ATTACHMENT OF ANTERIOR TOOTH FRAGMENTS

by

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I would like to thank the leaders of my graduate institution, Dr. David Jones, Dr. John Smith, Dr. James Johnson, Dr. William Miller, and Mr. John Doe for their support and guidance during this project. I would also like to acknowledge Dr. Jane Smith for suggesting the original idea and Dr. Robert Brown for his contributions during the development. Thanks also go to Mr. Smith for his assistance in the statistical analysis of the data.

Lastly, I would like to express my appreciation and love to my family, who offered their understanding, assistance, and support. Their love would never have been finished. To my children, my love—my best wishes for you seeing yourselves.

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Injuries to the anterior teeth present one of the more difficult and perplexing problems faced in dentistry. Not only is there physical trauma to the tooth or teeth but there is also a psychological impact on the patient and parents. The appearance that we present to others affects our self-image, as well as the way others react and relate to us.

Trauma to the anterior teeth is a common problem to the child and adolescent. Fractures often occur and the dentist is faced with choosing a treatment program that will return the tooth to its original condition insofar as possible. While acid etch resin restorations have been suggested as one of the better choices, another method to increase the function and esthetics of the tooth has been reported. Reattaching the original fractured tooth fragment to the tooth remnant enhances the durability of the restoration, since the fragment wears at the same rate as the other teeth, which is usually slower than the rate for composites. Also the natural enamel translucency and surface finish of the fragment provides the tooth with its original esthetics.

This study investigated the effectiveness of the fragment reattachment technique by measuring the forces required to cause separation of the fragment while comparing two different etching agents. Also compared were the forces required to break the reattachment with no mechanical tooth preparation versus reattachment after beveling the fractured enamel margins.
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This study investigated the effectiveness of the fragment reattachment technique by measuring the forces required to cause separation of the fragment while comparing two different luting agents. Also compared were the forces required to break the reattachment with no mechanical tooth preparation versus reattachment after beveling the fractured enamel margins.
In 1955 Steck and Jones\textsuperscript{1} wrote:

The psychological trauma which may follow the fracture of a permanent incisor in children aged 7-9 is in many cases underestimated and not entirely overlooked. It is important that the child's appearance be restored to normal as soon as possible. The consciousness of being 'different' from the rest, the teasing to be endured at school, and the family disappointment at this blow to beauty are sufficient in any children to cause disturbances in mental attitude ...

The authors 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 later the boy's mother reported he had lost his place in two school choir sections in which he had been an active member. Apparently due to his dental condition, he had begun to produce a whistling 'p' 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.

Trauma to the anterior teeth is a rather common occurrence. Ellis and Deery\textsuperscript{2} in 1970 reported that of 4,251 children studied, 4,21 had one or more teeth with a fracture of some sort. They stated that at least

\textbf{REVIEW OF THE LITERATURE}
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Trauma to the anterior teeth is a rather common occurrence. Ellis and Davey\textsuperscript{2} in 1970 reported that of 4,251 children studied, 4.2\% had one or more teeth with a fracture of some sort. They stated that at least
60-70% of all fractures of the teeth are of the Ellis Class II type (involving enamel and dentin only). Zadik\textsuperscript{3} 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. Baghdady et al.\textsuperscript{4} in 1981 reported similar results. In their study of 6,090 Iraqi and 3,507 Sudanese primary school children, 7.7% of the Iraqis and 5.1% of the Sudanese presented with trauma of the incisors.

Other investigators have reported an even higher incidence of trauma. Andreason and Ravn\textsuperscript{5} in 1972 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\textsuperscript{6} reported that of 386 children in a Head Start Program in New York with evidence of trauma to the anterior teeth, 30% had one or more primary teeth which exhibited evidence of trauma. Fractures were the most common type of injury; and of the 143 fractures reported, 121 involved only the enamel. No pulpal exposures as a result of fractures were reported, but these may have been included in the 49 cases found with missing teeth.

With this high rate of fractures, it becomes important to have a well-established and effective method of treating them. Many authors\textsuperscript{2,5,7-11} have dealt with the emergency and intermediate treatment and care of these teeth. They have also described methods of permanently restoring these teeth, depending on the particular injury to the tooth and other treatment considerations. Law\textsuperscript{12} has listed four requirements of a restoration for fractured young permanent incisors: (1) The preparation must be such that it does not injure the pulp; (2) It should not increase
the mesiodistal width or the labiolingual dimension of the original tooth; (3) It should be durable and functional; (4) It should be as esthetic as possible.

Burr in Hargreaves, Craig and Needleman\textsuperscript{11} 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. Of these 10, composite resins seem to meet Law's\textsuperscript{12} requirements best. This approach requires minimal preparation, can return the tooth to its original size and shape, is durable and functional, and is highly esthetic. Andreason,\textsuperscript{13} in discussing what he termed uncomplicated crown fractures where the pulp is not exposed, also recommends as the treatment of choice an acid-etched composite resin restoration.

