An in vivo comparison between a visible light-cured bonding system and a chemically cured bonding system

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Direct bonding of brackets has become a routine procedure in clinical orthodontics. Many techniques and materials are currently advocated and used, the most recent being light-cured composites. Advantages of the light-cured systems are their relative ease of use, improved bracket placement, and more rapid set of the composite. For a new system to be clinically viable, it must possess properties that are at least as reliable as existing systems. The purpose of this longitudinal clinical study was to evaluate and compare the rate of success and/or failure between a visible light-cured bonding material (Sequence) and a chemically cured bonding material (System 1+), using both systems in every patient. Contralateral quadrants were bonded with each system respectively. A total of 32 patients were followed for a mean period of 11 months (range of 3 to 21 months), with a total of 531 brackets bonded, 265 with visible light-cured and 266 with chemically cured resins. Failures for each system were recorded and failure rates calculated. The failure rate of the visible light-cured composite was 11.3% and that of the chemically cured composite was 12%. A Chi-squared ($\chi^2$) test did not reveal any statistically significant differences between the failure rates of the two systems, ($\chi^2 = 0.014$, df-1, $P > 0.9$). (Am J Orthod Dentofacial Orthop 1998;113: 271-5.)

Buoacore1 in 1955 introduced a method of etching enamel to enhance retention of acrylic restorations, and later Bowen2 developed a restorative material commonly referred to as a composite resin (BIS-GMA). Bonding systems and materials have undergone continued improvement over time. The acid etch process commonly used selectively dissolves the inorganic component of the enamel, thus creating many microscopic and submicroscopic pores and crevices that enhance retention of the composite to the etched enamel surface. The optimum concentration of acid to produce a consistent, evenly distributed, and optimal depth etch pattern is in the range of 30 to 50%.1,3,4 The most commonly used orthodontic etching agent is 37% orthophosphoric acid applied for 30 to 60 seconds;3 however, it has been shown that the time and concentration for the acid etching technique may be reduced.4,6

When an appropriate resin material is applied to a dry etched enamel surface, it is likely to be attracted to it by the physical or chemical forces of adhesion, which establish molecular contact. After polymerization of the resin has occurred, projections of the composite material will have penetrated into the enamel microporosities and serve to mechanically bond the resin onto the enamel surface.7-11

The chemically cured composites (self-curing acrylics) were the first systems developed for orthodontic bracket bonding.12 After the development of the BIS-GMA resin by Bowen,2 various modifications have been made to alter their properties and to enhance their performance in clinical use. More recently, the curing methods have been improved, with the most recent method being light curing of the resin. Ultraviolet (UV) light sensitive resins were developed as an alternative to the self-curing resins, the latter having a more rapid polymerization time. Earlier UV light-curing units had some disadvantages in that they leaked UV radiation, which, in turn, could reportedly produce skin cancer, eye damage, and erythema.13-18 Furthermore, the UV sensitive resin had a limited depth of curing that could not be improved.19

Owing to the limitations of the UV light systems, a visible light system was suggested by Douglas et al.20 The latter had curing units with a blue filter that
produced blue light at 420 to 450 nm. In addition, a new visible light sensitive resin system was designed to absorb blue light and initiate polymerization (photopolymerization). The visible light-curing units are regarded as being less hazardous than were the UV light systems. In addition, the curing depth of the composite resin was increased, and the visible light-cured composites required less light exposure time to cure. The first report of the clinical use of a visible light-cured composite was published by Bas-siony and Grant,21 in which they concluded that the new resin was easier to use. Tavas and Watts22 developed the transillumination technique to bond metal brackets onto teeth in vitro with visible light-cured composite. Read23,24 likewise published clinical studies that used the transillumination technique to bond metal brackets to teeth.

