# Glass Ionomers as Orthodontic Bonding Agents

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## Literature Review

The use of glass ionomers for the purpose of retaining orthodontic bands has been widely accepted as these cements have shown to exhibit bond strengths comparable to zinc phosphate cements (Forsten, 1977) and in addition, supply a reservoir of fluoride ions (Maijer and Smith, 1988). Their use, however, for bonding orthodontic brackets has not been as widely accepted. The reasons for this mainly lies with inferior bond strengths as compared to the widely accepted standard of bonding brackets with the acid etch/resin composite cement technique.

While resin bonding has proven to be a dependable and efficient method for bonding orthodontic brackets, there are several disadvantages associated with this technique. Etching, debonding, and cleanup procedures have been shown to irreversibly remove from 50-160um of enamel (Fitzpatrick et al., 1977, Brown et al., 1978, Diedrich 1981). During the process of debonding, residual resin is difficult to remove and requires the use of a high speed finishing bur to remove residual resin tags. If left behind, these resin tags may stain and leave an unesthetic appearance to the tooth. Enamel chipping and cracking have also been encountered in difficult debonding cases, especially those where a resin with a high filler content was used (Gwinnett et al., 1977). Areas of decalcification around the brackets may also be encountered (Fajen et al., 1990). Alternatively, glass ionomer cements require no acid etch procedure by virtue of their ability to bond chemically to enamel and some metals (Wilson et al., 1977). Debonding procedures are also reported to be easier when glass ionomer cements are used to bond orthodontic brackets (White, 1986).

Concurrent with any form of orthodontic therapy, it is understood that the appliances themselves pose as barriers to optimal oral hygiene. Plaque accumulation around orthodontic bands and brackets poses an obvious threat to the tooth unless the patient exercises and maintains scrupulous oral hygiene. The plaque content is altered to a condition which promotes facultative bacterial populations (Bloom et al., 1964) which pose an obstacle to remineralization and leads to the formation of white spot lesions (Creanor et al., 1986). Microscopic subsurface demineralization adjacent to bonded brackets has been demonstrated within one month after placement (O'Reilly et al., 1987). Furthermore, these investigators found that fluoridated toothpaste (1100ppm F) did not inhibit these incipient carious lesions. Prevention was found to occur only with a daily fluoride rinse (0.05% NaF) and 1100 ppm F toothpaste. Thus we see the need for patient compliance which may not always be 100%. Another study (Hallgren et al., 1993) demonstrated that a more caries associated microflora seems to form around brackets retained with resin composite as compared to glass ionomer cement. In light of these findings alone, we see a definite benefit in the potential use of glass ionomers for retaining orthodontic appliances. Unfortunately, the brushing habits and compliance of many patients may be far less than that desired by the orthodontist. It is disheartening upon debonding a case to discover generalized areas of decalcification or frank carious lesions which must require subsequent restorations.

Since their introduction by Wilson and Kent in 1972, glass ionomer cements have provided the benefits of being used as strong and durable luting agents and as a restorative material in themselves. Perhaps the most attractive attribute of this material however, is its ability to leach fluoride ions into the tooth surface on which they are placed (Cook and Youngson, 1988). The fluoride release from glass ionomer cements has been shown to continue at significant levels for at least 12 months (Swartz et al., 1984). The fluoride released has been shown to protect the tooth in the immediate vacinity of the cement but also exerts its affect virtually around the entire tooth (Swartz et al., 1980).

The use of glass ionomers as orthodontic bonding agents has been examined by numerous investigators. The majority of studies to date seem to reach the same conclusion that while glass ionomers have inferior bond strengths when compared to resin composite systems, the bond strengths obtained may be adequate for their clinical use. However, a study (Norevall et al., 1990) demonstrated a glass ionomer cement (Aqua Cem) to have significantly greater tensile bond strength fifteen minutes after bonding when compared to a resin composite (Unite). There was no significant difference in tensile bond strength after 24 hours though. In addition, the resin adhesive demonstrated far greater shear bond strengths. Only one study concluded that the material should not be considered as an orthodontic bonding agent (McCourt et al., 1991). A large problem with most studies is the lack of consistency in experimental design, materials used, debonding procedures, and units of measuring debonding force.

