

FRAGMENT REATTACHMENT WITH  
LIGHT-CURED GLASS-IONOMER

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INTRODUCTION



Trauma to the dentition from falls accounts for most dental injuries to young permanent teeth, while contact sports and automobile accidents cause significant dental injuries to both children and adolescents. Dental trauma has both a physical and psychological affect on a child by influencing a persons dental functioning and appearance.

Restoration of fractured teeth has been accomplished by several different methods in the past such as: stainless steel crowns, bands, and pin retained resins. Not until the advent of acid-etch resins has the restoration been accomplished with much overall success; however, success is very time limited due to the lack of wear and stain resistance. Solving the short comings of resins has been accomplished by a method where the fragment is reattached back to the fractured tooth with composite resin. A study by Dean<sup>1</sup> showed reasonable strength when the two fragments were meshed together and luted by resin. More recently there have been successful case reports involving fragment reattachment with glass-ionomer. Glass-ionomer is recommended in many situations due to its dentin bonding, fluoride releasing, and decreased microleakage properties.

This study was designed to investigate the effectiveness of the fragment reattachment technique by measuring the forces required to cause separation of the fragment while using a light cured glass-ionomer vs a light cured composite resin as luting agents. The nature of the fractured site was also determined (i.e., adhesive, cohesive, or mixed).



REVIEW OF THE LITERATURE

Trauma to the dentition of the young child or adolescent can have a long lasting effect on the physical as well as psychological well-being of the patient. Slack and Jones<sup>2</sup> described the case of a nine-year old boy who suffered a blow which resulted in fracture of three mandibular incisors and one maxillary incisor. One month after the accident the boy's mother reported he had lost his place in two school choirs in which he had been an active member. Apparently due to the dental condition, he had begun to produce a whistling "S" sound that resulted in a lisp which had forced the choir master to replace him. His mother also noticed that he had become quiet and moody, he was very self-conscious of his failures, and his sleep was constantly disturbed.

Dental treatment was begun to restore function and esthetics to these four fractured teeth, as well as speech therapy to correct his pronunciation difficulties. A few months after treatment the patient's entire outlook had changed. He began to assume the confidence he had lost, his appetite improved, and he now slept well. In addition, shortly afterward he regained his position as choir soloist.

The incidence of trauma encompasses a significant amount of the childhood population. Zadik<sup>3</sup> found traumatized teeth in 11.1% of the 965 five-year olds in West Jerusalem that he studied. The tooth most frequently affected was the maxillary central incisor and the fracture most commonly involved enamel with or without dentin. Andreason and Ravn<sup>4</sup> studied 487 Danish children and found that 30% had injuries to their primary teeth and 22% had injured their permanent teeth. In 1979 Ferguson and Ripa<sup>5</sup> also reported that 30% of the children in a Head Start Program in New York exhibited trauma to one or more primary teeth.

In the past, restoring a fractured anterior tooth was a difficult and time consuming venture that ended frequently in less than satisfactory esthetic results. Burr in Hargreaves, Craig and



Needleman<sup>6</sup> discusses 10 restorative options for permanent restoration of fractured teeth in young patients with the options varying in accordance with periodontal status secondary to trauma, condition of pulp, and occlusion. Burr lists in order of ability to preserve and protect the tooth the following 10 restorations: (1) composite resins, (2) pin build-ups, (3) Class IV inlays, (4) gold foil, (5) porcelain inlays, (6) three-quarter crowns, (7) porcelain jackets, (8) acrylic jackets, (9) acrylic veneer crowns, (10) porcelain gold crowns. Fortunately, due to composite resins<sup>7</sup> and the improved bonding characteristics obtained with the use of acid-etching technique to bond composite to enamel,<sup>8</sup> fractured incisors are easily restored<sup>9-11</sup> with little or no additional tooth preparation. However despite development of these materials, resins have their drawbacks such as: decreased wear resistance, difficult shade matching, and staining.

In 1978 Tennery<sup>12</sup> reported using the acid-etch technique with a composite resin to bond tooth fragments to the remnant tooth in five patients, all injured teeth were anterior Ellis Class II or III fractures. Pulpal involvement was not discussed. The technique involved keeping the fragment moist until bonding was to be attempted. Then, after determining the correct positioning of the remnant tooth, the fragment was pumiced, rinsed and dried. He used a finishing diamond to slightly taper the enamel on either side of the fracture line.

Etching the tooth and the fragment was accomplished before applying the bonding acrylic to both. Then an excess amount of composite resin was applied to the tooth and the fragment was repositioned and stabilized with finger pressure until the resin cured. Excess flash was removed and the resin was finished and polished.

Tennery's criteria for success were: retention of the tooth fragment, normal mastication, lack of gingival sequela and natural esthetics. Four of his patients were considered successful at the time the article was written, while the fifth patient suffered an additional trauma to the reunited tooth making it impossible to reunite the fragment again. Tennery described the procedure as a simple, inexpensive technique and recommended it as the procedure of



choice in the treatment of anterior dental fractures in children. The single disadvantage he noted is that it cannot be used if the tooth fragment is lost before the practitioner has a chance to reattach it.

Simonsen<sup>13</sup> in 1979 reported using the reattachment technique. In his method he suggested removing dentin from the fragment to allow room for calcium hydroxide ( $\text{Ca}[\text{OH}]_2$ ) placed in the exposed dentinal and/or pulpal areas and to increase the amount of internal enamel available on the fragment for etching.

Simonsen used three layers of resin. First, spot bonding was accomplished with an unfilled resin to ensure proper three dimensional alignment of the fragment. Secondly, an application of unfilled resin was placed on the entire junction( in this case Simonsen etched with 37% orthophosphoric acid for 60 seconds between the spot-bonding or placement of the unfilled resin). Finally, a mixture of a drop of Resin A (enamel bond) with a small portion of Paste B (Concise) to give a partially filled resin mix is applied. After curing, finishing and polishing area was accomplished.

Simonsen listed esthetics and incisal edge wear as advantages of this technique. He said that one disadvantage is that the fragments may become brittle much as an endodontically treated tooth does after its internal nutrient supply is cut off.

In 1979 Starkey<sup>14</sup> reported that an eight year six month girl was struck in the mouth with a baseball resulted in an Ellis Class II injury to her lower right central incisor and that the fragment was intact.  $\text{Ca}(\text{OH})_2$  was placed over the dentinal tubules of the remnant tooth and fragment during etching with a solution of 50% phosphoric acid. After the  $\text{Ca}(\text{OH})_2$  was removed, Nuva-Seal sealant was placed with a brush on the enamel which had been etched on both the remnant and the fragment. The two were then meshed and held in place while the resin sealant was polymerized with UV light. No enamel bevels were placed.

