Bracket Bond Strength with Transillumination of a Light Activated Orthodontic Adhesive and the Effect of Curing Time and Tooth Thickness on it: An in vitro Study

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ABSTRACT

Objective: This study was conducted to compare the shear bond strength of brackets bonded with the conventional technique, transillumination technique and the combination of both the techniques; the effect of curing time on the bond strength of the brackets bonded with the transillumination method; and the amount of light passing through different thickness of teeth.

Materials and methods: The study was conducted in vitro on 175 extracted human teeth (50 incisors and 125 premolars). In the first part of the study, the amount of light passing through different thickness of teeth was studied and, for second part, brackets were bonded with transillumination method and conventional method followed by shear bond strength testing using an instron machine.

Results: The amount of light passing through the tooth depends on the thickness of the tooth. Only a small fraction of the original light intensity passes through the tooth but this is adequate to achieve clinically acceptable bond strengths.

The bond strength achieved with transillumination method is comparable to the conventional light cure technique. Ten seconds of transillumination followed by conventional curing leads to an increase in bond strength and this increase is clinically significant.

Conclusion: Transillumination technique is a viable method for bonding orthodontic attachments.

Keywords: Transillumination, Orthodontic bracket, Bond strength.

INTRODUCTION

Buonocore in 1955 demonstrated the increased adhesion of attachments to tooth surface by conditioning enamel surface with 85% phosphoric acid for 30 seconds. This finding of Buonocore was brought into use in orthodontics by Newman in 1965 when he used epoxy resins to bond orthodontic attachments to teeth. Since then various advances in bonding systems in the form of better bonding materials, increase in bond strength, different types of curing systems, decrease in curing times as well as combining the various steps of bonding have led to ease of bonding and thus their increased popularity.

The normal or conventional method of bonding by light cure technique is through labial curing of the adhesive. It has been noted that light can be passed through teeth, that is, teeth show the property of transillumination. Transillumination directs the light through the tooth to the composite material placed on the other side of the tooth. This can be used when metal covers the majority of the composite material on the tooth, such as, in the case of metal orthodontic brackets. Thus, transillumination from the lingual side to light cure the composite resin has been advocated by some authors.

Oesterle et al studied the amount of light passing through teeth but the effect of the buccolingual tooth dimension on the light transmittance was not dealt with. Also there is no data to check the bond strength when both labial curing and transillumination are used simultaneously. Besides, the appropriate time required for curing and the effect of the buccolingual dimension of the tooth on the bond strength has not been dealt with adequately.

AIMS AND OBJECTIVES

The objectives of this study were as follows:

1. To compare the shear bond strength of brackets bonded with conventional technique, transillumination technique and a combination of the two.
2. To study the effect of curing time on the bond strength of the brackets bonded with the transillumination method.

3. To study the amount of light passing through different thickness of teeth and to evaluate the effect of tooth thickness on the bond strength of brackets bonded with the transillumination technique.

**MATERIALS AND METHODS**

Ethical clearance for this study was obtained from the college and there was no conflict of interest for any author. The study was self-financed and self-funded.

The present study was divided into two parts. In the first part of the study, the effect of tooth thickness on the amount of light passing through the teeth was studied.

In the second part of the study, comparison of the bracket bond strength between conventional light cure technique and the transillumination technique was done.

This study was conducted on 175 extracted human teeth—125 maxillary first premolars (orthodontic extractions) and 50 maxillary central incisors (from patients who had periodontally compromised dentition and had to undergo extraction of maxillary central incisors). The teeth were stored in a solution of 0.1% (wt/vol) thymol to prevent dehydration and bacterial growth.

A total of 125 upper premolar and 50 maxillary incisor brackets were used for the study (Gemini series, 3M Unitek, Monrovia, California). The bonding material used was Transbond XT with Transbond XT primer (3M Unitek, Monrovia, California). A conventional tungsten-quartz halogen curing light (3M Unitek) was used for the study.

To study the amount of light passing through the teeth, a Dual Channel Optometer (Model S 380, United Detector Technology) was used with a sensitivity of 1µW and a range of 450 mW. For the first part of the study, one group of premolars and incisors of 25 teeth each were taken as designated in Table 1. Following this the average thickness of teeth in each of the two groups was calculated using a Vernier Caliper.

