Effect of different surface treatment methods on the shear bond strength of orthodontic brackets to temporary crowns

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Available online: 19 February 2019

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Keywords
CO2 laser
Grinding
Sandblasting
Shear bond strength
Temporary crown

Summary

Introduction > The number of adult patients seeking orthodontic treatment has been consistently increasing. Since the placing of the final restoration must be postponed until the completion of the orthodontic treatment, provisional restoration is recommended for the duration of the orthodontic treatment. These surfaces have special chemical properties, which necessitate the orthodontists to prepare the bonding area with special measures.

Methods > Polycarbonate and polymethylmethacrylate (PMMA) crowns (n = 80) were randomly subdivided into 4 groups. Conditioning methods were grinding, sandblasting, CO2 laser and methyl methacrylate application. Samples underwent SBS testing. A scanning electron microscope (SEM) analysis was carried out. The data was analysed with ANOVA, Student t-test and Post-hoc test. Adhesive remnant index (ARI) was analysed with Chi² test.

Results > In all surface treatments, the mean Shear Bond Strength (SBS) of PMMA was significantly higher than that of polycarbonate (P < 0.001). In the polycarbonate groups, there was a significant difference between the mean SBS of the four treatment methods (P < 0.001). However, there were no significant differences in PMMA group (P = 0.076). In both crown materials, the mode of the failure was adhesive type, regardless of the conditioning method (P > 0.05).

Conclusions > PMMAs rendered higher bond strength than polycarbonates. In PMMA, all the surface treatment methods resulted in acceptable bond strength. However, if bonding the brackets to polycarbonate crown is needed, other conditioning methods are preferred over CO2 laser.
**Mots clés**
Laser CO₂
Meulage
Sablage
Résistance au cisaillement
Couronne provisoire

**Résumé**

Effet des différentes méthodes de traitement de surface traitement sur l’adhérence et la résistance au cisaillement des attaches orthodontiques sur les couronnes provisoires

**Introduction**

Adult orthodontic treatment has been increasing in recent years [1-5] and is often combined with further restorative treatment [4,6]. Since it is advised to defer final restoration until the completion of orthodontic treatment, prescribing a provisional crown is usually indicated for the duration of the orthodontic treatment [7]. This interim restoration is either prefabricated or custom made [8]. Polycarbonate crowns are a common type of prefabricated crown [8] and poly methyl methacrylate (PMMA) is the most commonly used type of acrylic resin for the fabrication of custom crowns [9,10].

Bonding the brackets is a critical step in orthodontics [11]. Various methods have been introduced to improve the bond strength of orthodontic brackets to superficial surfaces such as grinding [2,6,7,12], sandblasting [2,6,7,12,13], application of chemical agents [2,7,14] and more recently laser [5,15-17]. With the advent of CO₂ laser in dentistry, its effectiveness as a means of reinforcing the bond strength of orthodontic brackets to enamel has been investigated [18-21].

Until now only one study [7] has compared the effect of different surface preparation methods on the bond strength of brackets to polycarbonate crowns. In addition, limited investigations [2,6,12] have examined the outcome of surface treatment methods on the shear bond strength (SBS) of orthodontic brackets to PMMA. However, the findings were inconclusive.

To our knowledge, no studies have evaluated the CO₂ laser as a surface conditioning means of temporary restoration in orthodontics. In limited investigations, CO₂ laser has been examined for surface preparation of porcelain restorations and the results seems to be acceptable [5,15,16]. Moreover, considering the previous controversies [2,6,12], no study has recommended an effective method for conditioning the temporary crowns. So, the aim of this study was to compare the SBS of orthodontic brackets to polycarbonate and PMMA crowns with four different methods of surface preparation including surface roughening with greenstone, sandblasting, CO₂ laser and MMA application.