McDonald and Avery<sup>15</sup> have also reported the case of a 15 year old boy who fractured a maxillary central incisor and the successful management of a Class II fracture by reattaching the fragment with sealant and composite resin. At there writing the fragment has been maintained for more than seven years.



The fragment has been replaced twice during this time, and each failure resulted from an additional direct blow to the tooth.

McDonald and Avery described this technique as being atraumatic to the tooth and an ideal method of restoring the fractured crown with an essentially perfect temporary restoration. Sealing the exposed tooth and restoring it to normal contour and color are accomplished simply and provide an excellent service to the patient that in some cases may serve a long time.

In 1984 Croll<sup>16</sup> published a case report of a nine-year old boy who had received a Class III fracture of the left permanent central incisor. The fracture involved the apical one-third of the coronal portion of the tooth, exposing the pulp chamber. Due to the immaturity of the tooth development, apexification procedures were performed. Next, the tooth was prepared with a long scalloped bevel placed around the periphery of the fractured segment. Using a small round bur, dentinal channels were placed within the fragment to allow for penetration of the dentin adhesive agent. The tooth remnant and the fragment were then luted using a dentin bonding agent and a visible light-cured resin material. A custom-made soft vinyl mouth guard was delivered to the patient and he was instructed to wear it during all sports activities. A five-month recall revealed an intact restoration.

Burke<sup>17</sup> suggested that the use of such a reattachment technique may offer several advantages over the conventional acid-etch composite restoration. Among the advantages of reattachment are:

- (1) better aesthetics, as the shade match and translucency will be perfect;
- (2) more predictable long-term appearance: since only a minimal amount of restorative is exposed on the labial surface at the fracture line, the long term aesthetics will be better when compared to a large composite restoration with its potential for some discoloration with time;
- (3) the incisal edge will wear at a similar rate to adjacent teeth;
- (4) replacement of the fractured portion may be less time consuming than the placement of a large restoration.



In 1986 Dean et al<sup>1</sup>, studied in vitro the relationships of tooth preparation and resin material types in repair of fractured anterior teeth by reattachment of fractured tooth fragments. Extracted teeth were imbedded in acrylic and fractured with a blunt instrument. Only teeth with Ellis Class II fractures were kept. Two different procedures were performed on the same tooth. In the first series the tooth fragment of 22 teeth were bonded onto the tooth without mechanical preparation of either the tooth or the fragment. They were acid etched, (50% phosphoric acid) rinsed with tap water, and dried with compressed air. The teeth were repaired by using a light cured resin bonding agent (Prima-Fil Bonding Agent and Composite Resin) as the luting agent. An additional set of 22 teeth were restored using a chemically cured bonding agent (Compspan Bonding Agent and Composite Resin).

After completion of the thermocycling and shear strength tests on the 44 teeth, a second series of tests were conducted using the same teeth and the fragments remaining from the first test series. The teeth and their respective fragments were prepared with a 45° circumferential bevel. The teeth and the fragments were then etched, rinsed and dried. Half were restored with light cured resin and the other half with chemically cured resin. Thermocycling and shear strength tests were then performed.

Results revealed no difference in shear strength of the fragment between teeth with no mechanical preparation and those that received a 45° circumferential bevel. In addition, no difference was found between chemically cured versus light cured resin materials. This study suggests that simple meshing of the tooth components back together with a resin bonding agent and without any mechanical preparation of the teeth is a viable, relatively easy method to restore fractured anterior teeth.

In 1988, Croll<sup>18</sup> reported a case study in which a fifteen year old girl fractured a maxillary permanent canine resulting in a small pulp exposure. The tooth was treated by placing calcium hydroxide on the exposed pulp, cleansing the dentin surfaces of salivary contaminants with a brief wash of 10% polyacrylic acid, and rinsing. The fragment



was reattached onto the original tooth by the use of a chemically cured glass ionomer cement and a composite veneer restoration was placed on the labial and lingual surfaces for micro mechanical strengthening of the enamel-glass ionomer-composite resin bonded attachment. Croll's rationale was that glass ionomer would be beneficial in enhancing dentin bonding and would also minimize microleakage. At the time of the publication the tooth had maintained attachment without signs or symptoms of pathosis for twelve months.

Most recently in 1993 Andreasen<sup>19</sup> and colleagues studied the reattachment of sheep incisors with a variety of bonding agents and resins (Scotchbond MP, Gluma, and All-Bond 2). They found that loading of teeth bonded with these agents in an Instron testing machine at a speed of 1mm/min demonstrated similar fracture strengths as those previously achieved with Gluma, Scotchbond 2, or Tenure. A second study where fragments were reattached with Scotchbond MP and loaded at various speeds resulted in the fracture strength decreasing exponentially with increased loading speed. They concluded that currently available materials are probably sufficient to withstand such functional stresses; and that resin-bonding of fragments is a realistic treatment alternative to composite resin build-up.

Since the development of glass ionomer by Wilson and Kent<sup>20</sup> nearly two decades ago, it has been touted as the restorative material of the future, and gained increasing use in dentistry due to its remarkable properties. One of these properties is its anticariogenic potential. Glass ionomers leach fluoride ions for long periods of time.<sup>21</sup> These fluoride releasing restorations have been shown to collect less plaque than non fluoride releasing restorations,<sup>22</sup> thus reducing recurrent decay which is a leading cause of failure in non fluoride releasing restorations.

Another property of interest with glass ionomer is its ability to form a physicochemical bond with enamel<sup>23</sup> and dentin.<sup>24</sup> Polyacrylate ions from the glass ionomer become irreversibly attached to the surface of hydroxyapatite by displacing existing



phosphate ions.<sup>25</sup> This physicochemical bond was also shown to occur with treated platinum and gold.<sup>24</sup>

Microleakage has long been a detrimental property of restorations leading to their failure in vivo; however, because of the intimate bond and relatively slow development of shrinkage when compared to composite,<sup>26</sup> glass ionomer has made great strides to reduce microleakage to a minimum. In 1988 Arcoria<sup>27</sup> et al., found that glass ionomer significantly reduced microleakage in both amalgam and glass ionomer restorations even after being subjected to thermocycling between 4<sup>0</sup>C and 50<sup>0</sup>C, 625 times. In 1989 Davis<sup>28</sup> et al., compared the durability of the chemical bond formed by four materials attached directly to tooth structure. Tenure bonding agent recorded the strongest bond at each thermocycling time whereas the bond strength remained unchanged for Scotchbond bonding agent, Ketac-bond glass ionomer cement, and GC lining cement. Glass ionomer also showed no significant difference in microleakage between etched and non-etched glass ionomer liners.<sup>29</sup>

