A Comparative Evaluation of Bond Strength among Three Commonly used Straight Wire Brackets in Clinical Practice

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Abstract:
Background: The bonded brackets should have enough bond strength to withstand masticatory forces, and forces applied during orthodontic treatment and should enable easy debonding, clean up procedure at the end of the treatment without causing iatrogenic damage such as cracks and loss of enamel. Bond strength is reported as the initial mechanical load (stress) to fracture divided by the simple geometrically defined cross-sectional area of the bond. The bonded brackets should have enough bond strength to withstand masticatory forces, and forces applied during orthodontic treatment and should enable easy debonding, clean up procedure at the end of the treatment without causing iatrogenic damage such as cracks and loss of enamel. Bond strength is reported as the initial mechanical load (stress) to fracture divided by the simple geometrically defined cross-sectional area of the bond.

Materials and Methods: Shear and tensile bond strength of three commercially available pre-adjusted edge-wise premolar brackets with different base designs were used for the study on 54 premolar teeth. Hounsfield Tensometer Universal Testing Machine was used to determine the shear and tensile bond strengths. Shear strength and tensile strength were calculated. Statistical analysis: Students’ t-test and one-way ANOVA was performed.

Results: Ormco Optimesh brackets had the highest shear bond strength value of 20.08 MPa, followed by 3M Gemini bracket with a value of 16.22 MPa. The lowest bond strength value was noticed for TP Primekote brackets with 13.87 MPa. The tensile bond strength values of 3M Gemini brackets, Ormco Optimesh brackets and TP Primekote brackets were 7.42 MPa, 6.57 MPa and 7.31 MPa, respectively. The differences noted among the three brackets were not statistically significant.

Conclusion: There was a significant difference in shear bond strength of the three brackets compared. There was no significant difference in the tensile bond strength between the three brackets compared. Ormco Optimesh bracket and 3M Gemini bracket is a good choice for Orthodontic bonding in clinical practice.

Key Words: Bond strength, Ormco Optimesh bracket, TP Primekote bracket group, 3M Gemini wovenmesh bracket

Introduction
The bonded brackets should have enough bond strength to withstand masticatory forces, and forces applied during orthodontic treatment. Bond strength is reported as the initial mechanical load (stress) to fracture divided by the simple geometrically defined cross-sectional area of the bond, calculated as:

\[
\text{Bond Strength} = \frac{\text{Debonding force in Kgs} \times 9.8}{\text{Surface area of the bond in mm}^2} \text{ (and expressed in mega pascals.)}
\]

There are different types of bond strengths are evident.²

1. Shear bond strength, when the debonding force is applied parallel to the bonded surface
2. Tensile bond strength, when a tensile force is applied perpendicular to the bonded surface
3. Torsional bond strength, when a rotational force is applied
4. Peel bond strength, when a relatively light force is applied at the bonded bracket edge.

Bond strength of bonded orthodontic attachments is influenced by various factors like protocol followed during bonding procedure, method of conditioning of enamel, type of adhesive used, bracket type, and bracket base design.

Basically, 4 types of orthodontic attachments are available for bonding, i.e., plastic (polycarbonate), plastic with metal reinforcing, metal, and ceramic. Metal bracket relies on mechanical retention since adhesives used for bonding do not bond to metals.

This study was, therefore, undertaken to comparatively evaluate the shear and tensile bond strength of TP Nu-edge L.
N bracket system with Primekote base with that of Stainless Steel Optimesh brackets and Stainless Steel Gemini brackets with 80-gauge woven mesh base.

Thus, the aim of this study is to evaluate shear and tensile bond strength of Metal - Chrome Cobalt TP Nu-edge L N bracket system with Primekote base and to compare it with that of Metal - Stainless 3M Gemini Steel bracket with woven mesh base and Metal - Stainless Ormco Steel bracket with Optimesh base.

Materials and Methods
Shear and Tensile bond strength of three commercially available pre-adjusted edgewise premolar brackets with different base designs as given below were evaluated in this study.

Samples – brackets

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Base design</th>
<th>Number of samples</th>
<th>Surface area: As specified by manufacturer</th>
<th>Shear</th>
<th>Tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemini 3M Unitek</td>
<td>Metal-stainless steel</td>
<td>80-gauge woven mesh with smooth surface (mechanical retention)</td>
<td>9</td>
<td>10.58 mm²</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Monrovia, CA, U.S.A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimesh Ormco, Sds</td>
<td>Metal-stainless steel</td>
<td>Woven mesh with thermally sprayed metal particles (mechanical retention)</td>
<td>9</td>
<td>10.66 mm²</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Glendora, CA, U.S.A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primekote, TP Orbdontics, Inc., Laporte, Indiana, U.S.A</td>
<td>Metal-cobalt chromium</td>
<td>Woven mesh with smooth surface (chemical and mechanical retention)</td>
<td>9</td>
<td>9.23 mm²</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

Substrate
Premolar teeth: 54 numbers.

