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Glass Ionomer Cements as Luting Agents for Orthodontic Brackets

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ABSTRACT

The objectives of the present study were to (1) assess the shear bond strengths of resin-reinforced glass ionomer Fuji Ortho LC and GC Fuji Ortho cements under differing conditions and (2) compare their bonding performance with that of conventional resin composite bonding systems. A sample of 264 bovine incisors was divided into 22 groups of 12 teeth each and bonded with SPEED central incisor brackets. Enamel surfaces of the teeth in the two experimental groups were conditioned according to the manufacturer's instructions; moreover, groups unconditioned before bonding were also included under both wet and dry conditions. A self-cure composite resin (Phase II) and a light-cure composite resin (Transbond XT) served as controls and were etched with 37% phosphoric acid and bonded in a dry field. After incubation at 37°C for 24 hours and for seven days, the specimens were tested to failure with a shear force in an Instron machine. The Adhesive Remnant Index (ARI) was used to assess the amount of resin left on the enamel surfaces after debonding. Selected specimens were examined using scanning electron microscopy. Statistical analyses included analysis of variance tests, *t*-tests, and correlation coefficient calculations and showed that no significant difference existed between the glass ionomer cements under wet or dry conditions, provided the enamel was conditioned with 10% polyacrylic acid before bonding. Both glass ionomer cements were thus acceptable for bonding. Transbond XT had the highest mean shear bond strength irrespective of the incubation period. A positive correlation was obtained between the ARI scores and bond strength.

KEY WORDS: Resin-reinforced glass ionomer cements, Orthodontic brackets, Shear bond strength.

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INTRODUCTION Return to TOC

Direct bonding of orthodontic brackets has virtually replaced the fitting and cementing of bands.[1] Contemporary bonded fixed orthodontic appliances show improved esthetics, and the design also enhances oral hygiene. The elimination of tooth separation at the beginning of treatment and closure of band spaces at the end of treatment are additional advantages of the bonded appliance.[2] Interproximal enamel contouring during active treatment with a bonded appliance in place is also possible.[3] The contributions of enamel etching[4] and direct bonding[5] to the orthodontic profession have thus made treatment more efficient.

The traditional cementing agents for orthodontic brackets are resin materials, which were developed in the mid-1970s.[6,7] For clinical success, these materials need to be applied in a dry field and also require acidic conditioning of the enamel surface.[6] As these resin

cements have evolved, it has been shown that filled (composite) resins not only provide stronger bonds than do unfilled resins but also possess improved thermal expansion properties.[6–10] Composite resins can take up to 24 hours to reach the maximum bond strength, however, sufficient bond strength exists after only a few minutes have elapsed (especially with light polymerization), allowing the immediate placement of archwires without debonding of the brackets, which is convenient for both the patient and clinician.[7] These resin cements exist as chemically autopolymerizing paste-paste and autopolymerizing no-mix systems, visible light–polymerized systems, and dual cure systems.[11,12] Disadvantages of the resin-based systems, however, include loss of enamel during acid conditioning,[13,14] loss of the fluoride-rich surface enamel during debonding,[13,15–18] and demineralization of enamel around the brackets because of poor patient compliance with respect to oral hygiene.[19–21] In summary, resin cements have proved to be strong, durable, and reliable agents for the attachment of orthodontic brackets to teeth.

More recently, however, glass ionomer cements have been developed, advocated, and marketed for cementing orthodontic brackets to teeth. General dentists have been successfully using glass ionomer materials as luting, lining, and restorative agents for the past 15 years.[22] For orthodontists, there appears to be multiple benefits in using glass ionomer cements as a cementing agent. These include the release of fluoride with its known caries-inhibiting properties[23] and its ability to absorb fluoride from sources such as fluoride toothpaste, thus recharging its fluoride reservoir.[22] Furthermore, acid conditioning is not required so that both bonding and debonding procedures have the capacity to reduce iatrogenic damage to enamel,[22,24] and the bonding field does not have to be dry, thus increasing the speed and ease of bracket placement.[22]