Although a physicochemical bond between glass ionomer and tooth structure is achieved, the shear bond strength of glass ionomer has been a concern in the past. In 1984 two separate studies concluded that composite resin had a superior shear bond strength over glass ionomer when both were bonded to enamel<sup>30,31</sup>, and in 1990 Fajen<sup>32</sup> et al., compared the tensile bond strength of three glass ionomer cements and one composite resin. The results again revealed that the bond strength of the glass ionomer was significantly less than the composite resin but that one of the glass ionomers (Ketac Cem) may have adequate bond strength for clinical use. Tavas 1989<sup>33</sup> and White 1986,<sup>34</sup> both concluded that glass ionomer provided clinically adequate bond strengths when orthodontic brackets were bonded to enamel with glass ionomer; however, McCourt et al.,<sup>35</sup> found that the bond strengths of three glass ionomers that he evaluated had a significant decrease in shear strength to enamel thirty days after being bonded. Bond strengths of glass ionomers have improved immensely since the first generation glass ionomers came on the market in the early 70's. Bond strengths of three earlier glass ionomer materials (Fugii Ionomer Typell, Ketac-



Fil, and Aspa) were compared to a new anhydrous glass ionomer (ChemFil) when adhered to enamel and dentin. The study showed ChemFil to have a significantly higher bond strength.<sup>36</sup>

It is widely known that most failures of the glass ionomer bond are cohesive<sup>33,37,38</sup> and that contamination by saliva of freshly prepared dentin surface results in a marked decrease in bond strength.<sup>39</sup> These two adverse factors in the use of glass ionomer luting agents can be overcome by light cured glass ionomers. In a study by Holtan et al.,<sup>40</sup> in which he compared the shear bond strengths of two auto-cured and one light cured glass ionomer, he concluded that the light cured glass ionomer exhibited significantly better shear bond strength performance than the two auto cured glass ionomers. Mitra in 1990<sup>41</sup> had similar results showing that light cured Vitrabond had almost three times higher bond strength compared with self cured material, and that even after storage in 37°F water for seven months there was no significant difference in the values of compressive and diametral tensile strengths.

Bond strengths of tooth fragments reattached together by glass ionomer has yet to be reported in the literature. Because of the chemical bond formed by glass ionomers to tooth structure and the intimate meshing together of the two tooth pieces, it can be theorized that fragment restoration with glass ionomer would be comparable to that of composite resins.

METHODS AND MATERIALS



Bovine incisors were obtained from the Oral Health Research Institute of Indiana University. These teeth were kept in plain tap water up to and during the course of the study. The study consisted of five basic steps:

1. Fracture of the teeth.
2. Luting of the fractured fragment back to the tooth remnant using the materials to be tested.
3. Thermocycling of the repaired teeth.
4. Conducting the dislodgment test to determine the strength of the repair.
5. Determining type of fracture.

#### Fracture Procedure

Two hundred bovine incisors previously unrestored and noncarious were selected for the study. Each tooth was embedded in a 1.5 inch in diameter cylinder of model plaster. A 1.5 inch in diameter paper cup served as a mold of the model plaster. The teeth were then embedded into the unset model plaster so that only a mesio-incisal or a disto-incisal angle of each tooth was exposed. After the model plaster hardened, the plaster with tooth embedded was inserted in a vise with the tooth parallel to the floor and facial side up. Then a blunt chisel was placed at the tooth/plaster interface and a finger was placed on the lingual surface of the tooth for support. A hammer was used to strike the chisel to produce an Ellis Class II or small Ellis Class III fracture (less than .5mm pulp exposure in size). After all teeth were fractured and the plaster removed, a determination was made as to the acceptability of the fracture obtained and those teeth deemed unacceptable were appropriately discarded. Only 75 of the 200 teeth fractured were deemed acceptable for the study. Each tooth



and its fragment was stored together in water until further employed in the study.

### Luting

The acceptable teeth were randomly and equally assigned into one of the following test groups: (A) Light cured bonding adhesive and composite resin (Prisma-Fil Universal Bonding Agent and TPH Composite Resin, The L.D. Caulk Division, Dentsply International Inc. Milford, DE.), (B) Light cured glass-ionomer base (VariGlass VLC Base, The L.D. Caulk Division, Dentsply International Inc. Milford, DE.), (C) Light cured glass-ionomer liner (VariGlass VLC Liner, The L.D. Caulk Division, Dentsply International Inc. Milford, DE.) The light cured glass-ionomer base and liner are the same material they only differ in their viscosity. The ratio of powder to liquid is 1:1 for light cured glass-ionomer liner and 2:1 for light cured glass-ionomer base.

Group A: Teeth were restored by etching the exposed fractured enamel and dentin of the fragment and the remnant for 30 seconds with 37.5% phosphoric acid, rinsing with tap water, and drying with oil-free compressed air. Following this, bonding agent (Universal Bonding Agent, The L.D. Caulk Division Dentsply International Inc.) was applied to the two dental segments and they were gently meshed together into their original positions. While being held firmly in place each side was light cured for 30 seconds for a total of two minutes. Any small areas of enamel missing from the fracture were replaced with composite resin (TPH Composite Resin, The L.D. Caulk Division Dentsply International Inc.) and cured for 30 seconds per side.

Group B: The remnant and fragment were rinsed with tap water and lightly dried with oil-free compressed air without desiccating. Following this, the light cured glass ionomer base material (VariGlass VLC Base, The L.D. Caulk Division Dentsply International Inc.) were mixed according to manufacturer's recommendations and then applied to the exposed enamel and dentin surfaces of the segments. The two pieces were meshed gently together, held firmly and were then light cured for 30 seconds on each surface for a total of 2 minutes.



Group C: The remnant and fragment were rinsed with tap water and lightly dried with oil-free compressed air without desiccating. Following this, the light cured glass ionomer liner (VariGlass VLC Liner, The L.D. Caulk Division Dentsply International Inc.) were mixed according to manufacturer's recommendations and then applied to the exposed enamel and dentin surfaces of the segments. The two pieces were meshed gently together, held firmly and were then light cured for 30 seconds on each surface for a total of 2 minutes.

Any excess material extruded from the restored fracture line in Groups A, B, and C was gently removed with appropriate hand instruments and finishing burs so that a normal anatomical crown form was achieved. Groups B and C had bonding agent (Universal Bonding Agent, The L.D. Caulk Division Dentsply International Inc.) placed on any exposed glass ionomer and light cured for 30 seconds on each side.

#### Storage and Thermocycling

After restoration, all teeth were stored in tap water at 37°C for seven days. On the eighth day the restored teeth were subjected to thermocycling. They were cycled 2,500 times between two baths having a temperature differential of 40°C. The cold bath was held at 5°C and the hot bath at 45°C. The dwell time in each bath was 30 seconds.