Clinically, bond failure can occur when excessive forces, shearing, tensile, or torque forces, are applied to the bond. Failure results either at the enamel-resin interface, within the bonding material, at the resin bracket interface, or within the enamel.25,26

Both light-cured and chemically cured composites have been shown to be clinically acceptable and effective.18 There have been investigations evaluating the bond strengths of both chemically cured and light-cured composites, but the majority of these investigations have been in vitro studies.27-32,33 The results of in vitro studies have often been extrapolated to validate their clinical use. Results from laboratory investigations have suggested that visible light-cured composites have similar physical properties to the chemically cured composite resins. The failure rates of brackets bonded with visible light-cured or chemically cured composites have been assessed,34,35 but the reported failure rates have varied from study to study for both visible light-cured and chemically cured composites.

Whereas the chemically cured bonding systems have proven clinical applications, the visible light-cured bonding systems, while in clinical use, do not as yet have an adequate long-term clinically proven record.

The objective of the present investigation was to determine the in vivo differences in failure rate, if any, between a chemically cured bonding system and a visible light-cured bonding system.

MATERIAL AND METHOD

The subjects participating in this study were from the pool of patients seeking orthodontic treatment in the Orthodontic Department of the School of Dentistry of the University of Alabama at Birmingham.

Orthodontic brackets were bonded onto the teeth of 32 consecutive patients (10 male and 22 female). No selection was made based on sex, age, or race. The bonding followed a contralateral quadrant pattern (Fig. 1). Two hundred and sixty-five brackets were bonded with visible light-cured composite and 266 with chemically cured composite. A total of 531 attachments were bonded in this study. The contralateral bonding pattern was randomly alternated from patient to patient to eliminate any bias that may have been introduced from the clinician being right-handed. All the patients had fixed orthodontic appliances placed on the upper and lower arches. Mini diamond brackets (Ormco) were used with both the chemically cured bonding material (System 1+, Ormco) and the light-cured bonding material (Sequence, Ormco).

An effort was made to bond the same number of brackets on each side of each arch in each patient and to keep a similar number of brackets bonded at any point in time with the two types of composite resin. The teeth were pumiced with simple pumice (Italian ground lipari, Whip Mix Co.), rinsed, isolated, dried, and then etched for 60 seconds, with a 37% orthophosphoric acid solution (Ormco). The teeth were rinsed again for 10 seconds with copious amounts of water and dried with an oil-free air source. The bonding procedure was different for the two types of materials used.

For the chemically cured composite system, a thin coat of the System 1+ liquid activator was applied to each of the etched and dried teeth with a nylon brush supplied by the manufacturer. The activator was then applied to the etched area only. After this, a thin coat of activator was applied to the bracket base. The adhesive was then dispensed directly to the bracket base. Polymerization began when the adhesive was applied to the bracket base. The bracket was then placed without delay on the tooth directly on the previously etched and prepared surface. After the bracket was correctly positioned and aligned, within 5 to 10 seconds, it was firmly pressed into place and held for an additional 5 to 10 seconds. Excess unpolymerized resin surrounding the bracket was removed. Final set of the adhesive occurs approximately 24 hours after the initial set. However, the initial arch wire was placed within 5 minutes after the last bracket had been placed. The adhesive at this time had reportedly cured approximately 60%, according to the manufacturer.

The bonding technique for light-cured composite was that FluoroBond sealant (Ormco Corp., Glendora, Calif.) was applied to the etched surface of the tooth. A small amount of Sequence adhesive paste was syringed onto the base of the bracket. The bracket was lightly placed onto the tooth surface, adjusted to its final position, and then
pressed firmly. Excess adhesive was removed from the periphery of the bracket base. The adhesive was exposed to the curing light for 30 seconds. The bonding material was exposed by directing the visible light to both the mesial and distal edges of the bracket for 15 seconds each. Active arch wires were placed immediately after curing of the last bracket placed.

The subjects were followed for a mean period of 11 months and bracket failures were recorded for each patient.

RESULTS

The length of time that the brackets were bonded to the teeth ranged from 3 to 21 months, with a mean period of 11.2 months. The study was carried out over a 2-year period.