It is of concern, however, that bond strengths for glass ionomer cements are not of the same magnitude as those for the conventional resin cements and as a result the failure rate of bracket attachment to teeth is higher.[22,25–27] Using an in vitro bovine model developed in this laboratory, the present study was designed to compare the shear bond strengths of two recently introduced glass ionomer cements with those of two conventional resin cements, as well as to test the viability of reusing prepared specimens. The in vitro environment ensured the development of a standardized technique, which also allowed for the control of variables. The scanning electron microscopic examination of the failed shear bonds between the tooth and bracket surfaces during the present study improved the interpretation of the results.

MATERIALS AND METHODS

Tooth preparation

Bovine incisor teeth were decoronated, the coronal pulps removed with a dental explorer, and the crowns thoroughly washed free of blood and organic debris in running tap water. The teeth were divided into groups of 50, placed in containers with 250 mL of distilled water, and frozen at −20°C until required.

The freshly extracted frozen teeth were allowed to thaw at room temperature, rinsed in running distilled water for 30 minutes, and their pulp chambers filled with water-soaked sponges. The teeth were then embedded in polymethyl methacrylate (PMMA), which was mixed in accordance with the manufacturer's instructions and poured into a mould 2.5 cm in diameter and two cm in depth. During the embedding process, it was ensured that the labial surface projected above and parallel to the surface of the PMMA and that the teeth were kept wet. The embedded teeth were then stored in distilled water at 4°C before surface preparation and bracket application. A sample of previously embedded teeth was also stored at 4°C in distilled water containing thymol crystals (to inhibit bacterial growth). The feasibility of reusing teeth for this type of project after proper storage is not known.

Brackets and cementing materials

Maxillary left central incisor SPEED™ brackets were used in this study (Strite Industries, Cambridge, Ontario, Canada). Previous investigations have shown that the bases of these brackets are relatively flat, have 60-gauge foil mesh bases, and a mean base surface area of 7.41 ± 0.22 mm^2.[12,18]

Two composite resin cements were used as controls. These were the autopolymerizing Phase II (Reliance Orthodontic Products Inc., Itasca, Ill), and the visible light–cured Transbond XT (3M Unitek Dental Products, Monrovia, Calif). Two glass ionomer cements comprised the experimental materials: the autopolymerizing resin-reinforced GC Fuji Ortho and the visible light–cured resin-reinforced Fuji Ortho LC (GC Corporation, Tokyo, Japan).

Enamel surface preparation

Before bracket placement, the enamel surface of each embedded tooth was initially ground flat with water-irrigated #180 grit SiC paper. The final test surface was prepared by using water-irrigated #600 grit SiC paper. The enamel surfaces were observed under a light microscope at 35× magnification to ensure that enamel surface is intact and, for the reused teeth, that all residual resin is removed and no underlying dentin is exposed. The teeth that did not meet these criteria were discarded.

Experimental protocols

The experimental protocols used in this study are summarized in Table 1 ⊙=. Each experimental group consisted of 12 embedded teeth. All resin and glass ionomer cements were mixed and applied to the brackets and enamel in accordance with the manufacturers' instructions.

Where acid conditioning of the enamel surface was required before resin cement application, the surfaces were conditioned in the following way. The enamel surface was dried with an electric hair dryer (Handi-Dri, Lancer Pacific, Carlsbad, Calif) and the surface conditioned with a 37% orthophosphoric gel for 20 seconds (Phase II gel etch, Reliance Orthodontic Products). The conditioned surface was then rinsed for 20 seconds with running distilled water and dried with the hair dryer for 30 seconds after which the bracket was cemented in position.