Armamentarium
Hounsfield Tensometer (Tensometer Ltd., Croydon, England) Universal Testing Machine was used to determine the shear and tensile bond strengths (Figure 1).

Procedure
The selected brackets were bonded to the extracted premolar teeth to test the bond strength.

Preparation of the sample, prior to testing
54 premolar teeth which were extracted for the orthodontic purpose were cleaned of the soft tissue and then stored in thymol solution (0.1% Nt/vol) to prevent dehydration and bacterial growth. The teeth chosen were without any clinically visible enamel defects and free of restorations or caries that may decrease enamel strength. To mount the teeth in the Hounsfield testing machine, these teeth were fixed in a self-cure acrylic block. The acrylic blocks were made by pouring a thin consistency of the acrylic into a rectangular dye made of rubber base material.

The teeth fixed to the acrylic blocks were divided into three groups of 18 samples each. Color coding was done for all the groups for easy identification. Pink color – TP Primekote bracket group, White color – 3M Gemini wovenmesh bracket group and green color – ORMCO Optimesh bracket group. The selected brackets types were then bonded to the teeth mounted on the respective color coded acrylic blocks (Figure 2).

Transbond XT light-cure adhesive system (Figure 3) was used for bonding the brackets according to the following procedure.
1. Etching of enamel on the buccal surface of the tooth with 37% phosphoric acid solution for 30 s.
2. Rinsing of the etched enamel surface with water for 20 s and drying with oil-free air spray.
3. Application of transbond-XT bonding primer to the etched enamel surface and light curing it for 10 s.
4. Application of a uniform layer of transbond-XT adhesive to the base of the bracket, positioning the bracket on the tooth and removal of excessive flash around the brackets.

5. Light curing with a dentaurum light cure unit on the adhesive for 10 s on all four sides of the bracket.

The above procedure was done for all 54 samples, which are to be tested. The bonded teeth were then stored in water for 24 h prior to testing.

A special blade in cast iron was custom made with a beveled edge to apply a shear force (Figure 3). 010 double stranded ligature wire was used for applying tensile force (Figure 3). 18 samples in each group were subdivided further into two. The sub-divided group consisted of nine samples each for testing shear bond strength and tensile bond strength.

**Tests for assessing shear and tensile bond strengths**

Shear bond strength of the bonded samples were tested using a Hounsfield-universal testing machine. The upper holder of the testing machine was fitted with the custom made blade, and the lower holder was fitted with the bonded tooth sample to be tested. The sample was mounted vertically so that a shear force can be applied. The upper holder was moved to the bracket on the bonded tooth sample with a cross-head speed of 2 mm/min and force value was noted at the point when the bond failure occurred. The force value was read in Newtons directly from the digital monitor of the testing machine.

Bond strength was calculated in mega Pascals by using the following formula:

\[ \text{MPa} = \frac{\text{Force in Newtons}}{\text{Surface area of the bracket in mm}^2} \]

Tensile bond strength of the bonded samples was also tested using a Hounsfield-universal testing machine. Double strand of 0.010 ligature wire was looped around the bracket. The acrylic block with ligature wire looped around the bracket was placed in the lower holder in a horizontal position. The free end of the double stranded ligature wire was attached to the upper holder so that the ligature wire was pulled upwards at a cross-head speed of 2 mm to apply tensile force. Force value was noted at the point when the bond failure occurred, and the value was read in Newtons directly from the digital monitor of the testing machine.

Bond strength was calculated in mega Pascal's by using the following formula:

\[ \text{MPa} = \frac{\text{Force in Newtons}}{\text{Surface area of the bracket in mm}^2} \]

The above procedures of testing shear and tensile bond strengths were repeated for all 54 samples and their respective bond strength calculated and subjected to statistical evaluation.

**Statistical analysis**

Student’s *t*-test and one-way ANOVA was performed.

**Results**

Ormco Optimesh bracket had highest mean value of 20.08 MPa for the shear bond strength, followed by 3M Gemini bracket with a value of 16.22 MPa. The lowest mean value was for TP Primekote bracket and it was 13.87 MPa. The standard deviation for 3M Gemini, Ormco Optimesh and TP Primekote brackets were 1.89, 2.64 and 1.92, respectively. The variations noted in the shear bond strength among the three brackets were statistically significant (Table 1 and Graph 1).