In 1955 Buonocore\textsuperscript{14} first suggested the use of phosphoric acid to render enamel more susceptible to adhesion by resins. Although the exact mechanism for this increased adhesion was not fully understood at the time, Buonocore did realize and recommend its use in resin restorations and for pit and fissure sealants as a method of caries prevention. Lee et al.,\textsuperscript{15} in a laboratory study on bovine teeth, showed that pretreatment with 50% phosphoric acid significantly increased the bonding of direct filling resins to enamel. They also demonstrated that the use of a cavity sealer in conjunction with the acid etching enhanced the retention
of the resin to the enamel surface. This appears to be related to the ability of the resin to wet and adapt to the etched enamel surface. Poor results have been obtained for the adhesion of composite resins to dentin surfaces.

Microfilled composites have a significantly lower bond strength than conventional composites, which appears to be related to the concept that tensile strengths and bond strengths of composite resins have a high coefficient of correlation (0.74). When a composite-enamel bond is stressed to the breaking point, it is the resin itself that is fractured. This helps explain the high correlation between the tensile and bond strengths of composites.

Many authors have reported on the clinical success of using acid-etched resin restorations for fractured anterior teeth. Various tooth preparation methods were used, including combinations of bevels, butt-joint shoulders, feather-edging, or no preparation at all. The materials used to restore these teeth also varied. Unfilled resins, composites, composites with pit and fissure sealants, and composites with bonding agents were all used with varying degrees of success but all were clinically acceptable.

Several in vitro studies have evaluated the acid-etch resin restoration in fracture cases. Nelson et al. studied the relationships between tooth preparation, concentration of acid conditioner, and retention of restorative materials in 72 extracted maxillary central incisors. They found the 25% and 50% acid concentrations to be significantly better than a 75% concentration in preparing the tooth for restoration. The addition of a scalloped preparation in enamel increased
the resistance to displacement of the restoration compared to specimens with flat preparations. As for the type of restorative material, the Nuva-Seal/Nuva-Fila combination required the most force for displacement.

In 1977 Yates and Hembree studied 60 extracted maxillary central incisors and concluded that when using a beveled preparation a retentive groove will aid in resistance to fracture. Also, under the conditions of their study, Restodent was the resin most resistant to fracture.

In 1981 Black et al. studied the effect of various preparation designs on the retention of Class IV composite resins. The three major restorative techniques studied were the featheredge, the chamfer, and the bevel restorations. Thirty extracted human maxillary central incisors were divided equally for the three groups. The results in terms of load required to fracture the restorations showed, in decreasing order of retentive forces, the bevel highest, the chamfer next, and the featheredge lowest. Despite these results, the authors stated that the ease of performing clinical procedures is a major consideration when advocating a specific operative procedure for the restoration of fractured incisal edges. Taking this into consideration, a 45° bevel, extending the full enamel thickness, is recommended for accessible cavosurface angles to retain fractured incisal edge restorations.

Davis et al. in 1983 compared the marginal integrity of fractured anterior teeth prepared with the bevel versus the chamfer preparation, and restored with a conventional adhesive composite versus a microfill composite resin system. The chamfer preparation contained entirely

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a L.D. Caulk Co., Milford, Delaware.
b S. Lee Pharmaceuticals.
within enamel proved to be superior to the bevel preparation with respect to hydration and thermal effects on marginal integrity. The chamfer also offered improved esthetics compared to the butt joint preparation. The authors stated that the average life expectancy for an adhesive fracture repair is between five and 10 years. Their results indicated that the longest life span for a restoration is achieved by using the chamfer preparation. They also showed that the microfill resins had a higher incidence of marginal leakage, possibly due to the less compatible coefficient of thermal expansion or more difficulty with initial marginal adaptation.

Bagheri and Denehy\textsuperscript{36} measured the shear strength of Class IV composite resin restorations by using varying lengths of etched enamel bevels for retention. Using 70 noncarious, unrestored, freshly extracted human maxillary central incisors, they prepared 10 groups. Bevel lengths were either 1mm, 2mm, 3mm, or a 90° butt joint. The restoration lengths were also varied, either 2, 3, or 4mm. Analysis of their results showed no significant difference in shear strengths for different lengths of bevels. The only significant difference in shear strengths was between lengths of restorations.

While length of bevel did not alter retention significantly, the fact that there was a bevel, as opposed to a butt joint, did increase the retention. Also, retention was significantly better for the shorter restorations than for the longer ones.

Recently, several cases have been reported in which the original tooth fragment was reattached to the tooth remnant by means of an acid-etch resin. This type of restoration, if successful, would meet Law's\textsuperscript{12} requirements for a restoration even better than the composite resin.
Background

In 1978 Tennery reported using the acid-etch technique with a composite resin to bond tooth fragments to the remnant tooth in five patients: four children, ages 8 to 14, and one adult, age 30. All injured teeth were anterior Ellis Class II or III fractures. Pulpal involvement was not discussed.