The glass ionomer cements were applied in either a dry or wet environment to surfaces, which were unconditioned or conditioned with 10% polyacrylic acid. The enamel surface of teeth in all groups was first dried with an electric hair dryer. The groups that were designated for conditioning were conditioned with 10% polyacrylic acid (GC Ortho Conditioner, GC Corporation) for 20 seconds. The conditioner was then rinsed with running distilled water for 20 seconds and then the conditioned enamel surface was dried with hair dryer for 30 seconds. For teeth that were to be tested in a conditioned dry environment, the brackets were then bonded to this dried surface. A wet environment was created for teeth that were to be tested in such an environment. The dry conditioned surface was moistened using a cotton swab soaked in distilled water before the brackets were cemented. For teeth that were assigned to groups in which the enamel surface was not conditioned, the brackets were bonded to either a dry (electric hair drier) or a wet (moistened cotton swab) surface similar to that previously described.

Bracket placement

Irrespective of the cement used or the preparation of the enamel surface, the brackets were placed in the following manner:

- The base mesh surface of each bracket was coated with cement, taking care that no voids or air bubbles were included.

- The coated bracket was then placed by hand on the enamel surface.

- The slot in the bracket was then engaged by the weighted guide pin of a semiadjustable articulator (Teledyne Hanau, Buffalo, NY) to which a stone cylinder was attached (610 g).

- This arrangement ensured that all brackets were bonded using a standardized force and allowed the investigator's hands to be free to remove excess cement flash with a sharp explorer.

- Brackets that were cemented with visible light–cured cements were exposed to the light source for 10 seconds on each of the four sides of the bracket base for a total exposure time of 40 seconds.

- Brackets that were cemented with autopolymerizing cements were allowed to bench set for five minutes.

This technique is similar to that described by MacColl,[18] in which the thickness of the cement was shown to be consistently low.

Teeth in all groups were stored in distilled water at 37°C for either 24 hours or seven days after which they were shear tested to failure. To inhibit bacterial growth, crystals of thymol were added to the storage water. As indicated, an initial investigation was carried out to see whether teeth used in a previous investigation could be reused, and these groups were shear tested after seven days.

Shear bond strength testing

The embedded specimens were clamped in an Instron Universal Testing Machine (Model 4301, Instron Corp., Canton, Mass) so that the bracket was at 90° to the vertical plane, and the incisal edge of the tooth was below the compression cell. A sharpened chisel blade was placed in a one-kN compression cell and positioned at the bracket-enamel interface. Using a crosshead speed of 0.5 mm/min, the bonds were shear tested to failure. The shear force was recorded in Newtons and then converted to megapascals.

Resin location

The Adhesive Remnant Index (ARI) system of Artun and Bergland[28] was used to evaluate the amount of cement left on the tooth surface after debonding. In this study, both the tooth surface and the bracket base were examined under a light microscope at 35× magnification. To establish intra- and interoperator reliability for the ARI index, 40 specimens were randomly selected and assessed at two different times by the researchers.

Scanning electron microscopy

Before scanning electron microscopic examination, each tooth and its debonded bracket were placed in absolute alcohol for seven days after which they were allowed to air-dry. They were then mounted on scanning electron microscope (SEM) stud in such a manner that the enamel surface and the bracket base could be viewed and sputter coated with three nm of platinum in a Polaron SC 515 coating unit (International Scientific Instruments Inc., Santa Clara, Calif). The specimens were examined and photographed in a Hitachi S-2500 SEM at an operating voltage of 10 kV at magnifications of 30× (Hitachi Ltd., Mito City, Japan).

Statistical analysis

The mean shear bond strengths and standard deviations were calculated for each group. Initially, an independent two-tailed *t*-test was performed to determine whether a difference existed between fresh and reused teeth. A four-factor analysis of variance (four-way ANOVA) was used to evaluate whether there were any significant differences between autopolymerizing and light-cured glass ionomer cements, wet and dry environments, conditioned and unconditioned enamel surfaces, and shear bond strengths after 24 hours and after seven days.

A three-way ANOVA was used to compare resin cement control groups with the glass ionomer cement groups with respect to the setting mechanism, the time elapsed before debonding, a dry environment, and the treatment of the enamel surface. A test of interaction between the effects of the variables was included in ANOVA design, and if an interaction occurred, the main effects were retested at each factor level using the LSMEANS test.