#### Dislodgment Test

After thermocycling, all teeth were stored in tap water at 37°C for seven days. On the eighth day the teeth were embedded in a one inch in diameter cylinder of stone. A one inch plastic tubing served as a mold for the stone. The teeth were embedded into the unset stone exposing the crown of the tooth (figure I). To test the dislodgment strength the embedded teeth were inserted and fitted into a stabilizing jig (figure II). The teeth were positioned so that the facial plane of the crown is as perpendicular as possible to the applied force. The force will be applied to the fragment in a labial-



to-lingual direction by means of a small (1 millimeter) conical point inserted in the end of a pin which will be held in the cross head of a testing machine[(Instron Universal Testing Machine Model 1123, Instron Testing Co, Park Ridge, IL) figure III]. The specimens were loaded to failure at a cross-head rate of 0.5mm/min. The force required to detach the fragment was recorded.

Prior to the initial fracture of each repaired tooth, the fragments were marked on the facial surface with a number 4 round bur 1mm perpendicular to the fracture line (figure III). This was done to standardize application of the force with this point serving as the point of loading. Prior to loading each specimen, the bur mark on the tooth fragment was checked for alignment with the loading pin (figure IV).

After the dislodgment testing the fractured surfaces were examined with a light microscope to determine the nature of the fracture (i.e., cohesive, adhesive, or % mixed).

#### Statistical Analysis

A one way analysis for variance was performed for statistical evaluation and appropriate multiple comparisons were made by subjecting the data to the Neuman Kuels test, T tests, and Tukey's procedure.



RESULTS

The forces required to fracture each tooth after luting ranged from 5.0 kilograms to 116.6 kilograms (Figure V, VI, VII, and Table I). The mean force values for teeth repaired were as follows: light-cured resin required  $36.84 \pm 25.6$  Kg of force to dislodge the fragment, light-cured glass-ionomer base required  $36.44 \pm 26.79$  Kg of force to dislodge the fragment, and light-cured glass-ionomer liner required  $31.42 \pm 29.55$  Kg of force to dislodge the fragment( figure VIII).

The results of the analysis of variance are presented in Table II and III . The following variables were tested: (1) light cured resin, (2) light cured glass-ionomer base, and (3) light cured glass-ionomer liner. The "F" values for the variables tested were 0.304, indicating that the groups were not significantly different from each other at any level of confidence.

Multiple comparisons of the three groups: (1) light cured resin, (2) light cured glass-ionomer base, and (3) light cured glass-ionomer liner using repeated T-Tests, Neuman-Keuls Test and, Tukey's Procedure (Tables II and III ) revealed the following: there was no difference between the mean force required to produce failure in the teeth for Groups A, B, and C when compared with each other( $p < 0.05$ ).

Type of fracture was determined under a light microscope after dislodgment. Fractures were categorized as : (1) adhesive (dislodgment at the tooth/material interface), (2) cohesive(dislodgment within the material), and (3) mixed (combination of adhesive and cohesive). In all three groups the majority of the dislodgment's were the result of a cohesive dislodgment( Table I).



FIGURES AND TABLES



FIGURE 1. Bovine tooth mounted in acrylic ring with stone.

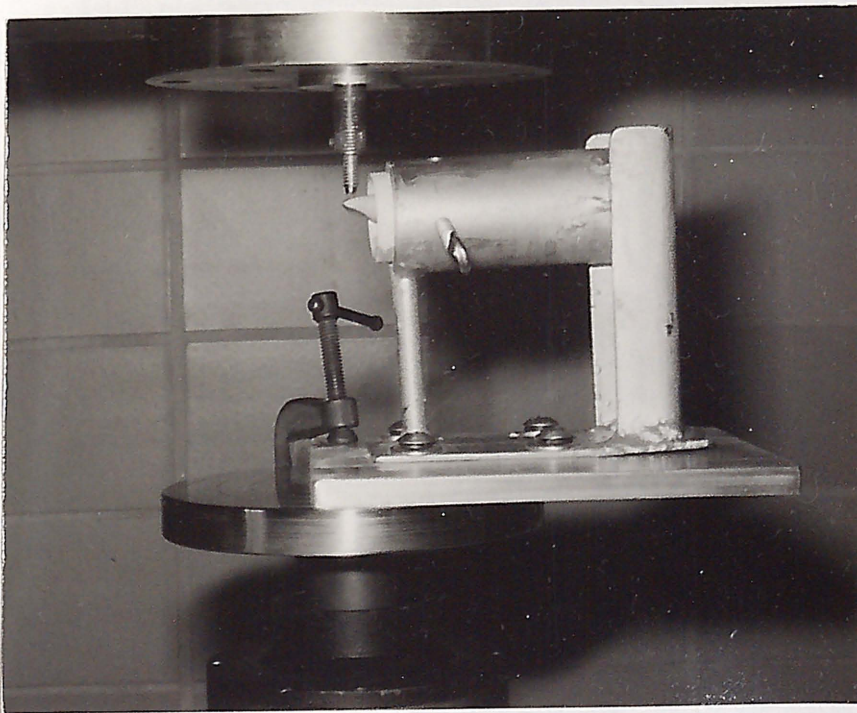


FIGURE 2. Tooth mounted in jig, placed on Instron machine and secured down.





FIGURE 3. Mounted tooth showing dimple mark 1mm perpendicular to the fracture line.

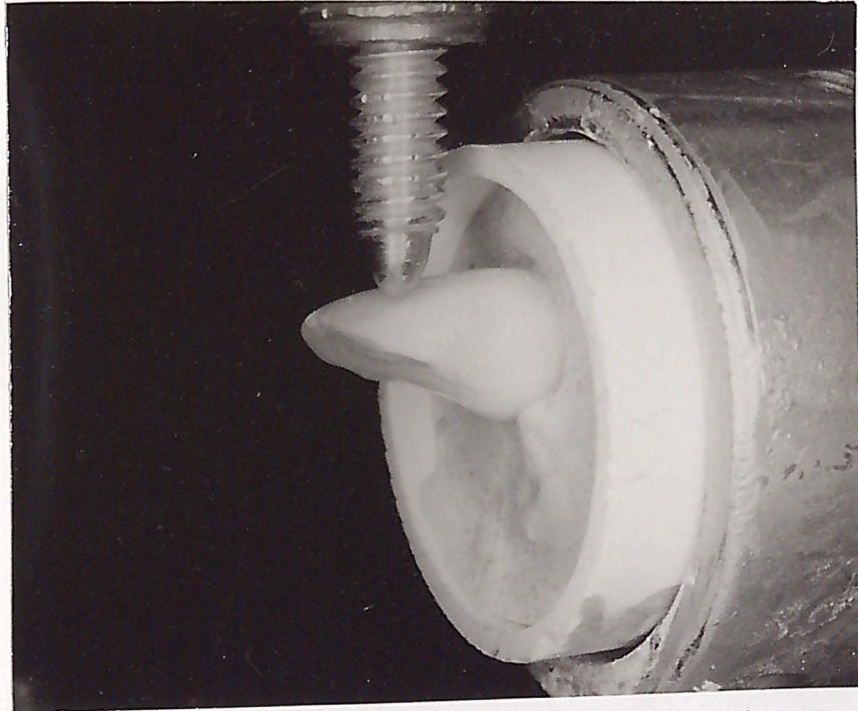


FIGURE 4. Loading pin seated into dimple prior to activating Instron machine.