Tennery's 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 finished and polished.

Tennery's criteria for success were: retention of the tooth fragment, normal mastication, lack of gingival sequelae and natural esthetics. Four of his patients were considered successful at the time the articles 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 in 1979 gave four reasons for using the circumferential bevel for reattachments:

1. It removes superficial enamel and fractured enamel prisms.
2. It allows for resin-enamel lap joint.
3. It forms a finishing line.
4. It presents enamel prisms in "end-on" relation.

He also suggested removing dentin from the fragment to allow room for calcium hydroxide (Ca(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.

In his technique, 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 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 are 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 reported a case of reattachment in a girl aged eight years and six months who had received an Ellis Class II injury to her mandibular right lateral incisor. Ca(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 Ca(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 made.

Starkey verbally related reports of similar reattachments being successful for one to five years or more. He warned that care must be taken in Ca(OH)$_2$ placement prior to acid etching due to close proximity of the fracture to the pulp. He also suggested that in cases where the fracture is very near the pulp, a six-week period of Ca(OH)$_2$ treatment for reparative dentin formation should be considered before luting the fragment to the tooth.

In 1982 Simonsen$^{40}$ again reported a case of reattachment, but in this case he used an external enamel bevel on the lingual of the tooth and fragment and an internal enamel bevel on the facial to increase esthetics. Some incisal dentin was removed from the remnant tooth to allow room for Ca(OH)$_2$ placement and the tooth and fragment were etched with 37% phosphoric acid. An unfilled resin layer was placed first with a microfilled resin over it. The fractured edges were nestled back into place and held during polymerization of the resin.

During the two years between placement of the restoration and publication of the article, the patient underwent orthodontic treatment requiring bonding to the tooth. The fragment remained attached even after removal of the orthodontic brackets. One concern mentioned was the white, chalkish appearance of the fragment compared to the remnant
tooth, due to the fact that the fragment was allowed to dry for one week before reattachment. Simonsen therefore suggested keeping the fragment moist between the time of injury and the time of reattachment. He added that many similar fractures have been treated using an internal enamel bevel around the whole tooth instead of just the facial. He stated that this is the preferred method.

McDonald and Avery described a case of reattachment of a Class II fracture on the maxillary left central incisor in a 15-year-old boy. The treatment was provided approximately two hours after the accident occurred and the fragment restoration had been retained for more than two years at the time they were writing. Their technique involved the following procedures. After confirming the fit of the fragment on the tooth remnant, a thin layer of Ca(OH)$_2$ was applied to the exposed dentin of the remnant tooth. To enable the fragment enamel to again mesh with the remnant enamel, a small portion of the fragment dentin was removed with a bur. Both the fragment and remnant were properly acid-etched and then meshed after being painted with a light covering of sealant material. The two were held together firmly while the resin was cured with the light, and a small defect of lost enamel on the labial surface was then repaired using a composite resin.

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 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 mouthguard was delivered to the patient and he was instructed to wear it during all sports activities. A five-month recall revealed an intact restoration.

A review of the literature makes it clear that there are several methods for reattachment of fractured incisal edges to the remnant tooth. Although these methods have been tried successfully in several clinical cases, no study has investigated the advantage of one technique over the other. This research has been designed to compare the effectiveness of two luting agents and two enamel preparation procedures in the fragment reattachment technique.
Extracted incisors were collected from oral surgery offices in the Indianapolis area. These teeth were kept in plain tap water up to and during the course of the study. The study consisted of four basic steps: (A) fracture of the tooth, (B) tooth preparation and luting of the fractured fragment, (C) thermocycling, and (D) shear strength test.

**Fracture Procedure**

After collection of the teeth, 93 previously unrestored and non-caries maxillary central incisors were selected for the study. The central incisors were embedded in a one-half inch in-diameter cylinder of tray acrylic. A one-half inch (inside diameter) plastic tubing served as a mold for the acrylic. The teeth were then embedded into the unpolymerized acrylic so that only a mesio-incisal or a disto-incisal angle of each tooth was exposed. After the resin hardened, the plastic tube was removed and the embedded tooth inserted in a vise with the incisal edge up. Then the exposed edge of the tooth was struck with a blunt instrument to produce an Ellis Class II fracture (Figure 1).

Unfortunately, this procedure did not always result in the desired fracture pattern; thus many teeth were discarded. Only 44 of the original 93 teeth fractured in the desired manner.
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\textsuperscript{a} Formatray, Sybron/Kerr, Romulus, Michigan.
The acrylic surrounding the crown of the tooth was carefully removed from the specimens so that only the root of each tooth remained embedded in the acrylic.