To determine the inter- and intraoperator differences when assigning ARI scores, an error study was performed using a paired *t*-test and a correlation analysis. A Kruskal-Wallis nonparametric ANOVA test was performed to determine the relationship between mean shear bond strength and mean ARI score. This was followed by a Spearman correlation test to assess whether the variables were perfectly related. The level of statistical significance for all tests was $P < .05$. The SAS system was used for the analysis of the data (prog GLM, version 6.10, 1994, Cary, Calif).

RESULTS Return to TOC

Fresh vs reused teeth

The results showed that the mean shear bond strength for reused teeth was not statistically significantly different from that for fresh teeth ($P > .05$). This result thus justifies the use of correctly prepared reused teeth (Table 1 ⊙=).

Shear bond strengths

The shear bond strengths are shown in Table 1 ⊙=. The control resin cement groups showed that the light-cured Transbond XT produced higher shear bond strengths at 24 hours and seven days than did Phase II. Both resin cements showed that shear bond strengths increased over a seven-day period when compared with those recorded at 24 hours, and these differences were statistically significant ($P > .05$).

The shear bond strengths of the autopolymerizing GC Fuji Ortho were consistently higher than those recorded for Fuji Ortho LC under all enamel surface preparation conditions (Table 1 ⊙=). The results also showed that wet unconditioned surfaces consistently produced higher shear bond strengths than did dry unconditioned surfaces. Wet or dry conditioned surfaces, however, produced higher shear bond strengths than did unconditioned wet or dry surfaces. With the exception of Fuji Ortho LC dry conditioned and GC Fuji Ortho dry unconditioned, shear bond strengths were higher at seven days than those recorded at 24 hours. In addition, GC Fuji Ortho produced shear bond strengths that were comparable with those of Phase II when the surfaces were wet or dry and conditioned with polyacrylic acid (Table 1 ⊙=).

When comparisons were made between Fuji light cured and GC Fuji Ortho applied under similar surface conditioning at 24 hours and seven days, it was found, with one exception, that there were no significant differences between the cements (Table 2 ⊙=). The exception noted was that after seven days, GC Fuji Ortho demonstrated a significantly higher shear bond strength than did Fuji light cured, where the enamel surface had been dried and conditioned with polyacrylic acid, $P < .05$. On the other hand, within-material comparisons for the glass ionomer cement materials between 24 hours and seven days showed that significant differences existed in shear bond strength for Fuji Ortho light-cured wet conditioned and wet unconditioned and for GC Fuji Ortho wet conditioned enamel surfaces (Table 3 ⊙=). In all three instances, there was an increase in shear bond strength. It should be noted, however, that shear bond strength increased over seven days wherever the enamel surface had been conditioned.

Resin location

The error study, to determine whether differences existed when assigning ARI scores, showed that there was strong interoperator (r = 0.91; $P = .18$) and intraoperator agreement over two time periods (r = 0.98; $P = 1.00$). The mean ARI scores for each of the 20 test conditions are shown in Table 4 ⊙=. The Kruskal-Wallis nonparametric ANOVA and Spearman correlation tests indicated that in general a linear relationship existed between the mean shear bond strength and ARI scores for each time interval. In other words, as the mean shear bond strength increases so does the ARI score because these variables are positively correlated.

SEM results

The results of SEM of both bracket and enamel surfaces illustrate the ARI scores where the luting material used was Fuji Ortho LC. An example of an ARI score of 0 shows that all the cement is left adhering to the bracket base with none on the enamel surface (Figure 1a,b ⊙⇨).

An ARI score of 1 indicated that less than half the adhesive was left on the enamel surface (Figure 2a,b ⊙⇨). A score of 2 indicated that more than half the adhesive was left on the tooth (Figure 3a,b ⊙⇨), and a score of 3 showed that all the adhesive was left on the tooth with a distinct impression of the bracket mesh (Figure 4a,b ⊙⇨). Similar criteria were used to assess ARI scores for both glass ionomer cements and resin control cements.