**Materials and methods**

**Materials**

In this in vitro study, two groups of prefabricated and custom resin crowns were examined (n = 84 for each group). Polycarbonate crowns (Dental polycarbonate temporary crown, Arnel, Switzerland) of right maxillary central incisor were selected. In the custom-crown group PMMA acrylic resin powder and liquid
were mixed according to the instructions of the manufacturer (Temptron, GC, Japan). When the material reached its plastic phase, it was poured into the mold. Once the PMMA set, it was removed from the mold and was stored for 24 hours to allow a complete polymerization. The specimens were then polished with pumice for 15 seconds using a felt wheel mounted on a laboratory lathe. In both groups, four crowns were considered as the samples for the pilot study.

Methods
Samples were randomly divided into eight groups with respect to the type of material and the mode of surface preparation. Groups one to four were polycarbonates and groups five to eight were PMMAs. Groups one and five were roughened with greenstone (CD-B20, Barrel diamond impregnated green stone, Prestige dental product, USA). Surface grinding with green stone was done with a low-speed hand piece at 2000 rpm for 10 seconds under constant pressure. Groups two and six were sandblasted with 50 μm aluminum oxide particles at 50 pound-force per square inch (psi) for 10 seconds and the nozzle was kept at a 10 mm distance from the surface (Micro-ETCH ERC II, Danville Engineering, San Ramon, California, USA). Groups three and seven underwent conditioning with CO₂ laser (SMART US-20, DEKA, Italy), in super pulse mode with 1 W power output setting, 2 Hz frequency, for 15 ms at a 12.5 mm distance. The laser irradiated a square area of 5 × 5 mm². This power was selected based on the results of the pilot study using CO₂ laser at 1, 2, 3, and 4 W power setting on the additional samples (n = 8) of both groups. This experiment suggested that 1 W power produces higher bond strength than other power settings. Groups four and eight were conditioned with MMA (Temptron, GC, Japan). The liquid was applied on the surface with disposable micro brush for five seconds. For bonding, the surface of each sample was rinsed with deionized water for 30 seconds and then dried with oil-free air. Subsequently, an adhesive primer (Transbond XT, 3M Unitek, Monrovia, Calif, USA) was applied on it. The adhesive paste was applied on the base of the metal standard Edgewise maxillary central incisor bracket with .022” slot and a surface area of 12.09 mm² (American Orthodontics, Sheboygan, W1, USA). The bracket was positioned on the crown and seated with firm pressure to minimize adhesive thickness. Light curing was done (Ortholux LED, 3M Unitek, USA) for 40 seconds (10 seconds on each wing). All the crowns were then mounted in dental stone cylinders (Elite Ortho, Zhermack, Germany).

For shear testing, a mechanical testing machine (Instron Corp, Canton, Massachusetts, USA) exerted an occluso-gingival force to the upper interface of the bracket base and crowns surface. SBS was measured at a crosshead speed of 0.5 mm/minute and calculated by means of dividing the force value by the bracket base area.

After the shear test, the brackets and crowns were analysed under a light stereomicroscope at 10X magnification to verify bond failure mode according to the adhesive remnant index (ARI). ARI scores were first stated by Artun and Bergland [22], ranging from 0 to 3 and categorize bond failure as follows:
• 0: no adhesive left on the crown surface;
• 1: less than half of the adhesive left on the crown surface;
• 2: more than half of the adhesive left on the crown surface;
• 3: the entire adhesive left on the crown surface.
The scanning electron microscopy (SEM) (LEO 1455 VP, Germany) analysis with ×1000 magnification was also performed.

Statistical analysis
Data were analysed by two-way analysis of variance (ANOVA) to assess the interaction between the crown type and surface treatment method as discriminating variables. An independent sample t-test was used to compare the effect of each surface preparation method on two types of crown. One-way ANOVA was performed to compare the effect of different surface treatment methods on the SBS of the brackets to each material. A Tamhane analysis was also used as a Post-hoc test to compare the conditioning methods. The Chi² test was used to determine whether the differences in the ARI scores of the conditioning methods were statistically significant (SPSS version 17.0, SPSS Inc.; Chicago, Illinois, USA). P-value ≤ 0.05 was considered as a level of significance.