**Tooth Preparation and Luting**

Two different procedures were performed on the same tooth; thus each tooth served as its own control. In the first test series, the tooth fragment was cemented onto the tooth without mechanical preparation of either the tooth or fragment. The fractured fragment and the enamel of each fractured tooth were etched for 60 seconds with 50% phosphoric acid, then rinsed with tap water for 30 seconds and dried with compressed air.

Twenty-two teeth were repaired by using a light-cured resin bonding agent\(^a\) as the luting agent. An additional 22 teeth were restored using a chemically-cured bonding agent\(^b\) for attaching the tooth fragment to the crown. A repaired tooth is shown in Figure 2.

After completion of the thermocycling and shear strength tests on the 44 teeth, a second series of tests was conducted using these same teeth. The teeth and their respective fragments were prepared for the second test series in the following manner. The preparation of each tooth and fragment involved placing a circumferential bevel at an angle of approximately 45° to the fractured surface by means of a 169 carbide bur. A high speed handpiece using air as the coolant was employed. The angle of the bevel preparation was produced as it would be in the clinical

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\(^a\) Prisma-Fil Bonding Agent and Composite Resin, Caulk Co., Div. of Dentsply International, Inc.

\(^b\) Comspan Bonding Agent and Composite Resin, Caulk Co., Div. of Dentsply International, Inc.
setting, simply by estimating the angle of the cut. The prepared enamel was etched for 60 seconds with 50% phosphoric acid, then rinsed with tap water for 30 seconds and dried with compressed air. The light-cured test group was then restored with a light-cured bonding agent and composite resin.\textsuperscript{a} The chemically-cured test group was restored with a chemically-cured bonding agent and composite resin.\textsuperscript{b} The respective composite resins in each test group were used to fill the "V" formed by the bevel preparation.

The curing time for the light-cured restorations was 60 seconds for each tooth surface (mesial, distal, facial, and lingual), or four minutes total. A 10-minute curing time was allowed for the chemically-cured restorations.

**Storage and Thermocycling**

After restoration all teeth were stored in tap water at 37°C for 28 days. During the third week of the four week storage period the restored teeth were subjected to thermocycling. They were cycled 2,500 times between two water baths having a temperature differential of 40°C. The cold bath was held at 12°C and the hot bath at 52°C. The dwell time in each bath was 30 seconds.

**Shear Strength Test**

In order to test the strength of the joint of the fracture repair, the embedded tooth with its luted fragment was inserted and fitted into the stabilizing jig shown in Figure 3. The tooth was positioned so that

\textsuperscript{a} Prisma-Fil Bonding Agent and Composite Resin, Caulk Co., Div. of Dentsply International, Inc.

\textsuperscript{b} Comspan Bonding Agent and Composite Resin, Caulk Co., Div. of Dentsply International, Inc.
the facial plane of the crown was perpendicular to the applied force. The force was applied to the fragment in a labial-to-lingual direction by means of a small stainless steel ball-bearing inserted in the end of a pin which in turn was held in the cross-head of an Instron universal testing machine (Figure 4). The specimens were loaded to failure at a cross-head rate of 0.030in/min (0.762mm/min). The force required to detach the fragment was recorded.

Prior to the initial fracture of each tooth, it was marked by means of a small round bur at a standardized point measured from the interproximal-incisal line angle on the facial aspect of the crown as shown in Figure 2. In all subsequent tests on that tooth this point served as the point of loading for that particular tooth. Prior to loading each specimen, the bur mark on the tooth fragment was checked for alignment with the loading pin by means of articulating paper.

The data collected were evaluated to determine the retentive capabilities of the no-preparation technique and bonding agent alone as compared to the 45° circumferential bevel technique using a combination of bonding agent and composite resin. Also, a comparison of light-cured versus chemically-cured resins was made. A two-way analysis of variance was used for statistical evaluation of data.
The forces required to fracture each tooth after luting ranged from 1.5 kilograms to 37.0 kilograms (Figures 5 and 6, Tables 1 and III). The mean force values for teeth repaired with the light-cured resin and the chemically-cured resin are shown in Figure 7. Light-cured repairs with no-mechanical preparation required 8.51 ± 4.24 kg of force to dislodge the fragment, while the light-cured restorations with a circumferential bevel required 8.92 ± 3.03 kg of force. The chemically-cured restorations with no-mechanical preparation required 10.56 ± 9.56 kg of force to dislodge the fragment, and the chemically-cured restorations with a circumferential bevel required 4.29 ± 4.45 kg of force.

RESULTS

The results of the two-way analysis of variance are presented in Table III. The following variables were tested: (1) materials (light-cured vs chemically-cured) and (2) preparation type (no-mechanical preparation vs beveled preparation). The "P" values for the variables tested were less than 0.05, indicating that the groups were not significantly different from each other at any level of confidence.

