Original Article

Shear Bond Strength of Metallic Brackets: An In Vitro Study

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Abstract

Objective: To evaluate in vitro the shear bond strength of metallic brackets. Material and Methods: Forty premolars were divided into four groups (n = 10) according to the type of brackets used (G1: Morelli® Light; G2: Morelli® Standard; G3: Morelli® Max; G4: Abzil® Agile). For bonding, Transbond XT® (3M Unitek) resin was used in all groups. Teeth were embedded in ¾ inch PVC tubes with special plaster stone, perpendicular to the ground. Brackets were fixed on the geometric centers of the exposed crowns. After bonding, teeth were stored in distilled water, incubated at 37ºC for 24 hours and submitted to 500 thermal cycles for 30 seconds in each bath (5°C and 55°C), respectively. The bond strength test was performed on the Instron® mechanical testing machine with 3kg load cell at speed of 0.5mm/min. Data were submitted to statistical analysis through the Statistica® software, version 5.0, by Kruscal Wallis test, ANOVA and Tukey (p< 0.05). Results: There was no statistically significant difference in the ARI scores; whereas for shear resistance, this difference was significant (Averages: G1 - Light: 17.53MPa; G2 - Standard: 18.11MPa; G3 - Max: 29.33MPa; G4 - Agile: 11.37MPa) and G3 showed better performance, compared to the others. All other groups showed similar behavior among themselves. Conclusion: Max bracket had the highest shear strength. Further studies should be conducted to investigate the meshes of brackets tested in this study.

Keywords: Shear Strength; Orthodontics; Orthodontic Brackets.
Introduction

The detachment of brackets, the result of factors such as failure in the bonding technique, little retentiveness of the base of accessories, action of chewing force and the reduced size of these bases for aesthetic reasons are part of the orthodontic practice and result in delays in service and increase the maintenance cost of fixed orthodontic brackets [1].

The success of the direct bonding of the dental enamel began in 1965 [2], through a study that established the bonding of brackets to the buccal surface of the teeth. From these advances, fixed orthodontics became widespread and popular, reducing its costs and increasing the accessibility of patients to such treatment. So, orthodontists needed to adapt to this demand through the use of national brands or those manufactured in Brazil of lower cost compared to imported brands. However, it is necessary to assess these products as imported products are thoroughly studied in literature [3-6], since professionals need to know if these materials exhibit good quality and adequate strength to withstand the stresses imposed by the masticatory system.

Shear tests performed in laboratory are one of the most common scientific ways to measure and assess the adhesiveness of restorative materials to dental tissues. Undoubtedly, one of the greatest advantages of laboratory tests is the possibility of a strict control of the study phases, since external variables could influence the results. From the classic study that first assessed the adhesive dentistry in 1955 [7], these tests have been used to evaluate the bond strength of dental materials [3-8].

Several studies in literature have analyzed shear tests with metallic and ceramic brackets [9], with recycled brackets [5], with etch self-adhesive systems [10], with metal brackets fixed with composite photo and chemically activated resins [11] and different cleaning methods for orthodontic bracket bases [8]. Based on the above, the aim of this study was to evaluate in vitro the shear strength of metallic brackets.

Material and Methods

An experimental in vitro study using 40 upper healthy premolars (first and second) extracted for orthodontic indication was conducted. According to ethical precepts, this research was approved by the Ethics Research Committee of FIP (Integrated College of Patos) under Protocol: 094/2012.

Teeth were cleaned in running water and stored in distilled water under cooling for 30 days when they were autoclaved in aqueous medium (distilled water) for 15 minutes at 121°C and randomly divided into four groups (n = 10), as shown in Table 1. The adhesive system was Transbond XT Light Cure Adhesive (3M Unitek/ Monrovia, CA, USA)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Bracket</th>
<th>Fixing Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 1</td>
<td>Bracket Light Roth Slot 0.22 (Morelli®/Sorocaba, SP, Brazil)</td>
<td>Transbond XT</td>
</tr>
<tr>
<td>G 2</td>
<td>Bracket Standard Roth Slot 0.22 (Morelli®/ Sorocaba, SP, Brazil)</td>
<td>Transbond XT</td>
</tr>
<tr>
<td>G 3</td>
<td>Bracket Max Roth Slot 0.22 (Morelli®/ Sorocaba, SP, Brazil)</td>
<td>Transbond XT</td>
</tr>
<tr>
<td>G 4</td>
<td>Bracket Agile Roth Slot 0.22 (Abzil®/ São José do Rio Preto, SP, Brazil)</td>
<td>Transbond XT</td>
</tr>
</tbody>
</table>
Teeth were fixed in PVC tubes with ¾ inch in diameter and 25 mm of height, with special stone plaster so that crowns remained exposed and perpendicular to the base of PVC cylinders, and both perpendicular to the ground. After fixation, the buccal surfaces of teeth were submitted to prophylaxis with extra fine pumice and water, washed and dried for 20 seconds [4]. Then, specimens were etched with 37% phosphoric acid gel; washed and dried with compressed air for 15 seconds. Brackets were fixed on the etched surface and at the geometric center of the clinical crown, applying consecutively adhesive and resin on their bases and light cured according to times recommended by manufacturers.