FIGURE 5. Dislodgment strength values of all specimens in the resin group and their mean value.

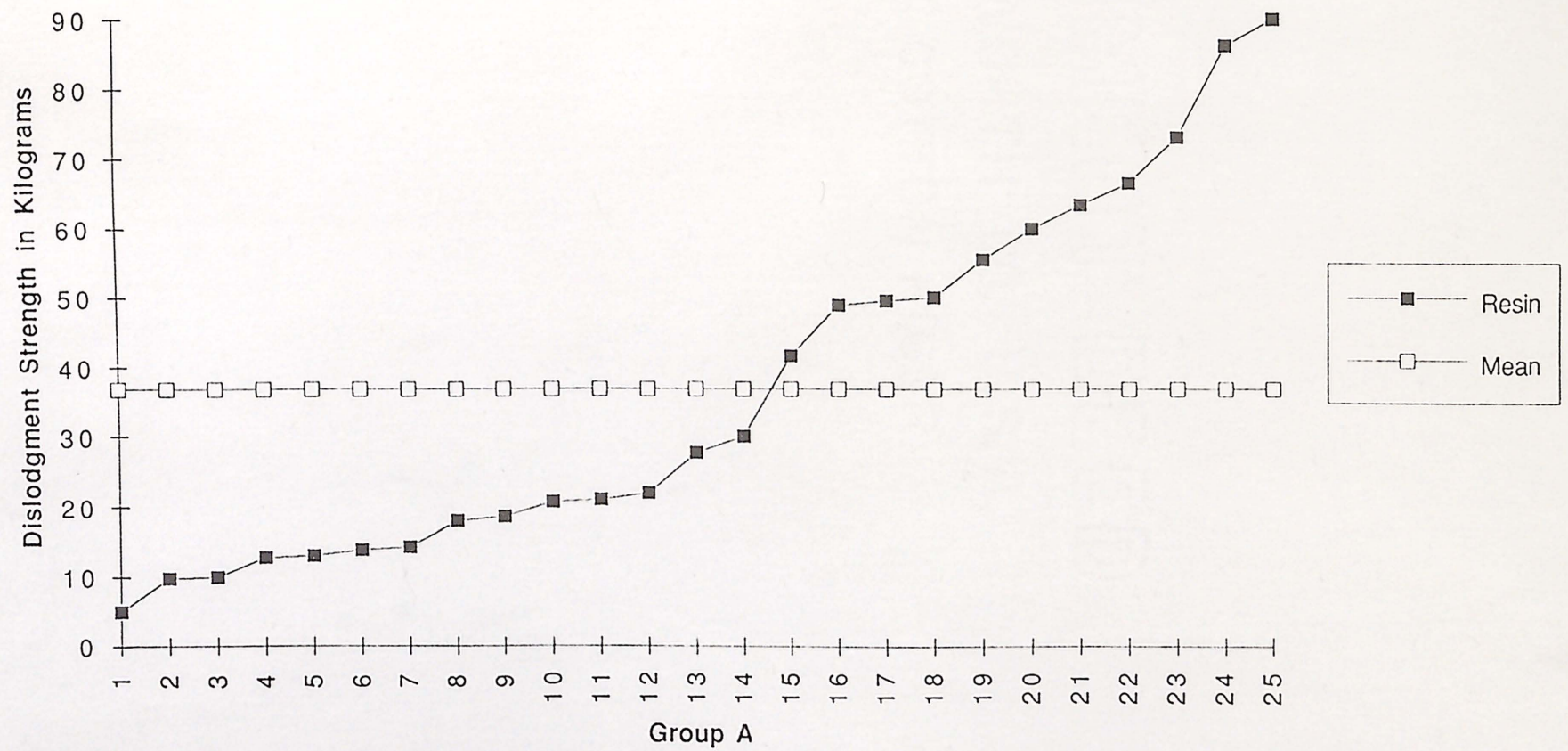




FIGURE 6. Dislodgment strength value of all specimens in the glass ionomer base group and their mean value.