The tooth specimens were divided into three groups based upon the orientation of the fracture plane to the long axis of the tooth. The three types of fractures are diagrammed in Figure 3. The fractures were classified as follows: Type A fracture - plane of fracture angled cervically in a lingual-to-facial direction when viewed proximally; Type B fracture - plane of fracture angled cervically in a facial-to-lingual direction when viewed proximally; and Type C fracture - plane of fracture approximately perpendicular to the long axis of the tooth.
The forces required to fracture each tooth after luting ranged from 1.3 kilograms to 37.0 kilograms (Figures 5 and 6, Tables I and II). The mean force values for teeth repaired with the light-cured resin and the chemically-cured resin are shown in Figure 7. Light-cured repairs with no-mechanical preparation required $8.51 \pm 4.24$ kg of force to dislodge the fragment, while the light-cured restorations with a circumferential bevel required $8.92 \pm 3.03$ kg of force. The chemically-cured restorations with no-mechanical preparation required $10.36 \pm 9.56$ kg of force to dislodge the fragment, and the chemically-cured restorations with a circumferential bevel required $8.28 \pm 4.45$ kg of force.

The results of the two-way analysis of variance are presented in Table III. The following variables were tested: (1) materials (light-cured vs chemically-cured) and (2) preparation type (no-mechanical preparation vs beveled preparation). The "F" values for the variables tested were less than 1.00, indicating that the groups were not significantly different from each other at any level of confidence.

The tooth specimens were divided into three groups based upon the orientation of the fracture plane to the long axis of the tooth. The three types of fractures are diagrammed in Figure 8. The fractures were classified as follows: Type A fracture - plane of fracture angled cervically in a lingual-to-facial direction when viewed proximally; Type B fracture - plane of fracture angled cervically in a facial-to-lingual direction when viewed proximally; and Type C fracture - plane of fracture approximately perpendicular to the long axis of the tooth.
In the light-cured group, seven teeth were classified as Type A fractures, 11 teeth as Type B fractures, and four teeth as Type C fractures. Tables IV and V list these data, along with the mean shear force values for each type fracture. The mean load required to induce failure in teeth with Type A fractures repaired via the light-cured resin was 11.09 ± 3.79 kg. Those with Type B fractures required a mean of 7.78 ± 3.58 kg force and those with Type C fractures required a mean of 7.13 ± 1.90 kg to produce fracture.

In the chemically-cured group there were nine Type A, five Type B, and eight Type C fractures. These individual data along with mean shear fracture values are also listed in Tables IV and V. The Type A fractures that were repaired with chemically-cured resin required an average of 13.56 ± 9.37 kg to produce failure, while Type B fractures required 4.91 ± 3.50 kg, and Type C fractures required 7.30 ± 3.60 kg. The means for both the light-cured and chemically-cured groups are shown in Figure 9.

Statistical analysis (Neuman-Keuls Test), Table VI, for the three types of fractures in both the light-cured and chemically-cured groups revealed the following: The mean force required to produce failure in teeth with Type A fractures was significantly higher than values obtained for teeth with Type B and C fractures (p < 0.05). There was no statistical difference between the means for the Type B and C fractures when compared with each other. This is true for both the light-cured and chemically-cured groups.
FIGURES AND TABLES
FIGURE 1. Typical fractured tooth used in the study.

FIGURE 2. Tooth repaired by reattachment of fractured fragment (arrow indicates fragment bur mark used to standardize point of shear force).
FIGURE 3. Instron machine and apparatus used to test shear strength.

FIGURE 4. Close-up photograph of shear strength test apparatus.
FIGURE 5. Comparison of force required to fracture for no-mechanical preparation and beveled specimens in the light-cured group.
FIGURE 6. Comparison of force required to fracture for no-mechanical preparation and beveled specimens in the chemically-cured group.
FIGURE 7. Comparison of mean force required to fracture for the light-cured and chemically-cured groups.
FIGURE 8. Drawings of Type A, B and C fractures.
**Type A** - fracture plane is angled cervically in a lingual to facial direction when viewed proximally.

**Type B** - fracture plane is angled cervically in a facial to lingual direction when viewed proximally.

**Type C** - fracture plane is approximately perpendicular to the long axis of the tooth.
FIGURE 9. Comparison of mean force required to fracture for Type A, B and C fractures.
# TABLE I