After bonding, teeth were stored in distilled water at 37ºC for 24 hours [9], and submitted to 500 thermal cycles for 30 seconds in each bath (5°C and 55°C), respectively. Specimens were attached to the Universal Instron® testing machine and submitted to shear stress test by promoting the detachment of brackets at a rate of 0.5 mm / min and 3KN load cell.

After detachment, the buccal surfaces of teeth were analyzed through stereomicroscopic magnifying glass with magnification of 40 times to detect the amount of remaining adhesive and classified according to the Adhesive Remnant Index (ARI) [8-13], proposed in 1986 [14], with scores from 0 to 3: Score 0 = no remaining adhesive; Score 1 = less than 50% of the remaining adhesive; Score 2 = more than 50% of the remaining adhesive; Score 3 = 100% of the adhesive on the tooth.

Data obtained were evaluated using the Statistica software, version 5.0, through the following tests: Kruskal Wallis test for the ARI scores; and for shear strength, ANOVA and Tukey analysis were applied (p <0.05).

**Results**

For ARI scores, there was no statistically significant difference among groups. The highest prevalence of zero score occurred for G4 (Abzil® Agile) (80%), and the majority of fractures, considering all groups, occurred at the enamel / adhesive interface (57.5%). Fracture type distribution in the tooth-material interface according to group is shown in Table 1.

**Table 1. Fracture type distribution in the tooth-material interface according to group (ARI scores 0-3).**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CP2</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>CP3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>CP4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP6</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP7</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP8</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP9</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP10</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

*Kruskal Wallis test (p <0.05), not significant.*
For the shear bond strength, the results showed a statistically significant difference among groups (Means: G1 - Light: 17.53 MPa; G2 - Standard: 18.11 MPa; G3 - Max: 29.33 MPa; G4 - Agile: 11.37 MPa); G3 being superior to the others. G1, G2 and G4 showed behavior similar to each other. The strength values for each group, and their mean values are respectively shown in Table 2 and Figure 1.

Table 2. Shear strength values distribution in MPa for each of the groups.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP1</td>
<td>22.22</td>
<td>7.78</td>
<td>42.44</td>
<td>12.25</td>
</tr>
<tr>
<td>CP2</td>
<td>8.25</td>
<td>8.97</td>
<td>33.02</td>
<td>13.90</td>
</tr>
<tr>
<td>CP3</td>
<td>12.42</td>
<td>12.16</td>
<td>25.15</td>
<td>17.25</td>
</tr>
<tr>
<td>CP4</td>
<td>10.51</td>
<td>14.66</td>
<td>30.75</td>
<td>11.84</td>
</tr>
<tr>
<td>CP5</td>
<td>16.75</td>
<td>16.90</td>
<td>32.93</td>
<td>14.30</td>
</tr>
<tr>
<td>CP6</td>
<td>22.42</td>
<td>24.48</td>
<td>27.60</td>
<td>8.03</td>
</tr>
<tr>
<td>CP7</td>
<td>16.91</td>
<td>22.51</td>
<td>30.29</td>
<td>10.81</td>
</tr>
<tr>
<td>CP8</td>
<td>25.56</td>
<td>23.65</td>
<td>22.34</td>
<td>12.42</td>
</tr>
<tr>
<td>CP9</td>
<td>17.45</td>
<td>30.41</td>
<td>28.51</td>
<td>4.42</td>
</tr>
<tr>
<td>CP10</td>
<td>22.80</td>
<td>19.59</td>
<td>20.27</td>
<td>8.48</td>
</tr>
</tbody>
</table>

ANOVA and Tukey tests (p <0.05), significant.