DISCUSSION Return to TOC

It has been shown in this study that embedded bovine incisor teeth can be reused in studies to assess mean shear bond strengths of orthodontic brackets to enamel. This finding is both cost-effective and time saving because bovine incisor teeth are expensive to harvest and the embedding process can take a considerable amount of time. Care must be taken, however, to ensure that no dentin is exposed during the regrinding of the enamel surface.

A bonded bracket must withstand both the forces of mastication and the orthodontic forces that it is subjected to in the oral environment. It is also a clinical requirement that the bond should reach sufficient strength shortly after bracket bonding to allow archwire placement at the bonding appointment. This mechanochemical bond must be durable enough to last over the period of active treatment. It has been established that tensile bond strengths of adhesives in the range of six to eight MPa are required for successful clinical bonding.[6] It has also been determined that there is no significant difference ($P > .05$) in the stress required to produce bond failure by either a tensile or a shear test model. It is thus not unreasonable to use these guidelines when considering the shear bond strengths recorded in this study.[29] The results of this study show that in a wet or dry environment, with conditioned enamel surfaces (either polyacrylic or phosphoric acid), shear bond strengths of the magnitude required for clinical success can be achieved. The evidence that glass ionomer cements can be placed in a wet environment is equivocal. Silverman et al[22] showed that brackets can be placed successfully in a wet environment, whereas Rossouw et al[30] demonstrated that the presence of contaminants such as saliva severely compromises shear bond strength. The results further indicated that bond strengths increased from 24 hours to seven days, but in all instances, the initial short-term shear bond strengths exceeded the minimum requirements outlined by Reynolds.[6] There is thus no apparent contraindication to placing archwires at the initial bonding appointment when using glass ionomer cements as the cementing medium.

Caution should be exercised because too high shear bond strength levels carry the consequent risk of enamel fracture during the debonding process. It has been shown that this can occur with tensile bond strengths as low as 9.7 MPa.[9,31] No enamel fractures were recorded as a result of shear bond strength testing to failure in this study, despite the fact that 16 of 22 groups of specimens demonstrated mean shear bond strengths greater than 9.7 MPa. It should further be noted that these groups included both the resin controls and the glass ionomer cements.

The use of rotary instruments to remove residual cement after bracket debonding may damage the enamel surface.[32] Because the superficial enamel surface has also been shown to be rich in fluoride, removal of adherent residual cement may also compromise future caries resistance.[33] This study has confirmed that the ARI system is user-friendly and easy to interpret, despite the criticism that it is a subjective evaluation. As a result it has been shown that a low ARI score is the preferred result after debonding because it indicates that the amount of adhesive remaining on the enamel surface is minimal and that the risk of iatrogenic damage to the enamel surface is minimized. The results obtained in this study indicate that as shear bond strength decreases so does the ARI score, indicating that less cement is left adhering to the enamel. The scanning electron microscopic observations support these findings. The shear bond strengths, however, indicate that these cements meet the clinical requirements recommended by Reynolds.[6] Similarly, because glass ionomer cements contain and leach fluoride, and that the fluoride content can be restored by topical application, residual retained cement may not be a disadvantage, provided that patient esthetics are not compromised.[22,23,34]

The results of this study suggest that glass ionomer cements provide sufficiently high shear bond strengths to retain orthodontic brackets under clinical conditions and, at the same time, could provide a reservoir of fluoride, thereby reducing the cariogenic potential of plaque-retaining orthodontic attachments.