Light-cured: kilograms force required to fracture

<table>
<thead>
<tr>
<th></th>
<th>No-Prep</th>
<th>Beveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>6.6</td>
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</tr>
<tr>
<td>2.</td>
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<td>5.2</td>
</tr>
<tr>
<td>3.</td>
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<td>15.0</td>
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<td>4.</td>
<td>13.0</td>
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<td>6.7</td>
</tr>
<tr>
<td>7.</td>
<td>5.7</td>
<td>8.6</td>
</tr>
<tr>
<td>8.</td>
<td>14.7</td>
<td>10.6</td>
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<td>9.</td>
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<td>9.8</td>
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<tr>
<td>11.</td>
<td>3.9</td>
<td>5.3</td>
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<tr>
<td>12.</td>
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<tr>
<td>13.</td>
<td>4.8</td>
<td>5.0</td>
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<tr>
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<td>11.8</td>
</tr>
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<td>15.</td>
<td>11.6</td>
<td>7.2</td>
</tr>
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<td>16.</td>
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</tr>
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<td>17.</td>
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<td>18.</td>
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</tr>
<tr>
<td>Mean</td>
<td>8.51 ± 4.24</td>
<td>8.92 ± 3.03</td>
</tr>
</tbody>
</table>
TABLE II

Chemically-cured: kilograms
force required to fracture

<table>
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<th>No-Prep</th>
<th>Beveled</th>
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<td>5.</td>
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<tr>
<td>22.</td>
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</tr>
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<td>8.28 ± 4.45</td>
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<td>SS</td>
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<td>Total</td>
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<td>2987.7</td>
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Type A = angled cervically in a lingual-to-facial cross section
Type B = angled cervically in a facial-to-lingual cross section
Type C = approx. perpendicular to the long axis of the tooth
<table>
<thead>
<tr>
<th>Light-Cured</th>
<th>Chemically-Cured</th>
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<td>9. Type A</td>
</tr>
<tr>
<td>10. Type C</td>
<td>10. Type A</td>
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<td>11. Type B</td>
<td>11. Type C</td>
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<td>12. Type A</td>
<td>12. Type A</td>
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<td>13. Type B</td>
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<td>14. Type A</td>
<td>14. Type A</td>
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<td>20. Type C</td>
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<td>21. Type A</td>
</tr>
<tr>
<td>22. Type C</td>
<td>22. Type C</td>
</tr>
</tbody>
</table>

Type A - angled cervically in a lingual-to-facial cross section
Type B - angled cervically in a facial-to-lingual cross section
Type C - approx. perpendicular to the long axis of the tooth
### TABLE V

Fracture type means and standard deviations

<table>
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<tr>
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<th>Light-Cured</th>
<th>Chemically-Cured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>11.09 ± 3.79 kg</td>
<td>13.56 ± 9.37 kg</td>
</tr>
<tr>
<td>Type B</td>
<td>7.78 ± 3.58 kg</td>
<td>4.91 ± 3.50 kg</td>
</tr>
<tr>
<td>Type C</td>
<td>7.13 ± 1.90 kg</td>
<td>7.30 ± 3.60 kg</td>
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</tbody>
</table>

Type A - angled cervically in a lingual-to-facial cross section
Type B - angled cervically in a facial to lingual cross section
Type C - approx. perpendicular to the long axis of the tooth
### TABLE VI

Statistical analysis for fracture Types A, B, and C; multiple comparisons using Newman-Keul's test

#### Light-Cured

<table>
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<tr>
<th>Types</th>
<th>DF</th>
<th>Difference</th>
<th>Test Value</th>
<th>Critical Value at P = .05</th>
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</thead>
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<tr>
<td>A - B</td>
<td>41</td>
<td>3.31</td>
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<td>3.96</td>
<td>2.608</td>
<td>2.432</td>
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<td>B - C</td>
<td>41</td>
<td>0.65</td>
<td>0.46</td>
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</table>

#### Chemically-Cured

<table>
<thead>
<tr>
<th>Types</th>
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<th>Difference</th>
<th>Test Value</th>
<th>Critical Value at P = .05</th>
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</thead>
<tbody>
<tr>
<td>A - B</td>
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<td>3.502</td>
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<td>A - C</td>
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<td>6.26</td>
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<td>B - C</td>
<td>20</td>
<td>2.39</td>
<td>1.675</td>
<td>2.086</td>
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</table>
This research project was designed to determine: (1) whether enamel bevels increased the retention for reattachment techniques, (2) whether there is a difference in retention for light-cured and chemically-cured resins, and (3) how the initial fracture angle affects the retention of the fragment. These three areas will be discussed individually.

Tooth Preparation

It has been found that to increase the retention for Class IV resin restorations it is necessary to place a 45° bevel circumferentially in the enamel.\(^7,11,12,33,36,42\) When reattaching a fractured tooth fragment to the original tooth remnant, a 45° circumferential bevel in the enamel of both the tooth fragment and the remnant tooth has also been recommended.\(^37,38,40,41\) This recommendation for the reattachment technique was made because of past studies for Class IV resin restorations and not because of clinical or laboratory studies with the reattachment technique. Starkey\(^30\) and McDonald and Avery\(^7\) have suggested, from case reports, that mechanical preparation in the enamel is not always necessary when reattaching the fractured fragment.