Of a total of 531 brackets bonded, 62 failed. The distribution of the bonding failures is presented in Table I. Only the first failure of any bracket was used for study purposes, and when a bracket failed more than once, only one failure was counted in this study.

A failure rate of 11.3% was recorded for the visible light-cured material, and a failure rate of 12.0% for the chemically cured composite. The distribution of the failures for each arch and each bonding material is presented in Tables II and III.

The failure rates for each arch were very similar for the light-cured and chemically cured bonding materials. When the anterior segments (central incisor to canine) were compared with the posterior segments (first and second premolars), it was noted that there was a tendency for the posterior segment to show a higher failure rate (Table IV). The failure rates for the anterior and the posterior segments, including both the chemically cured and visible light-cured bonded brackets, also indicated that there were more failures in the posterior segments of the dental arches (Table V).

Statistical Analysis

Of a combined 531 bonded brackets, there were 62 failures, yielding an overall failure rate of 11.7%. The chemically bonded failure rate was 12.0% and the light-bonded failure rate was 11.3%. Differences among the groups of sites defined by bonding agent and location were tested with the Chi-squared test, with modifications proposed by Donner and Banting. This method accounts for the correlation among observations in the same subject. The results of the analyses indicated that there was slight correlation within patients ($\chi^2 = 25.2$, df = 7, $p < 0.01$). However, further analyses indicated that the primary differences were in failures in the anterior and posterior locations (overall failure rate was 7.1% for the anterior sites and 19.6% for the posterior sites; $\chi^2 = 18.27$, df = 1, $p < 0.01$), but no differences were found for type of adhesive ($\chi^2 = 0.07$, df = 1, $p = 0.8$). Data analysis with a Chi-squared test demonstrated that there were no statistically significant differences between the failure rates of the visible light-cured and the chemically cured composites.

DISCUSSION

Visible light-cured composites may have some clinical advantages over the chemically cured composites and these include their relative ease of use, improved bracket placement possibilities, and faster set of the composite. Because mechanical and physical properties of both the visible light-cured and chemically cured composites had proven effective under in vitro conditions, a longitudinal in vivo clinical study of these adhesives was indicated to verify their clinical reliability. There are many factors that affect the effectiveness of an adhesive in a clinical setting that may not be directly related to the mechanical or physical properties of the bonding material. The latter include accidental moisture contamination of the etched enamel surface, partially erupted teeth that need to be bonded, occlusal interferences, and poor patient cooperation. Because this study was carried out in a teaching environment, the results may not necessarily be applicable to all clinical settings.

Table I. Number and percentages of failed brackets bonded with light-cured and chemically cured resin

<table>
<thead>
<tr>
<th>Adhesive type</th>
<th>No. bonded</th>
<th>Failed</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light cured</td>
<td>265</td>
<td>30</td>
<td>11.3%</td>
</tr>
<tr>
<td>Chemically cured</td>
<td>266</td>
<td>32</td>
<td>12.0%</td>
</tr>
</tbody>
</table>

Table II. Number and percentages of failed brackets per arch. Visible light-cured composite

<table>
<thead>
<tr>
<th>Arch</th>
<th>No. bonded</th>
<th>Failures</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>138</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Lower</td>
<td>127</td>
<td>18</td>
<td>14%</td>
</tr>
</tbody>
</table>

Table III. Number and percentages of failed brackets per arch. Chemically cured composite

<table>
<thead>
<tr>
<th>Arch</th>
<th>No. bonded</th>
<th>Failures</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>139</td>
<td>19</td>
<td>14%</td>
</tr>
<tr>
<td>Lower</td>
<td>127</td>
<td>13</td>
<td>10%</td>
</tr>
</tbody>
</table>
institution, initial inexperience of the operator may also have played a role.