Now the amount of light passing through the teeth for both the groups was calculated. For this the curing unit and the power meter were kept at standardized distance of 14 mm (fixed to accommodate the buccolingual thickness of the premolars and the bracket) and the light was made to pass through the tooth. A clay mould was made individually for each tooth to prevent the scattering of light. Then the readings from the power meter were recorded. Also the original intensity of light was calculated by placing the power meter and light guide at the standardized position with no tooth structure in between to facilitate comparison. The results obtained were subjected to Students t-test to know the difference in light passing through different thickness of teeth.

For the second part of the study five groups of maxillary premolars with 25 teeth each and two groups of maxillary incisors with 25 teeth each were taken. The teeth used in the first part of the study were also included for the second part and they were distributed randomly. The buccal surfaces of the teeth were polished with pumice slurry, then washed with distilled water and dried using oil free air from a three way syringe. This was followed by bonding of brackets on to the tooth surface as described in Table 2.

The bond strength in shear mode was recorded with Instron universal testing machine. A load side density of 0 to 50 kg was set in the Instron universal testing machine and the crosshead speed was adjusted for 1 mm per minute. Load was progressively applied till the bracket was debonded from the tooth surface.

| Table 2: Bonding protocol for various groups of incisors and premolars |
|---|---|---|
| Groups | Type of teeth | Curing protocol |
| Group 1 | Maxillary central incisors | Brackets bonded with conventional technique, i.e. curing time of 20 seconds mesially and 20 seconds distally. |
| Group 2 | Maxillary central incisors | Brackets bonded with transillumination technique from lingual fossa with a curing time of 40 seconds. |
| Group 3 | Maxillary first premolars | Brackets bonded with conventional technique, i.e. curing time of 20 seconds mesially and 20 seconds distally. |
| Group 4 | Maxillary first premolars | Brackets bonded with transillumination technique from occlusal surface with a curing time of 40 seconds. |
| Group 5 | Maxillary first premolars | Brackets bonded with transillumination method from occlusal surface with a curing time of 30 seconds. |
| Group 6 | Maxillary first premolars | Brackets bonded with transillumination method from occlusal surface with a curing time of 50 seconds. |
| Group 7 | Maxillary first premolars | Brackets bonded with transillumination method from occlusal surface with a curing time of 10 seconds followed by the conventional method. |
The values obtained in Newton were converted into MPa. For this, the surface area of the bracket was calculated with a stereomicroscope. Modified ARI was used to check for the site of bond failure in all the groups.

RESULTS

The results show that when no clay blocker was used and with the light guide placed just against the sensor, the power recorded was 427 mW. When no clay blocker was used and with the light guide in the standardized position, the power recorded was 318 mW. When clay blocker was used and with the light guide in the standardized position, the power recorded was 346 mW. With the incisor of mean thickness of 6.1 mm (Group A) placed in standardized position with clay blocker, the power meter reading was 2.02 ± 0.23 mW. With a premolar of mean thickness of 13.1 mm placed in standardized position with clay blocker, the power meter reading was 1.08 ± 0.31 mW (Tables 3 and 4).

The shear bond strength was recorded for each of the 25 teeth in all the seven groups (Table 5).

The 'p' values showed that there was no significant difference between the shear bond strengths of various groups except for groups 5 and 7 (Table 6).

The mean ARI values (Table 7) for incisor teeth were 3.1 for Group 1 and 1.9 for group 2. For the premolars, the ARI values were 3.3 for Group 3, 2.5 for Group 4, 2.6 for Group 5, 2.2 for Group 6 and 3.0 for Group 7.

DISCUSSION

The introduction of light cure adhesives to orthodontics was done in the year 1979 by Tavas and Watts. They had used the transillumination technique for bonding orthodontic attachments. Since then, light curing from the same side as that of the attachment placed has been the conventional method of bonding attachments to the tooth surface and the transillumination technique has been long forgotten.