Graph 1. Distribution of Means and Minimum and Maximum Shear Strength values. ANOVA and Tukey tests (p <0.05), significant.

Discussion

The bonding process is quite complex and involves the physicochemical characteristics of the adhesive system, dental substrate and the anatomical conformation of the bracket base. In addition, the professional technique should be developed according to protocols proposed by dental material manufacturers and technical steps of restorative dentistry.

Over the years, since the study carried out in 1965 [2], which idealized the bonding of brackets on the buccal surfaces of permanent teeth, numerous authors have studied ways of
improving bonding techniques and, increasingly, laboratory studies have shown great clinical applicability \[4-6,8,11,15-18\].

The great diversity of methods used in studies and the variety of statistical tests, substrates, samples and materials from different brands have made the comparison of results difficult. Therefore, the most used methodologies and statistical tests were applied to the study, as well as those most commonly used in literature.

The bonding material selected for fixing brackets (Transbond® XT) is frequently used in orthodontic bonding procedures, which is a brand already established in the dental market and in several studies in literature \[3,4,6-11\]. Conventional metallic orthodontic brackets were chosen because they are widely used in laboratory tests \[3-6\] and therefore widely used in orthodontic practice compared to national self-bonded and conventional imported materials.

ARI, classically described in literature in 1986 \[14\], despite being considered subjective, is the most complete method to define the fracture interface \[19,20\]. Regarding the scores of this index, there was no statistically significant difference. Links have failed, predominantly along the enamel / adhesive interface, which corroborates some results described in literature \[4-10\]; and disagrees from other studies \[3,13\]; where most fractures were in the bracket / adhesive interface. According to data discussed in a study published in 2009 \[13\] and pertinent to this discussion, the prevalence of failure in the bracket / adhesive bonding becomes a protective phenomenon to dental enamel, as at the time of detachment, this structure remains intact, preventing tissue damage through the loss of enamel fragments during removal of the orthodontic appliance.

Regarding the assessment of fractures predominantly occurring in this study, which were enamel / adhesive, anatomy, bending and retention of bases of orthodontic accessories may have been the factors responsible for the higher bonding strength between brackets and the bonding material. This result does not fail to favor the preservation of the dental enamel, discussed in the study mentioned above \[13\], because when the accessory with total adherence of the adhesive material on it detaches, the dental enamel will be submitted to minimum wear through drills for removal and cleaning of the remaining adhesive compounds.

As for the shear strength, significant differences were observed among groups, corroborating several studies published in literature \[4,9-11\]; and disagreeing from other studies \[3,8\].

The meshes of Standard, Ligth and Agile brackets have similar conformations, with small spaces among metal webs, which are welded on the bases of these accessories \[21-24\]. However, the sizes of these brackets differ, with Standard being larger than Ligth and Agile, which have similar sizes, highlighting the aesthetics of the fixed orthodontic appliance. However, this size difference did not lead to statistically different performances, and all showed similar shear strength.

Regarding Max bracket, according to literature \[21,24\], body and retentive base form a single structure, with base composed of pins of blasted surfaces and openings for the exit of air during bonding, when pressing the bracket against the dental crown.
It is suggested, therefore, that this difference in conformation among metallic meshes of accessories under study, may have contributed to greater adherence of the adhesive to the base of the Max bracket, achieving greater strength. However, other studies specifically focused on the bases of these orthodontic components must be carried out so that this hypothesis can be confirmed.

Shear tests contribute to the quality control of dental materials that are often launched into the market. However, these tests should always be conducted to reproduce possible clinical situations because no laboratory method can satisfactorily predict the clinical behavior of a material, but can provide some indication as to the quality and effectiveness of these products. Therefore, further studies should be conducted and clinical trials should complement laboratory trials. Further studies should specifically investigate the meshes of brackets tested in this study. Thus, it will be possible to provide dentists more security and reliability to choose their working material, and patients will benefit from a scientifically proven, more reliable and higher-quality treatment.

**Conclusions**

1) Morelli®Max bracket had the highest shear strength;
2) ARI has shown that most fractures occurred along the enamel / adhesive interface; and the highest prevalence of zero score occurred for Abzil® Agile bracket, but there was no significant difference among groups.

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**References**