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TABLE 1. Mean Shear Bond Strengths (MPa) of Fresh and Reused Teeth, Resin Controls, and all Glass Ionomer Cement Test Conditions at 24 h and 7 d[a]

Group	Material	Environment	Surface Treatment	n	Mean SBS ± SD	
					24 h	7 d
Fresh Teeth	Phase II	Dry	Etched (37% phosphoric acid)	12	—	21.46 ± 7.75
Reused Teeth	Phase II	Dry	Etched (37% phosphoric acid)	12	—	21.45 ± 9.33
Control	Transbond XT	Dry	Etched (37% phosphoric acid)	12	18.89 ± 4.39	25.48 ± 3.60
Control	Phase II	Dry	Etched (37% phosphoric acid)	12	15.11 ± 6.69	18.88 ± 4.43
Experiment 1	Fuji Ortho LC	Dry	Conditioned (10% polyacrylic acid)	12	13.94 ± 3.27	11.99 ± 5.05
	Fuji Ortho LC	Dry	Unconditioned	12	1.32 ± 1.18	1.86 ± 1.12
	Fuji Ortho LC	Wet	Conditioned (10% polyacrylic acid)	12	12.08 ± 2.23	15.86 ± 3.63
	Fuji Ortho LC	Wet	Unconditioned	12	5.86 ± 2.97	10.45 ± 5.09
Experiment 2	GC Fuji Ortho	Dry	Conditioned (10% polyacrylic acid)	12	14.35 ± 4.19	16.20 ± 3.72
	GC Fuji Ortho	Dry	Unconditioned	12	3.44 ± 1.62	2.31 ± 2.01
	GC Fuji Ortho	Wet	Conditioned (10% polyacrylic acid)	12	14.84 ± 4.86	17.88 ± 5.48
	GC Fuji Ortho	Wet	Unconditioned	12	7.28 ± 2.96	10.03 ± 4.18

[a] SD indicates standard deviation; SBS, shear bond strength.

TABLE 2. Comparison of the Effect of the Material When the Environment and the Surface Treatment are Constant at 24 h and 7 d[a]

Time	n	Environment/Surface Treatment	Mean SBS ± SD (MPa)		P value
			Fuji Ortho LC	GC Fuji Ortho	
24 h	12	Dry/conditioned	13.94 ± 3.27	14.35 ± 4.19	.7793
	12	Dry/unconditioned	1.32 ± 1.18	3.44 ± 1.62	.1534
	12	Wet/conditioned	12.08 ± 2.23	14.84 ± 4.86	.0631
	12	Wet/unconditioned	5.86 ± 2.97	7.28 ± 2.96	.3364
7 d	12	Dry/conditioned	11.99 ± 5.05	16.20 ± 3.72	.0049*
	12	Dry/unconditioned	1.86 ± 1.12	2.31 ± 2.01	.7598
	12	Wet/conditioned	15.86 ± 3.36	17.88 ± 5.48	.1731
	12	Wet/unconditioned	10.45 ± 5.09	10.03 ± 4.18	.7763

[a] SD indicates standard deviation; SBS, shear bond strength.
* Statistically significant difference ($P < .05$).

TABLE 3. Comparison of the Effect of the Time when the Material, the Environment, and the Surface Treatment are Constant[a]

Material	n	Environment/Surface Treatment	Mean SBS ± SD (MPa) 24 h	Mean SBS ± SD (MPa) 7 d	P value
Fuji Ortho LC	12	Dry/conditioned	13.94 ± 3.27	11.99 ± 5.05	.1903
	12	Dry/unconditioned	1.32 ± 1.18	1.86 ± 1.12	.7145
	12	Wet/conditioned	12.08 ± 2.23	15.86 ± 3.63	.0113*
	12	Wet/unconditioned	5.86 ± 2.97	10.45 ± 5.09	.0022*
GC Fuji Ortho	12	Dry/conditioned	14.35 ± 4.19	16.20 ± 3.72	.2124
	12	Dry/unconditioned	3.44 ± 1.62	2.31 ± 2.01	.4476
	12	Wet/conditioned	14.84 ± 4.86	17.88 ± 5.48	.0410*
	12	Wet/unconditioned	7.28 ± 2.96	10.03 ± 4.18	.0644

[a] SD indicates standard deviation; SBS, shear bond strength.
* Statistically significant difference ($P < .05$).

