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Shear Bond Strengths of Chemically and Light-Cured Resin-Modified Ionomers

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Despite the widespread usage and highly predictable results of composite resins in bonding to acid-etched enamel, these adhesives have a high degree of technique sensitivity, beginning with the need to maintain a totally dry working field.1,2 They are also prone to complications such as decalcification, resin retention and staining, and enamel fracture during debonding, especially with ceramic brackets.3

The newer resin-modified glass ionomer cements appear to resolve some of these clinical problems. Potential advantages include the speed and convenience of photoinitiated curing, enhanced physical and mechanical properties compared to conventional ionomers, the ability to bond in a moist environment, sustained fluoride release (possibly with a recharge capability), and easier debonding and clean-up.4

Obviously, ease of debonding is an advantage only if the bond strength has been sufficient to retain the brackets throughout active treatment. Studies suggest that the resin ionomers currently on the market have adequate bond strengths for successful bracket retention.5 These hybrid materials are designed to combine the best features of conventional glass ionomers with those of composite resins.

The purpose of this investigation was to compare the shear bond strengths of two resin-modified ionomers (one chemically cured and one light-cured) with a chemically cured composite resin and a conventional glass ionomer under various etching and storage conditions.

Materials and Methods

Non-carious maxillary and mandibular first premolars that had been extracted for orthodontic purposes were used for this study. The teeth were removed from their original germicidal storage solution and immersed in distilled water for one week prior to handling.

The roots were V-notched facially and lingually with a thin carborundum separating disc to enhance retention. To ensure uniform mounting, each specimen was set in carding wax and aligned parallel to its long axis with a dental surveyor. The tooth was then embedded in an epoxy material (Epoxydent) that was poured into a hollow, 3/4" threaded PVC fitting, which engaged a mounting plate in the No. 810 Material Testing Machine (Fig. 1).

A Twin-Edge .022" medium twin bicuspid bracket, with a mesh bonding pad area of about 11.45mm2, was bonded to each tooth. The four adhesives used in the study were a two-paste autopolymerizing composite resin, Concise; a conventional glass ionomer, Ketac-Cem; and two resin ionomers, Fuji Ortho and Fuji Ortho-LC. The two resin ionomers are basically identical, except that Fuji Ortho is entirely chemical (an acid-base reaction and a self-curing resin polymerization), while Fuji Ortho-LC contains an additional photoinitiator-activator system for light curing.

Five samples were tested in each experimental group. All materials were manipulated in strict accordance with the manufacturers? directions.

The Concise samples were cleaned with a slurry of non-fluoridated flour of pumice and water, rinsed, etched with 37% phosphoric acid for 30 seconds, thoroughly rinsed, and dried with oil-free compressed air. The enamel bond resins were mixed for 10 seconds and applied with a sponge.

Teeth to be bonded with Ketac-Cem were cleaned with pumice and rinsed, but no conditioner was applied. Enamel surfaces were kept moist prior to bonding with any of the ionomer materials, since water is required in the acid-base setting reaction.

The Fuji samples were treated in two different ways: one group was cleaned but not etched, while the second group was cleaned, conditioned with 10% polyacrylic acid for 20 seconds, and thoroughly rinsed. The rationale for this experiment was that the resin ionomers are recommended for use with or without acid conditioning, depending on the clinical situation.

After the removal of excess adhesive from around the bracket pads, the light-cured samples were polymerized with an ESPE-Elipar light (peak wave length of 470 nanometers) for about 15 seconds at each of the four margins, for a total curing time of 60 seconds. For the other cements, the excess was carefully removed with a curved scalpel blade after setting.

Two more groups of Fuji samples were bonded using the same cleaning, conditioning, and rinsing procedures. Immediately after bonding, the teeth were placed in a 37°C, 95% relative humidity chamber, simulating the oral environment, and stored there for 24 hours prior to testing. The five Ketac-Cem samples ere subjected to the same storage conditions to ensure that setting was complete before testing.

The samples that were not stored overnight were tested 20 minutes after bonding. All specimens were stressed to failure in a shear mode, using the MTS hydraulic apparatus at a crosshead speed of .02"/minute. Bond strengths in MPa were calculated by dividing the load at failure (Newtons) by the bracket pad area (square millimeters).

Failure modes were visually observed as being "adhesive", at the adhesive-bracket or adhesive-enamel interface, or "cohesive", with some adhesive remaining on the enamel and some attached to the bracket pad.

Data were analyzed using one-way or two-way analysis of variance and Duncan multiple comparisons to determine significant differences among means of the sample groups.

Results

Mean shear bond strengths ranged from 3.67 MPa for Ketac-Cem to 13.08 MPa for Concise (Table 1). The etched Fuji samples showed slightly higher mean bond strengths than the unetched samples. There was no significant difference in the bond strengths of the Fuji samples as a result of 24-hour storage in the humidity chamber.

Analysis of variance revealed statistically significant differences among all the mean values ($p < 0.05$). Duncan multiple comparisons showed a contrast between three homogenous subsets (Nos. 1, 2-5, and 3-6 below), arranged in the following decreasing order:
1. Concise

2. Fuji Ortho-LC (etched)
3. Fuji Ortho-LC (unetched)
4. Fuji Ortho (etched)
5. Fuji Ortho (unetched)
6. Ketac-Cem

Concise was significantly stronger than any of the other adhesives; the light-cured resin ionomer, Fuji Ortho-LC, when conditioned with 10% polyacrylic acid, was significantly stronger than the conventional light-cured ionomer, Ketac-Cem.