Results
Two-way ANOVA determined a highly significant correlation between the crown type and surface conditioning method (P < 0.001). Student’s t-tests showed that in all surface treatments, the mean SBS of PMMA was significantly higher than that of polycarbonate (all P < 0.001). In the polycarbonate groups, the mean SBS of sandblasting was the highest (8.13 ± 2.23 MPa) and laser (2.54 ± 0.84 MPa) was the lowest. One-way ANOVA showed that there was a significant difference among the mean SBS of the surface treatment method (P < 0.001) (table I). The post-hoc Tamhane test demonstrated that sandblast and laser groups showed significant differences with other groups (P < 0.05) but there was no significant difference between grinding and MMA application (P = 0.993). Nevertheless, no significant differences were found between the surface treatment methods when PMMA crowns were studied (P = 0.076).
The ARI scores are presented in table II. Since only one sample had an ARI score greater than 1, we categorized the ARI score 0 as negative (no adhesive remained on the crown) and 1, 2, and 3 as positive (some adhesive remained on the crown). Chi-square test showed no significant difference among the ARI scores of different surface treatment methods for both polycarbonates (P = 0.439) and PMMAs (P = 0.156).
### Table I

**Mean shear bond strength (SBS) values and summary of statistical analysis.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Method</th>
<th>SBS (mean ± SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grinding</td>
<td>Sandblasting</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td></td>
<td>5.48 ± 2.22a</td>
<td>8.13 ± 2.23b</td>
</tr>
<tr>
<td>PMMA</td>
<td></td>
<td>13.47 ± 3.43a</td>
<td>14.78 ± 4.01a</td>
</tr>
<tr>
<td>P-value**</td>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*In each row, different letters in superscript show statistical significant difference between groups (post-hoc Tamhane test). PMMA: polymethylmethacrylate; MMA: methyl methacrylate. **Using one-way ANOVA test. *Using student’s t-test.

### Table II

**Adhesive Remnant Index (ARI) scores and results.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Method</th>
<th>ARI scores</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Negative (0), n (%)</td>
<td>Positive (1-3), n (%)</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>Grinding</td>
<td>19 (95)</td>
<td>1 (5)</td>
</tr>
<tr>
<td></td>
<td>Sandblasting</td>
<td>18 (90)</td>
<td>2 (10)</td>
</tr>
<tr>
<td></td>
<td>Laser</td>
<td>18 (90)</td>
<td>2 (10)</td>
</tr>
<tr>
<td></td>
<td>MMA</td>
<td>17 (85)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>PMMA</td>
<td>Grinding</td>
<td>17 (85)</td>
<td>3 (15)</td>
</tr>
<tr>
<td></td>
<td>Sandblasting</td>
<td>12 (60)</td>
<td>8 (40)</td>
</tr>
<tr>
<td></td>
<td>Laser</td>
<td>7 (35)</td>
<td>13 (65)</td>
</tr>
<tr>
<td></td>
<td>MMA</td>
<td>13 (65)</td>
<td>7 (35)</td>
</tr>
</tbody>
</table>

*PMMA: polymethylmethacrylate; MMA: methyl methacrylate.

### Discussion

Polycarbonate is a thermoplastic polymer. Besides the special composition, the surface integrity of the crown is enhanced through finishing and glazing procedures, which makes the surface conditioning difficult [7]. Sandblasting created randomized and profound irregularities. In the grinding group, the surface roughness was in the form of grooves, which were shallower than the sandblasted group based on SEM evaluation. MMA produced superficial fissures, which are of little benefit in improving the adhesive bond. On the other hand, application of CO₂ laser was not satisfactory and engendered detrimental effects on the polycarbonate. Heat produced by the laser beam melted the surface. Some microdroplets of resolidified molten material could be seen on the lased area (figures 1 and 2). It is clear that this method of surface conditioning should be avoided in polycarbonate crowns.