The results of this study indicate that there is no statistically significant difference with respect to shear bond strength between the method of reattaching the tooth fragment with the use of a bevel and the method of simply luting the tooth fragment without preparation of either the tooth or the fragment. Beveling has been suggested prior to attachment as a means of achieving the desired etching pattern within
This research project was designed to determine: (1) whether enamel bevels increased the retention for reattachment techniques, (2) whether there is a difference in retention for light-cured and chemically-cured resins, and (3) how the initial fracture angle affects the retention of the fragment. These three areas will be discussed individually.

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The results of this study indicate that there is no statistically significant difference with respect to shear bond strength between the method of reattaching of the tooth fragment with the use of a bevel and the method of simply luting the tooth fragment without preparation of either the tooth or the fragment. Beveling has been suggested prior to attachment as a means of achieving the desired etching pattern within
the enamel for improved retention. Apparently though, the no-mechanical preparation procedure allows for precise interlocking of the irregular fractured enamel, leaving no voids and only a thin layer of bonding agent at the interface of the fragment and the tooth.

These results suggest that placing a circumferential bevel on the tooth and fragment before luting the restoration is not necessary since it does not increase retention. Clinically, this finding is quite important since the tooth involved has just undergone significant trauma. Ideally, the restorative procedure should require minimal tooth preparation in order to decrease the amount of manipulative trauma to the tooth. The no-preparation technique affords such a restoration, whereas the beveling technique does not. In addition, the no-preparation technique requires less chair time for the patient. This is important for the patient since it reduces stress, especially with children. It is also important for the practitioner because most trauma cases must be seen on an emergency basis. By reducing the chair time the office schedule is less interrupted.

The chemically-cured no-mechanical preparation group had a relatively high standard deviation. The mean fracture value was 10.36 ± 9.56 kg. This high standard deviation was the result of the unusual fracture values for specimen numbers 3, 4, and 9, which did not follow the general trends of the remaining specimens. This can be seen on Figure 6. There is no apparent explanation for these high values.

One preparation technique advocated by Simonsen for the reattachment procedure is different from either technique used in this study. The bevel technique used in this study is described by Simonsen as an external bevel. In his most recent article, he recommended an internal
bevel technique which involves placing a V-shaped groove circumferentially within the enamel of both the fragment and the tooth remnant. He said he prefers it because of the superior esthetics that are achieved. This technique was not studied in the present project since each tooth served as its own control, making it impossible to test-prepare both the internal and external bevel on the same tooth. When an internal bevel is placed, the enamel closest to the exterior of the tooth becomes unsupported. This unsupported enamel probably does little to increase the fracture-resistance of the luted fragment. However, the improved esthetics afforded by this technique does make it a candidate for future study.

Resin Material

A light-cured composite resin (Prisma-Fil)\textsuperscript{a} and a chemically-cured composite resin (Comspan)\textsuperscript{a} were studied. An attempt was made to compare differences in the shear strength of the two resins when used in the reattachment technique. It has been shown previously that light-cured resins can have diametral tensile strengths and compressive strengths similar to chemically-cured resin systems.\textsuperscript{43}

Depth of cure becomes a significant factor in reattachment techniques with light-cured resins, since luting without preparation requires curing through enamel. Depth of cure is affected by curing time,\textsuperscript{45,46} with the curing depth increasing proportionately to the logarithm of the product of exposure time by radiation intensity. It should again be pointed out that in reattachment of tooth fragments via light-cured resin, each

\textsuperscript{a} L.D. Caulk Co., Medford, Delaware.
surface was cured for a full minute, for a total of four minutes per tooth. This was done in an attempt to obtain as complete polymerization as possible with the light-cured system. For chemically-cured resins, other factors such as base/catalyst ratio and amounts of accelerator and initiator play an important role.\textsuperscript{44}

Measuring transverse strength has been shown to be a sensitive technique for characterizing depth of cure.\textsuperscript{45} Therefore, the transverse strength comparison of the light-cured versus chemically-cured resins was made to see if the method of curing played a factor in bond strength for the reattachment technique. The results indicate that the two resin systems studied here were essentially equal in ability to bond the tooth fragment to the original tooth remnant. Figure 7 represents the data graphically.

One variable inherent in this study was the inability to exactly duplicate the reattachment of the fragment after the circumferential bevel was placed. Every attempt was made to achieve identical results in the reattachment. However, the possibility of bonding agent being left on the exposed dentin at the interface of the fragment and tooth, together with the necessity of digital replacement (by sight only) may have caused some slight deviation in the positioning of the fragment.