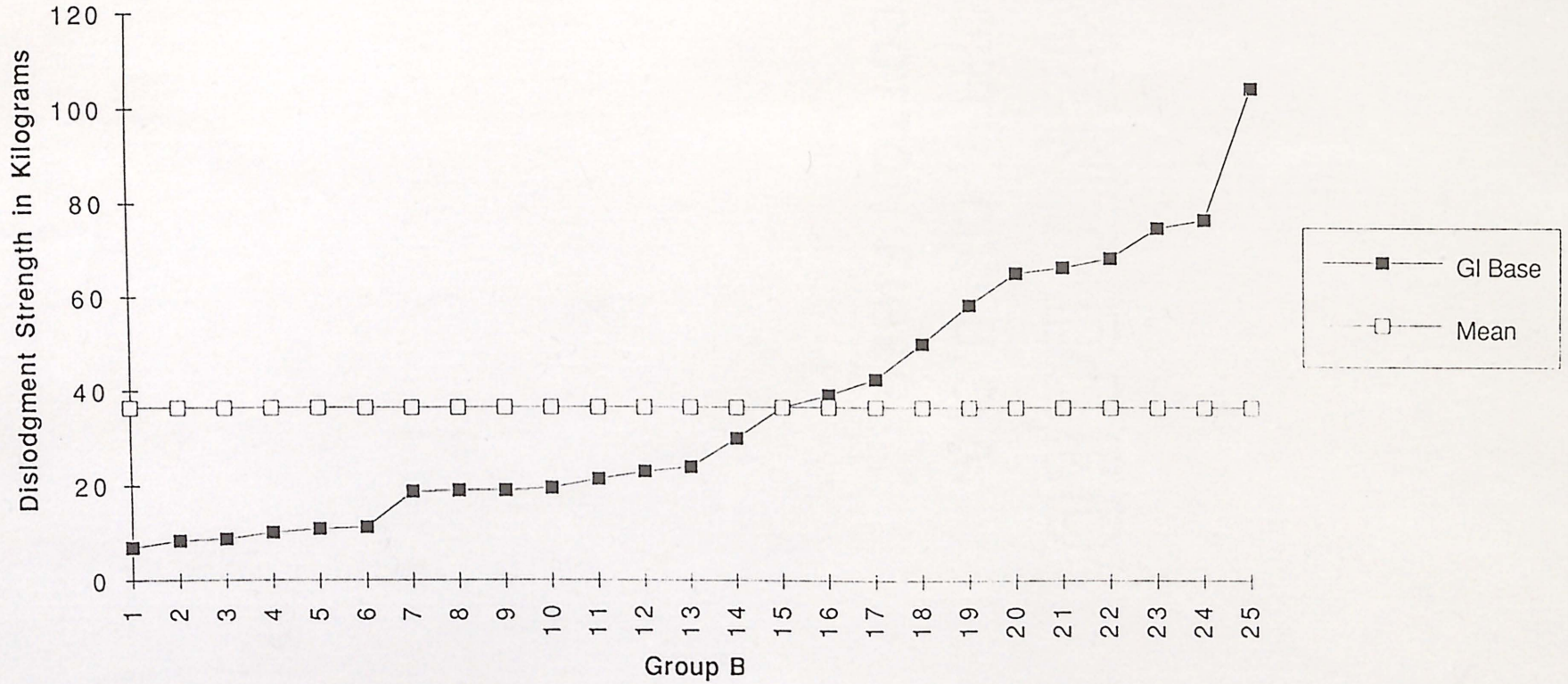


FIGURE 7. Dislodgment strength values for all specimens in the glass ionomer liner group and their mean value.

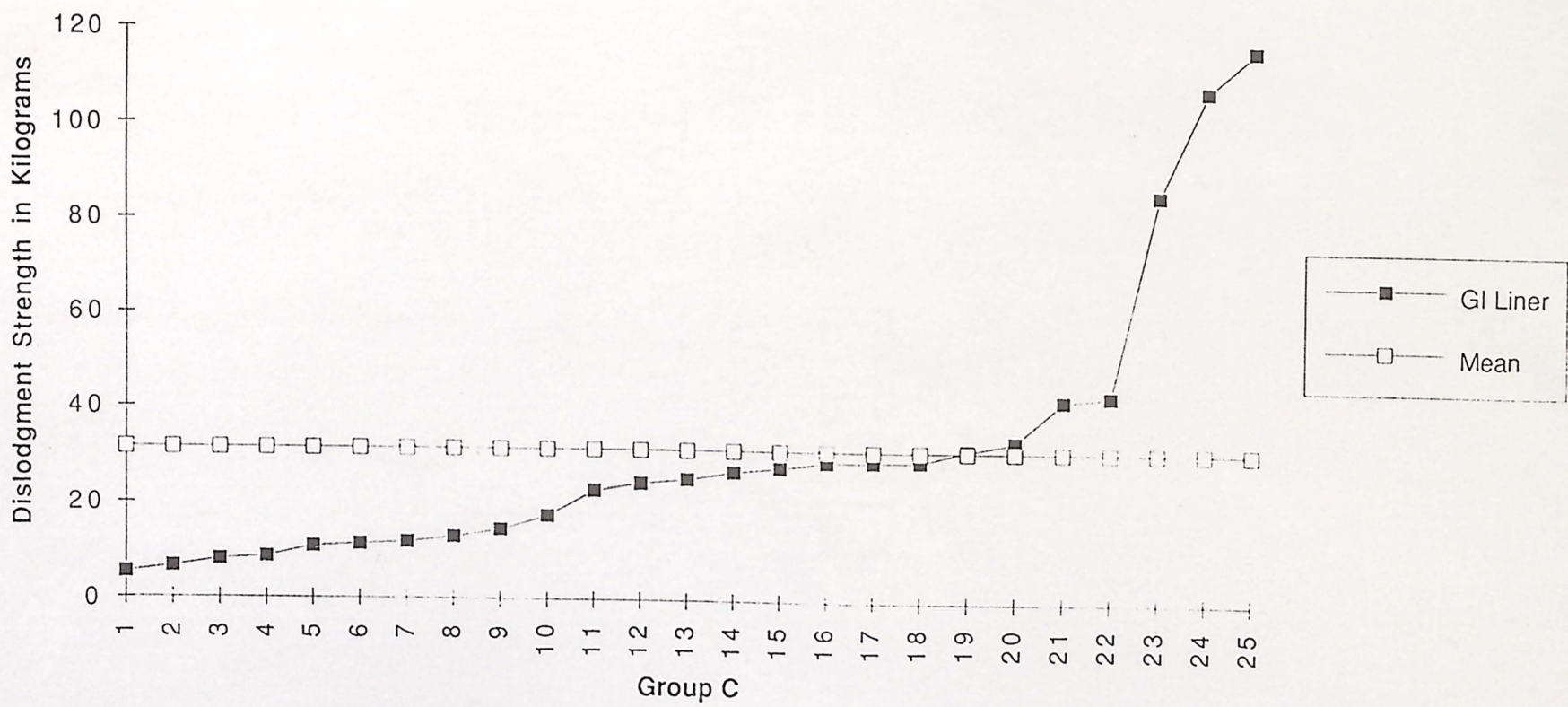




FIGURE 8. Dislodgment strength mean and standard deviations for Groups A, B, and C.

