The evaluation of dual cement resins in orthodontic bonding

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Dual-cement resins are composite resins that are both light activated and chemically cured. They can be cured completely with a visible light source or by the catalyst and base reaction of the material. With the control of setting time, dual cements appear to offer clinicians advantages in orthodontic bonding. The purposes of the present research are to compare various dual cements in regard to orthodontic bonding and to evaluate them in relation to currently used chemically cured and light-cured composite resins for bonding stainless steel mesh-backed orthodontic brackets. Seven currently available orthodontic bonding systems (three light cured and four chemically cured) and three dual cements were evaluated. Each of the 10 groups contained 15 noncarious mandibular incisors. Mandibular incisor brackets were bonded to the teeth in accordance with the manufacturer's recommendation. After bonding, the teeth were stored for 5 days in water at 37° C. An Instron machine (Instron Corp., Canton, Mass.) was used to test samples. All samples were compared with Concise orthodontic bonding composite (3M, St. Paul, Minn.). The results of this investigation show that it is possible to bond solid, mesh-backed metal orthodontic brackets to teeth with a dual cement. The shear bond strengths of the dual cements, as tested in the laboratory, should be adequate to withstand normal orthodontic forces. Increased control of the setting time of the dual cements will allow the clinician more time to correctly position brackets and to remove excess resin before curing. In addition, the clinician can be assured of complete polymerization with the chemical properties of the dual cement resins. (Am J Orthod Dentofac Orthop 1993;103:448-51.)

Since the beginning of orthodontic treatment, the orthodontist has been trying to get a "handle" on teeth so that they can be moved more efficiently. The use of the "bandelette" to move teeth by tying them to metal plates with wire has been traced to Pierre Fauchard.[1] In the 1920s Angle first introduced the edgewise appliance. In contemporary orthodontics the stainless steel-bonded bracket has become the medium through which orthodontic forces are applied. With the introduction of the fully preadjusted appliance by Andrews, the straight-wire appliance, precise bracket placement has become even more crucial for correct administration of the orthodontic forces.[2-3]

Since the introduction of the acid etch technique to orthodontic bonding by Newman, many different bonding systems and techniques have evolved.[4-10] Clearly, the chemically cured one- and two-paste systems have been the traditional approaches in bonding. These resins have ample bonding strength; however, with their use the clinician is unable to control setting time, must rapidly position the bracket, and must wait until final set to remove excessive composite to be assured of maximum bonding strength.

The introduction of ultraviolet and, later, visible light-cured composite resins has enabled the clinician to overcome some of these drawbacks, in part by being able to directly control the setting time and by removing excess material before curing. Manufacturers producing light-cured resins for bonding orthodontic brackets have recommended curing their materials indirectly for 40 to 60 seconds per bracket by shining the light source at the various bracket margins. When brackets are bonded with visible light resin systems cured by transillumination, the times of 60 to 120 seconds per bracket have been advocated.[9-15] Thus drawbacks with light-cured composite resins can be associated with (1) the amount of time required to cure stainless steel brackets and (2) the fact that, whatever curing time is used, one can never be assured complete polymerization of the resin under the bracket.

In the 1980s, dual-cement composite resins were introduced into restorative dentistry. These resins are both light activated and chemically cured. Thus they can be cured completely by using a light source or by the catalyst and base reaction of the material. These resins originally were applied to composite buildups

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and to cementing of laminate veneers where depth of cure is essential.

The purposes of the present research are to compare various dual cements in regard to orthodontic bonding and to evaluate them in relation to currently used chemically cured and light-cured composite resins for bonding stainless steel mesh-backed orthodontic brackets.

METHODS AND MATERIALS

Seven currently available orthodontic bonding systems and three different dual cements were evaluated. The groups were as follows:

Orthodontic bonding systems

Chemically cured

Concise Orthodontic (3M, St. Paul, Minn.)
Right-On (TP, LaPorte, Ind.)
Phase II (Reliance, Itasca, Ill.)
Unite (Unitek, Monrovia, Calif.)

Light cured

Transbond (Unitek, Monrovia, Calif.)
Reliance "light cured" (Reliance, Itasca, Ill.)
Silux (3M, St. Paul, Minn.)

Dual cements

Vivadent "thick" (Vivadent, Tonowanda, N.Y.)
Vivadent "thin" (Vivadent, Tonowanda, N.Y.)
Reliance "fluoride releasing" (Reliance, Itasca, Ill.)