The resin ionomer materials showed cohesive bond failures in about 60% of the samples and adhesive failures at the adhesive-bracket interface in the remainder (Table 2). The Concise bond failures were all at the adhesive-bracket interface. Eighty percent of the Ketac-Cem failures were cohesive, with the rest occurring at the adhesive-enamel interface.

Discussion

The shear strength required for successful bonding has been estimated by various investigators to be in the range of 6-8 MPa.6 The present study suggests that the two resin-modified ionomers tested would be adequate for clinical use. However, 20-second conditioning with 10% polyacrylic acid appears advisable, even though one of the purported advantages of these materials is that etching is not required in most cases.7

Conventional glass ionomers have a relatively sluggish setting reaction that leaves the incompletely mature cement highly vulnerable to an early gain or later loss of water.8 In the recently developed hybrid ionomers, the light- or chemically cured resin provides an effective early protection from the oral environment while allowing the ion-exchange process (calcium to aluminum polyacrylate) to continue hardening and strengthening the adhesive.9 In this study, the light-cured resin ionomer, Fuji Ortho-LC, attained the highest shear bond strength among the ionomer materials after only 20 minutes of setting. The chemically cured resin ionomer, Fuji Ortho, even when tested immediately, was stronger than the conventional ionomer, Ketac-Cem, after 24 hours of setting. It therefore seems acceptable to place a light archwire after 20 minutes of setting with either Fuji adhesive.

The bond failures of the resin ionomer materials were either cohesive or adhesive at the adhesive-bracket interface, similar to the failure mode of the Concise composite resin. The conventional glass ionomer failed cohesively more often, due to its lower cohesive strength, and showed adhesive failures only at the adhesive-enamel interface, because its bond strength is greater to stainless steel than to enamel. These observations are in general agreement with those of other studies.10

If the shear bond strengths attainable with resin-modified ionomers are indeed sufficient to retain brackets throughout active treatment, as suggested by this and other studies, their advantages in terms of moisture compatibility, fluoride release and recharge, and relative ease of debonding may make them attractive alternatives to composite resins in clinical practice.

FIGURES

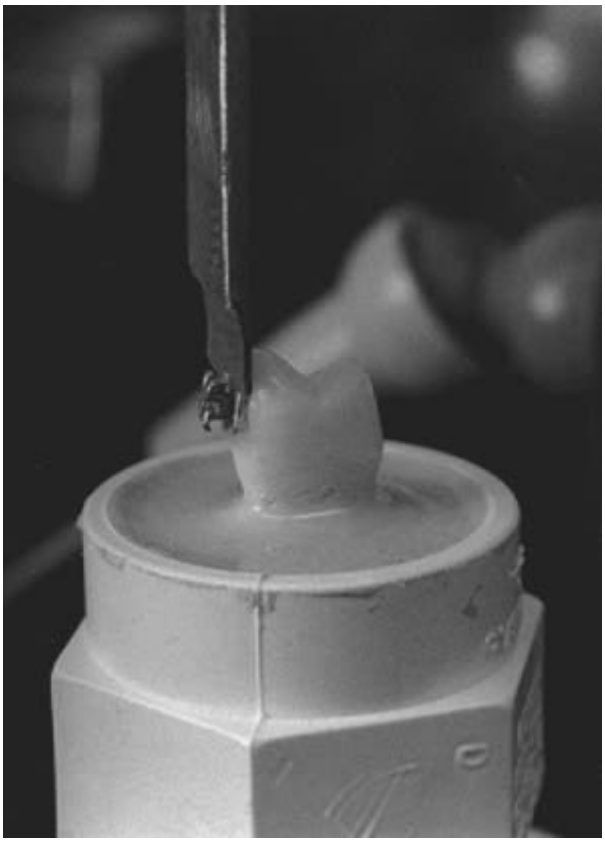

Fig. 1 Shear bond strength testing apparatus.

TABLES

TABLE 1
SHEAR BOND STRENGTHS (MPa)

	Mean	S.D.
Concise (20-minute setting)	13.08	2.16
Ketac-Cem (24-hour setting)	3.67	1.28
Fuji Ortho		
Etched (20-minute setting)	5.89	1.84
Etched (24-hour setting)	8.13	3.74
Unetched (20-minute setting)	5.15	0.66
Fuji Ortho-LC		
Etched (20-minute setting)	7.84	0.87
Etched (24-hour setting)	7.63	1.68
Unetched (20-minute setting)	5.95	0.83

Table. 1

TABLE 2
BOND FAILURE SITES (%)

	Cohesive	Adhesive-	
		Bracket	Enamel
Concise	0	100	0
Ketac-Cem	80	0	20
Fuji Ortho and Ortho-LC	60	40	0

Table. 2

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FOOTNOTES

1 Epoxydent: E & D Dental Products, 71 Veronica Ave., Somerset, NJ 08873.

2 Material Testing Machine: MTS Systems Corp., 1400 Technology Drive, Eden Prairie, MN 55344.

3 Twin-Edge: TP Orthodontics Inc., 100 Center Plaza, La Porte, IN 46350.

4 Concise: 3M Unitek, 2724 S. Peck Road, Monrovia, CA 91016.

5 Ketac-Cem, Elipar: ESPE-Premier Sales Corp., P.O. Box 11, Norristown, PA 19404.

6 Fuji Ortho, Fuji Ortho-LC: GC America Inc., 3737 W. 127th St., Chicago, IL 60658.