The manipulation properties of the bonding agents used in this study were clinically acceptable. The viscosity of System 1+ resin, a no-mix chemically cured composite, was high enough to prevent slippage of the bracket on the enamel surface before setting of the bonding material. In addition, the no-mix system avoids incorporation of air bubbles into the composite, which may affect the adhesive. Voids within the material may be sites where structural failure could occur, and also oxygen trapped in the voids could inhibit complete polymerization of the resin. Thickness of the bonding material between the bracket base and the enamel surface may also affect bond strength. An excessive thickness of bonding material, which could be the consequence of the contour of the base of the bracket not accurately conforming to the surface anatomy of the crown of the tooth, could result in incomplete polymerization of the resin. Another factor influencing clinical performance is the setting time of the chemically cured composites. The chemically curing composites used in this study required a setting time of 5 minutes, according to the manufacturer. The latter reportedly would result in a 60% curing of the composite, which reportedly was sufficient to resist the forces generated by the initial ligation of the first arch wire. Complete curing of the composite would reportedly occur after 24 hours.

The visible light-cured composite used in this study was Sequence. The command set of the visible light-cured composite is an advantage in that it allows time for accurate bracket positioning on the tooth. The setting time of the light-cured composite was 30 seconds, during which time the composite is exposed to a source of blue light of 420 to 450 nm. After the 30-second light cure, the initial arch wires may be ligated. Newman et al.33 recommend that it is advisable to change the light bulb of the light-curing unit every 6 months to avoid a decrease in the wave length. In addition, the light tip must be kept clean for optimal effect.

The overall failure rate recorded in this study for the chemically cured composite was 12.0%. The visible light-cured composite had a failure rate of 11.3%. These figures are somewhat larger than the values reported by O’Brien et al.,34 who reported a failure rate of 4.6% for the visible light-cured composite and 6% for the chemically cured composite. The values obtained in this study are smaller than the values reported by Lovius et al.,35 who obtained a failure rate of 23% for the visible light-cured composite and 16% for the chemically cured composite. Zachrisson and Brobakken36 evaluated chemically cured composites only and reported a failure rate of 4% to 10% for the anterior segment of the arch and 20% to 30% for the posterior segment. Gorelick37 also evaluated chemically cured composites and reported a failure rate of 4% to 8%. The variations noted in the results from these studies may be attributed to differences in the mechanical and physical properties of the materials tested in each study, the period of observation, the criteria used to include a broken bracket as failing, and the ability of the operator.

Newman et al.33 found that no-mix adhesives were adequate for anterior teeth, but posterior teeth should be bonded with paste-sealant adhesives that have a higher bond strength, the latter being required to withstand the forces in the posterior segment of the arch. This could also explain, in part, the differences in the failure rates of the anterior versus the posterior segments found in the current study, (upper anterior 8%, upper posterior 25%; lower anterior 6%, lower posterior 16%).

### Table IV. Number and percentages of failed brackets of anterior versus posterior segments

<table>
<thead>
<tr>
<th></th>
<th>Chemically cured</th>
<th>Light-cured</th>
<th>Chemically cured</th>
<th>Light-cured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
<td>Anterior</td>
<td>Posterior</td>
</tr>
<tr>
<td>Bonded</td>
<td>91</td>
<td>48</td>
<td>90</td>
<td>48</td>
</tr>
<tr>
<td>Failed</td>
<td>7</td>
<td>12</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>%</td>
<td>8</td>
<td>25</td>
<td>2</td>
<td>21</td>
</tr>
</tbody>
</table>

### Table V. Percentages of failed brackets of anterior versus posterior segments. Visible light-cured and chemically cured composites combined

<table>
<thead>
<tr>
<th></th>
<th>Anterior</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Rate</td>
<td>7.1%</td>
<td>19.6%</td>
</tr>
</tbody>
</table>
CONCLUSIONS

1. Both the visible light-cured bonding material and chemically cured bonding material methods were found to be clinically acceptable. There was no statistically significant difference in the failure rates when comparing the two systems.

2. There were statistically significantly more failures in the posterior segments of the dental arches than in the anterior segments.

REFERENCES