One of the major drawbacks of composite materials is its high shrinkage toward the light source. When curing composite material from the same side (conventional technique) there is a tendency for the bulk of the material to move away from the tooth structure (etched enamel rods) toward the light source and thus it may cause not only a weakening of the bond strength but also increased microleakage at the tooth composite interface. Various methods have been advocated to overcome this drawback including the use of dual cure composites, pulsed-light sources and ramped light where the intensity of light increases gradually. Although these methods can reduce this shrinkage to some extent, yet they cannot overcome this drawback totally. Using transillumination technique for polymerization of composite material, this shrinkage may be more of a benefit than a drawback. When light source is directed at the tooth surface from the opposite side, the composite tends to move toward the light source, that is, it will move toward the tooth or into the etched enamel rods, thereby increasing the bond strength.

Another drawback of the conventional method is that most of the composite material is covered by the bracket. Little or no light passes through the bracket and the central part of the composite below the bracket may remain uncured. The curing of the composite is dependent on the total light energy reaching it. The total light energy in turn is dependent on the intensity of the light source, the duration of cure and the distance between the light guide tip and the composite material. Rueggeberg et al have shown that a minimum of 400 mW/cm² of light intensity is required for complete polymerization of composite material. The general assumption has been that the use of transillumination technique which involves directing the light through the opposite enamel, the dentin, the pulp chamber, and through the adjacent dentin.
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...and enamel to reach the composite material would require considerably more light energy and thus more curing time.13,14 This is explained on the basis that most of the light is scattered within the pulp chamber and absorbed by the tooth surface, so only a very small fraction of the original intensity of light is utilized for the purpose of polymerization of the composite material present below the bracket. Behrents et al13 suggested the increase in curing time to 2 minutes to ensure complete polymerization when using transillumination technique for bonding. Cheng et al 15 in their study found that even by increasing the curing time up to three times, complete polymerization of the composite material was not seen with transillumination technique. They also suggested that complete curing may not in fact be necessary for adequate bond strength. Cacciafesta et al16 suggested the use of high powered lights for curing by transillumination.

In the first part of the current study the buccolingual thickness of maxillary central incisors and maxillary first premolars was calculated and the amount of light passing through various thicknesses of teeth was calculated. According to the Beer-Lambert Law the intensity of light (or any other form of electromagnetic radiation) passing through a sample diminishes exponentially with the concentration and the thickness of the sample. In case of our study this would depend only on the thickness of the sample, the rest of the parameters being constant.

The results suggested that approximately 90% of the light intensity was lost when transillumination technique is used for bonding. Further it also shows that as the buccolingual dimension of the tooth increases there is a corresponding decrease in the amount of light that passes through the tooth. In spite of only a small amount of light reaching the composite material it was found that the bond strength of brackets cured by conventional method and transillumination technique were almost the same.

The shear bond strength values obtained by transillumination method in this study were higher than what would be expected from the light transmittance data. This suggests that even with the less than the recommended light energy, achieved polymerization was sufficient to give adequate bond strength values. This can be explained due to two phenomena. In the conventional technique due to the presence of bracket and due to the convexity of the teeth almost none of the composite material gets cured directly by the light source. In order that the light reaches the composite adhesive, the light must be refracted within the enamel, the dentin and the pulp chamber back to the composite beneath the metal bracket base. Additionally the physical presence of the bracket prevents the light guide tip from being placed directly on the tooth surface, further decreasing the total light energy as a function of distance. This is similar to the light interference and the increased distance that occurs in transillumination, where light must be transmitted and refracted through the increased thickness of enamel, dentin and pulpal tissues. This means that probably the degree of polymerization of the composite material is almost the same whether we use conventional technique or transillumination technique.