In a similar study, Blakey et al. [7] compared the effect of surface conditioning methods on the bond strength of metal brackets to polycarbonate crowns. Their results showed that the bond strength in crowns roughened by sandblasting was the highest. The SBS obtained by surface grinding and sandblasting was higher than the control group, although, not statistically significant. Overall, the bond strength in all groups was lower than that which was recorded in our study. It may be related to different instruments used for roughening the surface, different surface preparation time (Blakey et al. did not mention the sandblasting time) and different crosshead speed of the shear-testing machine. Blakey et al. used a crosshead speed of 0.254 mm/min, whereas we used 0.5 mm/min.

PMMA is a long single chain polymer, which has more carbon-carbon double bonds on the surface as a potential bonding site [10,13]. While grinding created small fissures, sandblasting created numerous micro porosities on the surface. It was seen that CO₂ laser and MMA application produced deep craters in a honeycomb pattern and swelled the surface with some hollow like retentive areas, respectively. Wetting the repaired surfaces with methyl methacrylate (MMA) has been used to soften PMMA [23]. This agent has a capability of swelling the PMMA surface and making it more soluble. Consequently, at the repair site, a strong chemical bond between PMMA and the resin material will be created [24].

Chay et al. [12] examined the effect of grinding with greenstone and sandblasting on SBS of brackets to PMMA restorations. Almeida et al. [2] worked on self-etching acrylic resin and used surface grinding with softex sandpaper disc, sandblasting and MMA application as the methods of surface treatment. Both studies concluded that there was no significant difference between the conditioning methods, which is in accordance with our study. In another study, Al Jabbari et al. [6] examined the outcome of grinding and sandblasting on the SBS of orthodontic brackets to PMMA. They reported that sandblasting provided significantly higher bond strength compared to grinding. The difference between the results of this study and others may be attributed to the grinding method and the instrument. Al Jabbari
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Figure 1
a–e SEM photomicrographs of polycarbonate with different surface conditioning methods (magnification: 1000 times): a: unconditioned surface; b: grinding; c: sandblasting; d: CO2 laser; e: MMA application
**Figure 2**

a–e SEM photomicrographs of PMMA with different surface conditioning methods (magnification: 1000 times): a: unconditioned surface; b: grinding; c: sandblasting; d: CO2 laser; e: MMA application
et al. [6] used silica carbide paper as the grinding instrument, but green stone was used as the grinding instrument in our study and the study of Chay et al. [12].

ARI was used in our study to specify the mode of bond failure. In both polycarbonate and PMMA groups, the brackets debonded at crown-adhesive interface, which is an adhesive type failure (score 0 and 1). This finding is in agreement with previous studies [2,7,12]. In addition, the mode of failure was independent of the surface preparation method. The study of Chay et al. [12] showed the same result. Conversely, Al Jabbari et al. [6] and Blakey et al. [7] reported that sandblasting had a significant effect on increasing the ARI scores.

Since oral environment can adversely affect the bond strength through adhesive resin degradation, it is recommended to evaluate the efficacy of the mentioned surface preparation methods in an in vivo study.

Conclusion

PMMA crowns, showed higher mean SBS than polycarbonate crowns.

In polycarbonate crowns, sandblasting produced the highest bond strength.

In PMMA crowns, the SBS is not depended on the surface treatment method.

In polycarbonate and PMMA crowns, the mode of failure is adhesive.

Acknowledgement: The authors thank the Vice-Chancellor of Shiraz University of Medical Sciences for supporting this research. The authors thank Dr. Mehdad Vosough of the Dental Research Development Center, of the School of Dentistry for the statistical analysis.

Disclosure of interest: The authors declare that they have no competing interest.

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