### Table 1: Student’s *t*-test for shear bond strength.

<table>
<thead>
<tr>
<th>Type of Bracket</th>
<th>Shear strength Mean±SD</th>
<th>Comparison groups</th>
<th><em>t</em> value</th>
<th><em>P</em> value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gemini</td>
<td>16.22±1.89</td>
<td>1 versus 2</td>
<td>3.56</td>
<td><em>P</em>&lt;0.01 (significant)</td>
</tr>
<tr>
<td>Optimesh</td>
<td>20.08±2.64</td>
<td>1 versus 3</td>
<td>2.60</td>
<td><em>P</em>&lt;0.05 (significant)</td>
</tr>
<tr>
<td>Primekote</td>
<td>13.87±1.92</td>
<td>2 versus 3</td>
<td>5.69</td>
<td><em>P</em>&lt;0.001 (significant)</td>
</tr>
</tbody>
</table>

SD: Standard deviation

**Figure 3:** Adhesive system and instruments used for bonding. Custom made blade and wire for applying load.

**Graph 1:** Comparison of shear bond strength for Gemini, Optimesh and Primekote.
3M Gemini bracket had a slightly higher mean value in tensile bond strength than TP Primekote and Ormco.

Optimesh brackets, which, however, was not significantly different. They mean values were 7.42 MPa, 6.57 MPa with standard deviation of 1.21, 0.78, and 0.68 for 3M Gemini, Ormco Optimesh and TP Primekote brackets, respectively (Table 2 and Graph 2). The observation made for shear bond and tensile bond strength test for the three different bracket groups were further confirmed using ANOVA test (Tables 3 and 4).

Discussion

Bond strength is one of the main criteria for success in bonding without which, a stable bracket - adhesive interface to transfer the loads generated from the engagement of an activated arch wire to the teeth and to withstand the masticatory forces would not be possible. Orthodontic bond strength assessment can be done using finite element analysis, modeling components of the enamel – adhesive – bracket system and finding the stress distributions on it.

In this study, an in vitro bond strength characterization was chosen due to relative simplicity, mode of load application by shear and tension. Shear and tensile bond strength tests were performed, since shear bond strength test simulates masticatory forces applied on the bracket, and tensile bond strength test simulates the force applied on the bracket by tying the arch wire to the bracket. Torsional bond strength has been considered as less relevant to clinical practice and so this test was not performed in this study.

Bond strength is influenced by many factors namely the nature of the enamel surface, preparation of enamel surface, type of the adhesive system and designs of the bracket base influences bond strength. Hounsfield Tensometer (Tensometer Company, Croydon, England) was used to determine shear and tensile bond strengths in this study, Hounsfield is similar to Instron Universal testing machine, which is being used by many of the investigators. The difference is being only in the manufacturing company.

For shear bond strength testing, a custom made blade was fabricated to apply a shear stress. Wire or Jig looped around the bracket and pulled in a parallel direction, though apply a shear stress it also possess a tensile property, hence to avoid this drawback, a blade was used. For testing tensile bond strength double stranded. 010 ligature wire was looped around the bracket and a tensile pull was applied in direction perpendicular to the bracket.

The result of this study showed that there is a statistically significant variation in the shear bond strength among the three bracket studied.

Optimesh brackets had the highest shear bond strength value of 20.08 MPa, followed by Gemini bracket with a value of 16.22 MPa. The lowest bond strength value was noticed for Primekote brackets with 13.87 MPa. The finding, however, is in contrast to the observations made by Devanathan. They have reported significantly enhanced bond strength for Nu-edge bracket.

Optimesh brackets had the least shear bond strength values, proving that providing a chemical retention for a metallic attachment is good in theory but did not prove to be effective in practice and priming of metal base has not been able to obviate the need for mechanical locking as reported by Reynolds and von Fraunhofer and Matasa. This can possibly be due to the primer applied to the mesh base partially obliterating the mechanical retentive mesh base.
The tensile bond strength value of all the brackets studied was generally about one-half of the values noted for shear bond strength. This is possibly due to tensile force being directed perpendicular to the enamel rods. The tensile bond strength values of Gemini brackets, Optimesh brackets and Primekote brackets were 7.42, 6.57, and 7.31 MPa, respectively. The differences noted among the three brackets were not statistically significant. The values obtained in the study was similar to values noted by Reynolds (1976) where he suggested tensile bond strength values between a range of 5.9 and 7.9 MPa was adequate to withstand orthodontic treatment forces.

**Summary and Conclusion**

1. There was a significant difference in shear bond strength of the three brackets compared.Ormco Optimesh bracket had the highest shear bond strength, followed by 3M Gemini bracket and the lowest shear bond strength was noticed for TP Primekote brackets.
2. There was no significant difference in the tensile bond strength between the three brackets compared.
3. Thus, Ormco Optimesh bracket and 3M Gemini bracket is a good choice for Orthodontic bonding in clinical practice.

**References**