The second phenomenon that may explain this finding is that with the transillumination technique, the composite material moves toward the tooth tissue into the enamel rods rather than moving away from the rods as in case of bonding with conventional light cure technique. This in turn may lead to the formation of deeper resin tags with a better retention on to the enamel surface and thereby increase the bond

Table 6: Comparison of test of significance in premolars and incisors for brackets bonded with different techniques

<table>
<thead>
<tr>
<th>Groups</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Group 2</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
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</tr>
<tr>
<td>Group 4</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
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<td>Group 5</td>
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<tr>
<td>Group 6</td>
<td>&gt;0.05</td>
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<td>&gt;0.05</td>
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<tr>
<td>Group 7</td>
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<td>&gt;0.05</td>
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</table>

Table 7: Modified ARI scores of brackets bonded with conventional technique and transillumination technique

<table>
<thead>
<tr>
<th>Score</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 All adhesive on tooth</td>
<td>24%</td>
<td>48%</td>
<td>20%</td>
<td>44%</td>
<td>40%</td>
<td>56%</td>
<td>32%</td>
</tr>
<tr>
<td>2 More than 90% adhesive on tooth</td>
<td>20%</td>
<td>28%</td>
<td>12%</td>
<td>4%</td>
<td>16%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>3 10-90% adhesive on tooth</td>
<td>8%</td>
<td>8%</td>
<td>24%</td>
<td>16%</td>
<td>4%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>4 Less than 10% adhesive on tooth</td>
<td>16%</td>
<td>16%</td>
<td>12%</td>
<td>28%</td>
<td>12%</td>
<td>16%</td>
<td>28%</td>
</tr>
<tr>
<td>5 No adhesive remaining on tooth</td>
<td>32%</td>
<td>0%</td>
<td>32%</td>
<td>8%</td>
<td>28%</td>
<td>12%</td>
<td>24%</td>
</tr>
</tbody>
</table>
strength. In a study by King et al, no clear relationship was found between the tooth thickness and the bond strength.\(^{17}\)

The present study found that an increase in tooth thickness is related to a decrease in the intensity of light passing through it. In case of incisor teeth which were cured by 40 seconds of transillumination the bond strength was found to be slightly higher than 40 seconds of conventional cure whereas in premolars which have a greater buccolingual diameter the bond strength of teeth cured by transillumination was slightly less than that cured with 40 seconds of conventional light cure method. This finding suggests that on increasing the tooth thickness there is a corresponding decrease in the shear bond strength.

Brackets cured by 10 seconds of transillumination followed by 40 seconds of conventional curing the bond strength was higher than that of any other group. This can again be explained due to the fact that with initial lingual curing the resin tags would have moved into the enamel surface and then a better cure might have been established with the conventional curing method. The other finding was that in this group the standard deviation was minimum suggesting more uniform bond strength with this method. One of the methods to evaluate whether there is any increase in the resin tag formation by the transillumination method as compared to the conventional light cure technique is by evaluating the site of failure following the debonding procedure. Hence, the modified ARI index was used to evaluate the site of failure for all the groups. The results indicated that in brackets bonded with the transillumination technique the mean ARI index scores were higher than those bonded with the conventional light cure technique. This also suggests that there may be a lower microleakage at bracket composite interface by transillumination technique.\(^{18}\)

One of the problems of using transillumination technique for bonding orthodontic attachments is the increased transmission of heat as well as light energy to the tooth and the dental pulp tissues. The exothermic reaction of the polymerizing composite also generates additional heat. Increases in pulpal temperature above 42.5° are reported to produce irreversible damage to the pulpal tissues. Hannig and Bott\(^{19}\) in a study on Class II restorative preparation with 1 mm of dentin between pulp and composite resin found the temperature increase in pulpal chamber up to 6°C with 40-second exposure with conventional tungsten-quartz curing light. With a xenon plasma arc curing unit they found the 40-second exposure with conventional tungsten-quartz curing leads to an increase in bond strength, which may be clinically significant. The amount of light passing through the tooth depends on the thickness of the tooth. Only a small fraction of the original light intensity passes through the tooth but this is adequate to achieve clinically acceptable bond strength.

Further research needs to be done to check the microleakage and to establish transillumination technique for bonding orthodontic attachments as a routine in clinical practice.

**SUMMARY AND CONCLUSION**

Transillumination technique is a viable method for bonding orthodontic attachments. The bond strength achieved with this method is comparable to the conventional light cure technique. Ten seconds of transillumination followed by conventional curing leads to an increase in bond strength, which may be clinically significant. The amount of light passing through the tooth depends on the thickness of the tooth. Only a small fraction of the original light intensity passes through the tooth but this is adequate to achieve clinically acceptable bond strength.

**REFERENCES**

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