Each of the groups contained 15 noncarious mandibular incisors. The teeth were stored in water after extraction. All tissue tags and bone fragments were removed from the teeth, and all teeth were visually inspected for fractures by coating them with methylene blue and observing them under a 10× microscope. Acceptable teeth were stored in water until testing.

Chemically cured bonding systems

Fifteen teeth in each of four groups, Concise Orthodontic, Right-On, Phase II, and Unite, were cleansed with fine grit, nonfluoridated pumice and water and rinsed thoroughly. Next, the teeth were etched with the acid etch provided by the manufacturers for the prescribed time. Each tooth was dried, and the bonding agent for the corresponding resin was applied to the etched surface. The bonding agent was then applied to the mesh-backed surface of the orthodontic bracket—a mandibular lower incisor bracket (Ormco Corp., Glendora, Calif.)—followed by the appropriate chemically cured resin. The brackets were positioned on the facial surface of the tooth and left undisturbed for 10 minutes before flash removal. After bonding, the teeth were stored in an incubator at 37° + 1° C for 5 days. The teeth were then mounted in die stone disks to facilitate testing. The samples were tested in the Instron machine (Instron Corp., Canton, Mass.) with the use of a shear/peel test. A 0.020-inch stainless steel wire loop was placed under the gingival wings of the twin bracket and moved occlusally away from the sample until bond failure at a crosshead speed of 0.02 inches per minute. The values of all resins tested were compared with those of the Concise Orthodontic bonding system.

Light-cured bonding systems

Fifteen teeth in each of three groups, Transbond, Reliance "light bond," and Silux, were cleansed and pumiced as previously described. The Transbond group was bonded in accordance with the manufacturer's recommended procedure. The teeth were etched with the Transbond etchant for 30 seconds and then rinsed and dried for an additional 30 seconds. The bonding agent was applied to the bracket and to the etched tooth. Transbond composite was placed on the bracket and positioned on the teeth. All excessive flash was removed before curing. The composite was activated by the light source, Optilux 400 (Demetron Research Corp., Danbury, Conn.), for 10 seconds at each of the bracket tooth margins (mesial, incisal, distal, and gingival) (40 seconds total). The Reliance "light bond" was bonded as previously described.

The Silux samples were pumiced and etched as previously described. The appropriate bonding agent was applied to the teeth and bracket. Silux was placed on the bracket, and the bracket was properly positioned on the tooth. The material was cured by transillumination. The light source was shown at the incisal-mesial margin for 10 seconds and at the gingival-distal margin for 10 seconds. Next, the light was shown through the tooth (light source on the lingual directed facially through the tooth) for 60 seconds. All samples were stored, mounted, and tested as previously described.

Dual cements

Fifteen teeth in each of three groups, Vivadent "thick," Vivadent "thin," and Reliance "fluoride releasing," were cleansed and pumiced as described previously. A 37% phosphoric acid gel was used for 30 seconds to etch the facial surface of each tooth. Next, the teeth were rinsed for 30 seconds and dried with air. Equal portions of the Vivadent "thick" two-paste dual cement were combined until a homogeneous mixture was obtained. The Vivadent bonding agent was applied to the etched tooth surface and to the mesh-backed orthodontic bracket. The composite material was placed on the bracket and then properly positioned on the tooth. Excessive composite material was removed. Next, the composite curing light was shown at a 45° angle to the mesial-gingival corner of the bracket for 5 seconds and then at a 45° angle to the distal-occlusal corner for 5 seconds. The teeth were stored, mounted, and tested as previously described. The same procedures were carried out for 15 teeth with the use of the Vivadent "thin" dual cement. The teeth on which the Reliance "fluoride releasing" dual cement was used were bonded as described previously except that its appropriate bonding agent was used.

RESULTS

The data were analyzed by a one-way analysis of variance (ANOVA) and a Tukey analysis. The mean bond strengths, standard deviations, and ranges are listed in Table I. Rank order and comparison of bond

Table I. Force values given in pounds

Composite resin	*N*	*Mean*	*SD*	*Range*
Chemically cured				
Concise	15	24.8	3.0	19.6-31.1
Phase II	15	17.0	5.6	4.9-27.3
Right-On	15	25.6	3.1	18.2-31.0
Unite	15	26.6	4.1	16.8-32.6
Light cured				
Transbond	15	23.1	4.2	17.0-29.1
Reliance light cured	15	24.9	1.5	21.3-30.5
Silux	15	18.9	2.7	10.9-24.5
Dual cements				
Vivadent "thin"	15	44.1	3.5	36.8-50.9
Vivadent "thick"	15	26.9	2.1	21.9-33.9
Reliance "fluoride releasing"	15	15.3	6.2	6.0-31.8

SD, Standard deviation.