**Angle of Fracture**

Figure 8 shows the three general types of fractures obtained initially when the teeth were fractured by means of a blunt instrument. The reattached fragments for the fractured Type A incisors withstood fracture significantly better than did the Type B and C fractures. This may be explained by considering the amount of lingual support that the tooth
provided the fragment when the load was applied on the labial of the fragment. In Type A fractures the fragment is partially supported from lingual displacement by the tooth. Type B and C fractures do not have this lingual support and therefore repairs are less resistant to forces applied to the labial. The Type B and C fractures were found to possess essentially the same resistance to fracture. This suggests that fragment restorations in teeth with Type A fractures will withstand labial forces better than the Type B and C fractures, in vivo.
SUMMARY AND CONCLUSIONS

No significant difference was found between the tests on the teeth after luting the fragments with no-mechanical preparation and after luting the fragments again using a 45° circumferential bevel. The mean fracture value for all no-mechanical preparation specimens was 9.86 kg and for all beveled specimens it was 9.60 kg. These results suggest that the bevel need not be placed in vivo before luting the tooth fragments. The no-mechanical preparation technique minimizes the trauma to which the tooth is subjected following the initial injury. Also, the chair time necessary for treatment is reduced.

The light-cured resin showed no significant difference in performance from the chemically-cured resin. It is apparent that, when properly
An in vitro study of 44 maxillary central incisors was undertaken to analyze certain methods of reattachment of fractured anterior tooth fragments. Two main variables were investigated: preparation type and resin material. The teeth were divided into two groups with 22 in the light-cured group and 22 in the chemically-cured group. Each tooth served as its own control, with each being reattached twice, once with no-preparation and once with a circumferential bevel. Following each reattachment procedure, the teeth underwent a 40°C differential thermal cycling procedure. In addition, they were stored in a 37°C water bath for 28 days 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 tests on the teeth after luting the fragments with no-mechanical preparation and after luting the fragments again using a 45° circumferential bevel. The mean fracture value for all no-mechanical preparation specimens was 9.44 kg and for all beveled specimens it was 8.60 kg. These results suggest that the bevel need not be placed in vivo before luting the tooth fragments. The no-mechanical preparation technique minimizes the trauma to which the tooth is subjected following the initial injury. Also, the chair time necessary for treatment is reduced.

The light-cured resin showed no significant difference in performance from the chemically-cured resin. It is apparent that, when properly
cured, these two materials perform equally well in the reattachment technique.

The effect of the fracture angle on retention was also studied. Three types of fractures were formed when the teeth were initially fractured prior to reluting: Type A fractures had an angle sloping cervically in a lingual-to-facial direction when viewed proximally; Type B fractures angled cervically in a facial-to-lingual direction when viewed proximally; and Type C fractures were angled approximately perpendicular to the long axis of the tooth. Reattached fragments from Type A fractures had significantly better retention when loaded from the facial surface than either the Type B and C fractures. Reattached fragments from Type B and C fractures showed no significant difference in retention from each other. Clinically, this suggests that teeth fractured in a Type A manner, when the fragments are luted, will withstand subsequent labial forces better than the B and C types.

In summary, this study suggests that fragment reattachments using no-mechanical preparation are as retentive as fragment reattachments prepared with a 45° circumferential bevel. In addition, the light-cured resin used in this study proved as retentive as the chemically-cured resin. Reattached fragments of teeth fractured initially with a fracture plane sloping cervically in a lingual-to-facial direction will be more retentive than other types of fractures when subjected to a dislodgment force directed lingually from the labial.
REFERENCES


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American Society of Dentistry for Children
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American Academy of Pediatric Dentistry
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American Society of Dentistry for Children
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Indiana Society of Pediatric Dentistry
ATTACHMENT OF ANTERIOR TOOTH FRAGMENTS

by

Jeffrey A. Dean

Indiana University School of Dentistry
Indianapolis, Indiana

This investigation examined the relationships of preparation and resin material types in the reattachment of fractured anterior tooth fragments. A total of 44 extracted maxillary central incisors were tested. Statistical analysis revealed that air-blastpiece preparation was as retentive as a 45° circumferential bevel (p < .01). In addition, the light-cured resin proved as retentive as did the chemically-cured resin (p < .01).

Also examined was the effect of the initial fracture angle on retention of the fragment after relaying. Teeth fractured with an angle sloping cervically in a lingual-to-facial direction when viewed proximally were more retentive than other types of fractures when subjected to a lingually directed force from the labial (p < .05).
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This investigation examined the relationships of preparation and resin material types in the reattachment of fractured anterior tooth fragments. A total of 44 extracted maxillary central incisors were tested. Statistical analysis revealed that no-handpiece preparation was as retentive as a 45° circumferential bevel \((p < .01)\). In addition, the light-cured resin proved as retentive as did the chemically-cured resin \((p < .01)\).

Also examined was the effect of the initial fracture angle on retention of the fragment after reluting. Teeth fractured with an angle sloping cervically in a lingual-to-facial direction when viewed proximally were more retentive than other types of fractures when subjected to a lingually directed force from the labial \((p < .05)\).