TABLE 4. The Comparison of Mean Shear Bond Strengths (MPa) and the Distribution of ARI scores for each Test Condition[a]

Time	Material	n	Mean ± SD (MPa)	ARI Score 0	1	2	3	Mean ARI ± SD
24 h	Transbond XT dry/etched	12	18.89 ± 4.39	0	5	6	1	1.67 ± 0.65
	Phase II dry/etched	12	15.11 ± 6.96	0	8	3	1	1.42 ± 0.67
	Fuji Ortho LC dry/conditioned	12	13.94 ± 3.27	1	3	7	1	1.67 ± 0.78
	Fuji Ortho LC dry/unconditioned	12	1.32 ± 1.18	11	1	0	0	0.08 ± 0.29
	Fuji Ortho LC wet/conditioned	12	12.08 ± 2.23	0	10	2	0	1.17 ± 0.39
	Fuji Ortho LC wet/unconditioned	12	5.86 ± 2.97	7	5	0	0	0.42 ± 0.52
	GC Fuji Ortho dry/conditioned	12	14.35 ± 4.19	2	8	2	0	1.00 ± 0.60
	GC Fuji Ortho dry/unconditioned	12	3.44 ± 1.62	12	0	0	0	0.00 ± 0.00
	GC Fuji Ortho wet/conditioned	12	14.84 ± 4.86	4	8	0	0	0.67 ± 0.49
	GC Fuji Ortho wet/unconditioned	12	7.28 ± 2.96	11	1	0	0	0.08 ± 0.29
7 d	Transbond XT dry/etched	12	25.48 ± 3.60	0	9	3	0	1.25 ± 0.45
	Phase II dry/etched	12	18.88 ± 4.43	3	7	2	0	0.92 ± 0.67
	Fuji Ortho LC dry/conditioned	12	11.99 ± 5.05	0	3	7	2	1.92 ± 0.67
	Fuji Ortho LC dry/unconditioned	12	1.86 ± 1.12	12	0	0	0	0.00 ± 0.00
	Fuji Ortho LC wet/conditioned	12	15.86 ± 3.63	0	9	2	1	1.33 ± 0.65
	Fuji Ortho LC wet/unconditioned	12	10.45 ± 5.09	5	7	0	0	0.58 ± 0.52
	GC Fuji Ortho dry/conditioned	12	16.20 ± 3.72	0	8	4	0	1.33 ± 0.49
	GC Fuji Ortho dry/unconditioned	12	2.31 ± 2.01	9	3	0	0	0.25 ± 0.45
	GC Fuji Ortho wet/conditioned	12	17.88 ± 5.48	0	10	2	0	1.17 ± 0.39
	GC Fuji Ortho wet/unconditioned	12	10.03 ± 4.18	3	9	0	0	0.75 ± 0.45

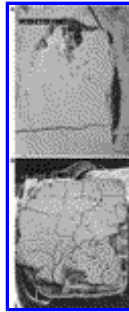[a] SD indicates standard deviation; ARI, Adhesive Remnant Index.

FIGURES
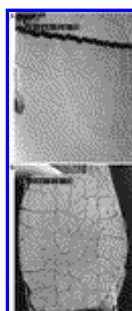
Click on thumbnail for full-sized image.

FIGURE 1. ARI score of 0 showing (a) no adhesive on enamel surface and (b) all the adhesive on bracket base
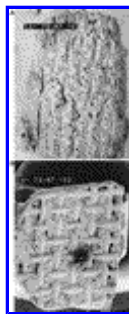
Click on thumbnail for full-sized image.

FIGURE 2. ARI score of 1 showing (a) less than 50% adhesive, but not 0, on enamel surface and (b) more than 50% adhesive on bracket base

Click on thumbnail for full-sized image.

FIGURE 3. ARI score of 2 showing (a) more than 50% adhesive, but not 100%, on enamel surface and (b) less than 50% adhesive on bracket base

Click on thumbnail for full-sized image.

FIGURE 4. ARI score of 3 showing (a) all the adhesive on enamel surface with imprint of base design in cement and (b) no adhesive on bracket base except that in the retentive foil mesh. Compare with Figure 1b 🔍

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