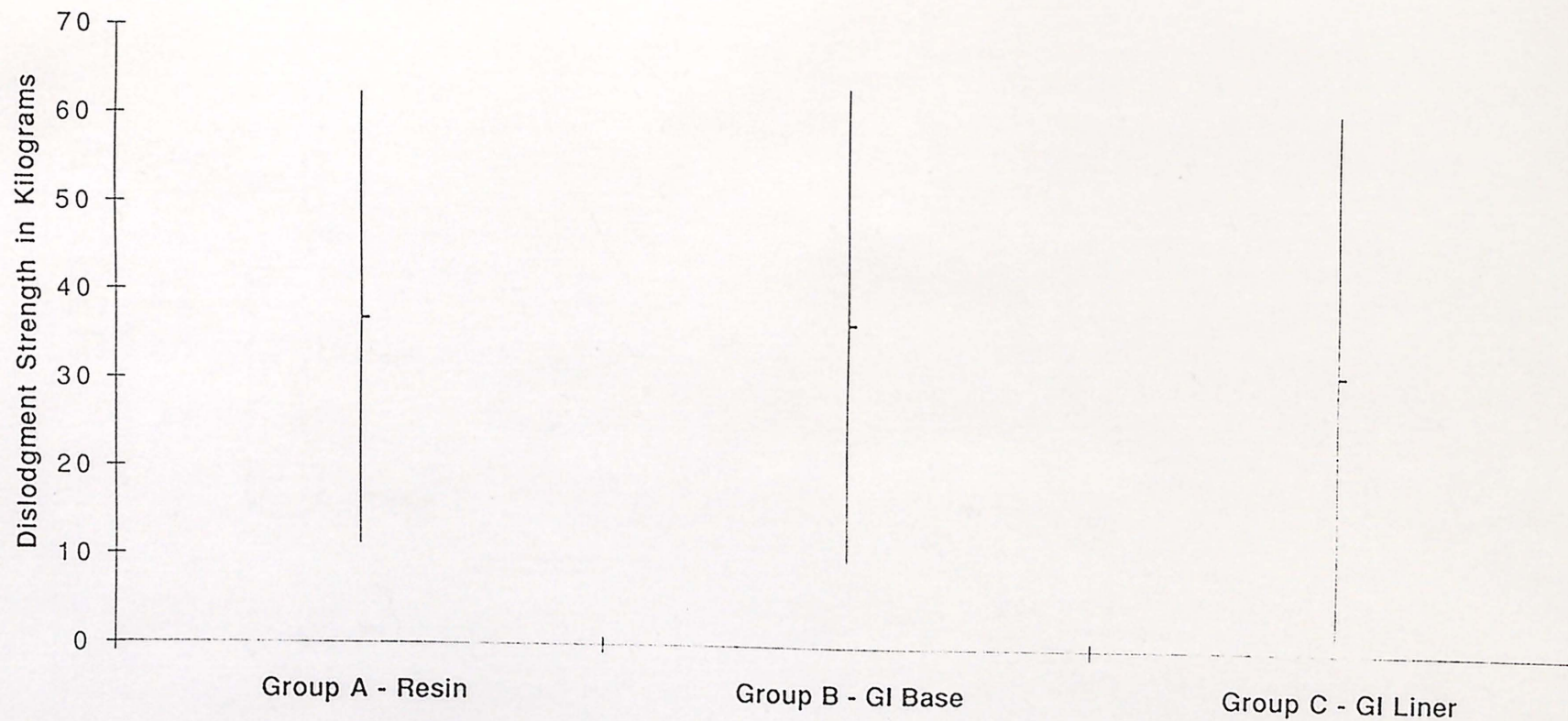


TABLE I  
Fragment Dislodgment Strengths

	Resin(Kg)	GI Base(Kg)	GI Liner(Kg)
1.	49.5	74.5*	28
2.	50	104*	43.3*
3.	59.8	7	11.3
4.	12.8	8.8	25.4
5.	10	42.3	17.5
6.	41.6	19.5	14.6
7.	63.3	36.4	6.5
8.	14.3	50	13
9.	13	19	27
10.	21.9	39.1	23
11.	5	66.2	31.9
12.	48.8	8.4	29.5
13.	66.5*	21.3	29.3
14.	30	19	11.9
15.	55.4	29.9	42.3
16.	20.7	22.9	116.6*
17.	90	10.1	33.7
18.	9.8	23.9	29.4
19.	18	76.3*	86*
20.	73*	58.2	108*
21.	13.9	68.2	24.6
22.	18.6	10.9	10.9
23.	21	11.3	5.3
24.	86.3*	18.8	8.6
25.	27.7	65	8
-----			
Ave	36.8	36.4	31.4

TYPE OF FRACTURE

RESIN	GI Base	GI Liner
cohesive 19	cohesive 18	cohesive 18
mixed 3	mixed 3	mixed 2
	adhesive 1	adhesive 1

\* Denotes that fragment was not dislodged but that tooth fractured either at the CEJ or completely within the root.



TABLE II

## DESCRIPTIVE DATA

GROUP	NUM	MEAN	VAR	STD DEV	STD ERR
1	25	36.836	655.3703	25.6002	5.12004
2	25	36.44	717.6935	26.7898	5.35796
3	25	31.424	873.1908	29.5498	5.909961

## ANALYSIS OF VARIANCE

SOURCE	D.F.	S.S.	M.S.	F
AMONG GROUPS	2	455.0547	227.5274	.304
WITHIN GROUPS	72	53910.1	748.7514	NA
TOTAL	74	54365.16	NA	NA

CRITICAL 'F' VALUE @ 5=3.126 (WITH 2,72 D.F.)

\*THEREFORE THERE IS NO SIGNIFICANT DIFFERENCE @ 0.05 LEVEL OF SIGNIFICANCE

## MULTIPLE COMPARISONS USING REPEATED T-TESTS

GROUPS	D.F.	DIFF	TEST VAL	CRITICAL VALUE AT P=	
				0.05	0.01
1-2	72	.3959999	.051	1.994	2.646
1-3	72	5.411999	.699	1.994	2.646
2-3	72	5.015999	.648	1.994	2.646

TABLE III

## MULTIPLE COMPARISONS USING NEWMAN-KUEL'S TEST

GROUPS	D.F.	DIFF	TEST VAL	CRITICAL VALUE AT P=	
				0.05	0.01
1-2	72	.3959999	.051	1.996	2.652
1-3	72	5.411999	.699	2.397	3.017
2-3	72	5.015999	.648	1.996	2.652

## MULTIPLE COMPARISONS USING TUKEY'S PROCEDURE

GROUPS	D.F.	DIFF	TEST VAL	CRITICAL VALUE AT P=	
				0.05	0.01
1-2	72	.3959999	.051	2.397	3.017
1-3	72	5.411999	.699	2.397	3.017
2-3	72	5.015999	.648	2.397	3.017



DISCUSSION

This research project was designed to determine: (1) whether there is a difference in dislodgment strength between light cured glass-ionomer base, light cured glass-ionomer liner and light cured composite resin, and (2) the nature of the dislodgment (i.e., adhesive, cohesive, or mixed).

### Dislodgment Strength

Glass-ionomer has been shown to form a physicochemical bond with tooth structure<sup>23,24,25</sup> allowing an intimate interlocking. Shear bond strengths of conventional self curing glass-ionomers have been shown to be much weaker when compared to composite resins<sup>30,31</sup>; however, light cured glass ionomers combined with a "dual set" reaction appear to resolve the problem of the delayed setting reaction of conventional chemically-cured glass ionomer cements<sup>42</sup> and have been shown to improve the shear bond strength significantly over chemically curing glass ionomers<sup>40,43</sup>, as much as three times stronger<sup>41</sup>.