Table II. Rank order strongest to weakest bond strength

Resin	*p value*
Vivadent "thin"*	$p < 0.01$
Vivadent "thick"	NS*
Unite	NS
Right-On	NS
Reliance "light cured"	NS
Concise	—
Transbond	NS
Silux	NS
Phase II	NS
Reliance "fluoride releasing"*	$p < 0.01$

*Significantly different from Concise at indicated *p* levels.
NS, Not significant.

strengths with Concise Orthodontic bonding resin are shown in Table II. Vivadent "thin" had a significantly higher bond strength ($p < 0.01$) than any other composite resin used. Reliance "fluoride releasing" had a significantly lower bond strength ($p < 0.01$) than Concise Orthodontic bonding resin.

DISCUSSION

When evaluating the optimum bond strength required for bonding orthodontic appliances, the literature has a wide variety of values, 29 kg/cm to 80 kg/cm. Testing in vitro bonding strength will always depend on variables associated with the tooth-adhesive-bracket interface.[6,16,17] Another problem that has always existed when comparing in vitro bond strengths is the method of testing. Variability exists in the type of machine used in testing, the method of evaluating strengths (shear, peel, tensile, brittleness, hardness, or compressive), and the type of mounting apparatus. Therefore the gold standard for comparison in this study was Concise Orthodontic bonding resin because of its long history as the standard in orthodontic bonding. The bond strengths obtained for Concise Orthodontic bonding resin in this study compare favorably with those of other studies.[13,18,19]

The "thin" dual cement was shown to have a statistically higher bond strength than the other cements tested. Clinically, one might explain this on the basis of its reduced viscosity, which would allow for increased wetting. However, because of this, the handling properties are diminished because of a tendency for severe drift of the bracket after initial placement. When this cement was used, bond failure occurred at the bracket composite interface. The "thick" dual cement has increased filler, which reduced bracket drift. The "thick" dual cement was not significantly different from the majority of commercially available resins used in this study for orthodontic bonding at $p < 0.01$. The "fluoride releasing" dual cement had a statistically significantly reduced bonding strength. The material was extremely viscous, and all failures occurred at the tooth adhesive interface. When checked with a scaler after testing, all resin was determined to be completely cured in all dual-cured resins used.

The results of this investigation show that it is possible to bond solid mesh-backed metal orthodontic brackets to teeth with a dual cement. The bond strengths of all three dual cements were significantly ($p < 0.01$) different. The shear bond strengths of the dual cements, as tested in the laboratory, should be adequate to withstand normal orthodontic forces.

In clinical trials the "thick" dual cement was chosen because its clinical handling properties were similar to contemporary orthodontic resins. In a recent clinical pilot study, a bond failure rate of 2.9% occurred in 10 full-treatment nonextraction orthodontic cases, which compares favorably with previous studies.[10] Its main advantage over visible light-cured resins appears to be the reduced bonding time. In the visible light-cured systems, the time required to cure an entire maxillary and mandibular arch (5×5) is 20 brackets $\times$ 40 seconds, or approximately 13.5 minutes. The curing time required when a dual cement is used is 20 brackets $\times$ 10 seconds + 3 minutes for final set at the end of curing, or approximately 6.5 minutes, which is about half the time required to cure with a visible light-cured resin. The dual cement can also be completely polymerized with a visible light source in 30 seconds, 15 seconds at the mesial-gingival corner and 15 seconds at the distal-occlusal corner.

Clinical disadvantages that appeared with the use of the dual cements centered around the chemically cured properties of the dual cements. In an environment void of light, the dual cements had an initial setting time of 8 to 10 minutes. Therefore there is not an unlimited working time with the dual cements. Placement of a bracket with a half-hardened cement or removing the flash from such a bracket would drastically effect the bonding strength. In clinical testing each quadrant was bonded with a single mix of the dual cement to help reduce premature polymerization of these cements.

With the use of a dual cement for orthodontic bonding, the clinician can control the setting time by (1) allowing the resin to set by chemical cure, (2) curing with a visible light source for 30 seconds, or (3) curing with a visible light source for 10 seconds and then allowing the resin to completely polymerize with its chemically cured properties. Increased control of setting time enables the clinician more time to correctly position the bracket and to remove excess resin before curing. The dual cements also have about half the curing time required for curing a full orthodontic setup as compared with visible light-cured orthodontic bonding agents. Further, the clinician can be assured of complete polymerization with the chemical properties of dual cements.

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