no significant differences in the ARI scores of 3 groups when either the Clarity (chi-square, P = 0.37) or the Inspire ICE (chi-square, P = 0.79) brackets were tested. All groups in the study had mean ARI scores of 3; this indicates that almost all adhesive was left behind on the tooth surfaces with a clear imprint of bracket base.

The mean increases in pulp chamber temperature for groups 3, 4, and 5 were statistically significantly less (P < 0.01) than the 5.5°C increase threshold and not significantly different (P < 0.01) from the 1.8°C standard. Group 6 had a mean pulp chamber increase significantly greater than the 1.8°C standard and not significantly different (P < 0.01) from the 5.5°C standard (Fig 2).
DISCUSSION

Previous studies have shown that lasers can significantly reduce ceramic bracket debonding force. In this study, we investigated the effects of using a diode laser for debonding. The relatively small size, weight, power requirements, and lower cost make this laser a more practical addition to an orthodontic practice.

The use of the diode laser was ineffective in significantly lowering the required debonding force for the polycrystalline brackets (Clarity). Two levels of lasing were tested, and neither resulted in a significantly different debonding force when compared with the nonlased control.

The use of the diode laser was effective in significantly lowering the required debonding force when monocrystalline brackets (Inspire ICE) were tested. Both the 3-W and the 5-W per square centimeter laser protocols yielded significantly lower debonding force than the nonlased control group. There was, however, no significant difference in debond force when the 2 laser power levels were compared.

The significant reduction in the debonding force of the monocrystalline brackets after lasing, but not of polycrystalline brackets, might be explained by their uniform crystal structure that enables high transmissibility, thereby limiting energy loss. Furthermore, the polycrystalline brackets used in this study (Clarity) have a stainless steel slot. This most likely shielded the bracket base and the adhesive layer from some laser energy; it might have absorbed or reflected this energy away.

Tocchio et al.36 described 3 methods of debonding: thermal softening, thermal ablation, and photo ablation. The diode laser debonding protocol we used did not produce any of the explosive “blow offs,” noticeable carbonization-like changes to the remnant resin, or decomposition of the bracket base as reported by Hayakawa41 when using an Nd: YAG laser. It appears that the effect of the diode laser was to provide thermal softening of the adhesive.

There were no significant ARI score differences between any of the groups tested. Uniformly, they all had a mean ARI score of or close to 3. In almost all samples, all or most of the adhesive remained on the tooth, with an imprint of the bracket pad after debonding.

The mean temperature changes of the pulp chamber walls of the laser groups were compared with the experimental results reported by Zach and Cohen.43 They found no pulp damage with an intrapulpal temperature increase of 1.8°C when external heat was applied to

Table II. Mean SBS values (MPa)

<table>
<thead>
<tr>
<th></th>
<th>Clarity</th>
<th>Inspire Ice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 3</td>
</tr>
<tr>
<td>n</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Mean</td>
<td>9.79</td>
<td>9.68</td>
</tr>
<tr>
<td>SD</td>
<td>3.20</td>
<td>2.63</td>
</tr>
</tbody>
</table>

Fig 1. Mean shear bond strengths of Clarity and Inspire ICE brackets.
teeth. With an increase in pulpal temperature of 5.5°C, they found pulpal necrosis in 15% of teeth. Only group 6 had a mean pulp chamber wall temperature increase that was not significantly below 5.5°C ($P < 0.01$). The other laser groups had mean pulp chamber wall temperature increases that were significantly below this threshold ($P < 0.01$).

We used a bovine tooth model. It is possible that a human tooth model would have yielded different results. In today’s world of conservative dental practice, obtaining large quantities of extracted human teeth in a suitable condition for bonding studies is difficult. Using different bonding agents than we used in this study, Nakamichi et al. found that the adhesion to enamel and the superficial layer of dentin showed no statistically significant differences between human and bovine teeth.

Many different ceramic brackets are available today. We tested only 1 polycrystalline bracket and 1 monocrystalline bracket. Further testing should be done to determine whether there are differences among other brackets in these 2 groups.

Other variables that could be studied are the thickness of the bracket base and the thickness of the bracket itself. Brackets with larger profiles would be expected to transmit less laser energy to the bracket base and the underlying layer of adhesive.

We used 2 laser outputs: 3 and 5 W per square centimeter for 3 seconds. Alternatively, a future study could investigate the effect of varying the lasering time on SBS and keeping the output power constant. However, it can be expected that the heat generated in the pulp chamber would increase with the time of exposure to the laser output. Another potential study would be to increase the laser output power from those tested and decrease the exposure time. In theory, the SBS values would be further reduced without an adverse effect on pulp chamber temperature.

CONCLUSIONS

1. Diode laser use significantly decreased the debonding force required for monocrystalline brackets without increasing the internal pulp chamber wall temperature significantly.
2. Diode laser use did not significantly decrease the debonding force required for polycrystalline brackets with stainless steel slots.
3. The use of the diode laser did not alter the amount of adhesive remaining on the tooth surface after debonding.

REFERENCES