The light cured glass-ionomer used in this study (VariGlass VLC, The L.D. Caulk Division Dentsply International Inc.) is generally not considered a "true" light cured glass-ionomer. VariGlass powder is a blend of two glasses: strontium and barium boron aluminosilicate. The glasses provide radiopacity and fluoride release. The liquid is polyacrylic acid, PENTA, and visible light cured active monomers. VariGlass is cured by light activation only.<sup>44</sup> VariGlass lacks the ability to chemically react in the dark which is a property of "true" light cured glass-ionomers. Hybrid glass-ionomers or glass-ionomer resins such as: Fugii II LC (GC America Inc.); Photac-Fil (ESPE Premier); VariGlass (L.D. Caulk/Dentsply); Vitremer (3M) usually contain a small amount of resin and thus incorporate properties of both resin and glass-ionomer.<sup>45</sup> Due to the composition of VariGlass it cannot be completely compared to other glass-ionomers.



The results of the dislodgment tests of the light cured glass-ionomer liner (VariGlass VLC Liner, The L.D. Caulk Division, Dentsply International Inc.), light cured glass-ionomer base (VariGlass VLC Base, The L.D. Caulk Division, Dentsply International Inc.), and composite resin (Universal Bond and TPH Composite Resin, The L.D. Caulk Division, Dentsply International Inc.) indicated that the three materials were essentially equal in their ability to bond the tooth fragment to the original tooth remnant.

One variable to consider in the study is the angle of the fracture. Dean's<sup>1</sup> results showed that teeth that had a lingual fracture and thus lingually supporting tooth structure withstood labial forces better than teeth without lingual support. In this study, teeth were blindly assigned to one of the three groups and it is possible that one group ended up with more of one type of fracture.

Another variable inherent in this study was the difference in size of each fragment and the distance difference of the loading force from the incisal edge. Distance from the fractured site was kept consistent at 1 mm from fracture but leverage of the force would be different due to the varying lengths of the remnant. This could have been controlled had all remnants been the same size, length, and angle of fracture; however, again due to random assignment this may or may not have been a factor in the overall results of the study.

Ten teeth in the study (3 Resin, 3 GI Base, and 4 GI Liner) did not dislodge at the original fractured site, instead the loading force fractured the tooth at a new site in the crown or root of the tooth leaving the luted remnant and tooth site completely in tact (Table I, specimens marked with \*). This suggests that the dislodgment strength must have been greater than what we recorded since we stopped once the tooth fractured.

Since the viscosity of the light cured glass-ionomer base is thicker than the light cured glass-ionomer liner, the base group would not have been able to accomplish the same intimate meshing of the remnant and fragment that the liner accomplished; however,



since the dislodgment strength between the two forms of glass-ionomer are not significantly different this does not lend support to the intimate meshing providing any strength. Further studies should test more viscous material than VariGlass glass-ionomer base to provide support or discount the intimate meshing theory.

Light cured glass ionomers have the advantage over resins by not further traumatizing the teeth because light cured glass ionomers do not require acid etching which may add to the trauma; however, if the teeth in the glass ionomer groups had been acid etched would this have increased the dislodgment strength a statistically significant amount? Also future research should look into the use of newer glass ionomers which may allow for better bond strength.

#### Type of Fracture

Shear strength studies of glass ionomers have shown that the weak link in the bonding of glass ionomer to enamel or dentin is in the infrastructure of the glass ionomer, a cohesive failure.<sup>33,37,38</sup> All dislodged fragments and remnants were studied microscopically for the type of fracture. The overwhelming majority of dislodgments were the result of a cohesive failure in both the resin and glass ionomers (composite resin 86.4%, glass ionomer base 81.8%, and glass ionomer liner 85.7%). This supports previous studies.

Further studies need to compare etched vs non-etched glass ionomer reattachments, the relationship of surface area to dislodgment strengths, the relationship of the point of the loading force and the size of the fracture.



SUMMARY AND CONCLUSIONS

An in vitro study of 75 bovine incisors was undertaken to analyze certain materials that were used in the reattachment of fractured anterior tooth fragments. The teeth were divided into three groups with 25 in the light cured composite resin group, 25 in the light cured glass ionomer liner group, and 25 in the light cured glass ionomer base group. The teeth were fractured and reattached back together with one of the materials without any tooth preparation. Following each reattachment procedure and after eight days of storage in 37°C water, the teeth underwent a 40°C differential thermocycling procedure. In addition, they were stored for eight days again in 37°C water prior to testing in the Instron machine. The kilograms of force required to refracture the fragments was recorded and analyzed for statistical significance.

No significant difference was found between the three groups following dislodgment testing with the Instron machine. The mean fracture value for the three groups were as follows: light cured composite resin was 36.8 kg, light cured glass ionomer liner was 31.4, and light cured glass ionomer base was 36.4. These results suggest that the three materials are equally as strong, and that light cured glass ionomers are a viable option in the reattachment of tooth fragments.

The nature of the fracture was also studied. After the dislodgment of the fragment, each tooth was analyzed with a microscope to determine whether the fracture was adhesive, cohesive or mixed. The results reveal that the majority of the fractures were cohesive in nature ( composite resin 86.4%, Glass ionomer base 81.8%, and glass ionomer liner 85.7%). Clinically this continues to support previous studies that the material is the weakest link in the bond.

In summary, this study suggests that fragment reattachments using light cured glass ionomers are as retentive and strong as composite resins. Also, the viscosity of the glass ionomer has no



significant difference on the strength of the bond. Finally, the majority of the type of fracture of the 75 teeth is cohesive in nature.

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FRAGMENT REATTACHMENT WITH  
LIGHT-CURED GLASS-IONOMER

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This investigation examined the relationships among light cured glass ionomer liner, light cured glass ionomer base, and composite resin material in the reattachment of fractured anterior tooth fragments. Seventy-five bovine incisor teeth were fractured and luted back together with three different materials (Universal Bonding Agent/TPH Composite Resin; VariGlass VLC Liner; VariGlass VLC Base, LD Caulk Div Dentsply Int Inc, Milford, DE) of equal number. The reattached fragments were subjected to thermocycling with a 40<sup>o</sup> C differential and then were loaded until the force required to detach the fragment was reached. The mean dislodgment strengths were 36.8 ( $\pm$  25.6)kg for the composite resin, 36.4 ( $\pm$ 26.7)kg for the glass ionomer base, and 31.4 ( $\pm$  29.5)kg for the glass ionomer liner. Analysis of variance demonstrated no significant difference between the three groups at  $p \leq 0.05$ .

Also examined was the type of fracture after reattachment. Of the sixty-five teeth that were studied microscopically, 84.6 percent of the fractures were cohesive in nature, thus a breakdown occurred within the material itself.



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