The bond strengths required for a material to be used as a successful orthodontic bonding agent are questionable (Fajen et al., 1990). It is difficult to access bond forces since the stresses placed on a bond are either tensile, shear, torsional, or a combination of all these. It is said that no specific in vitro or in vivo test can be valid for all the various clinical applications of the adhesive materials (Rezk-Lega et al., 1991). Incisal biting forces are said to be in the range of 30-38 pounds (Garner et al., 1973) while maximum occlusal forces range from 68-77 pounds (Proffit et al., 1983). Orthodontic forces are estimated not to exceed one pound per tooth (Newmann, 1965; Wheeler et al., 1983). This is equivalent to 50 psi using mesh backed medium twin ormco brackets (Fajen et al., 1990). However, Newmann (1965) has estimated that 200 psi per tooth is probably the maximum amount of orthodontic force which could occur in a clinical situation. Keizer and coworkers (1976) have suggested a maximal bond strength of 400 psi as adequate for bonding orthodontic brackets while Maijer and Smith (1979) describe a bond strength of 1100 psi as being adequate. Reynolds (1975) conducted another study in which he suggested orthodontic forces are unlikely to exceed 3.2 lb.. Additional studies by Keizer and ten Cate (1976) suggest a maximum bond force of 7.8 lb. as being adequate for orthodontic purposes while Maijer and Smith (1979) proposed a bond force of 21.4 lb. as being adequate. Thus we find no real consensus as to what bond strength must be obtained for success. The wide range of values reported are probably the result in variations in experimental design (Rezk-Lega et al., 1991).

Each study regarding bonding with glass ionomer cements finds itself faced with the dilemma of weaker bond strengths obtained with glass ionomer cements and the lack of a universal standard bond strength value for which to determine the clinical acceptability of the material. The results of most studies seem to encourage further investigation and research in this area as the material seems to hold promise as an orthodontic bonding material.

An investigation which also considered the material properties of glass ionomers has been conducted (Voss, Hickel, and Molkner; 1993). This in vivo study on the bonding of orthodontic brackets used Ketac Fil and conventional Dentarum brackets. In addition, however, a new experimental bracket design was tested. The experimental bracket could best be described as a hollow cylinder with an internal retentive groove. The premise behind the new bracket design was to allow for a greater bulk of glass ionomer cement as the material was considered to be stronger in bulk. No acid etch was performed when bonding with the glass ionomer and no resin composite control group was established. The teeth were bonded after receiving a prophy polish with pumice. The shear bond strength was tested 24 to 32 hours after bonding. The bond strength using the conventional brackets was found to be 3.6 +/- 1.1 MPa while that of the experimental bracket was 5.8 +/- 1.0 MPa. These authors quoted a bond strength of 3 MPa which must be achieved for successful bonding. McCourt, Cooley, and Burnwell have quoted a bond strength of 5 MPa for successful bonding. The values obtained by Voss and coworkers with the experimental bracket surpassed this limit and were said to approach those of resin composites. Bond failures were found to occur at the bracket/adhesive interface with the conventional brackets but occurred at the tooth/adhesive interface with the experimental bracket.

Wilson and Prosser (1982) showed the bond strength of glass ionomer to enamel (3.2-7.5 MPa) to be greater than its bond to stainless steel (0.7 MPa). This finding would suggest that bond failures would most likely occur at the band or bracket interface. However, this has been shown to not always be true. Cohesive failures have been demonstrated (Klockowski et al., 1989; Norevall et al., 1990). Bond failures at the tooth/adhesive interface were found to be the most common type of bond failure in a study by Cook and Youngson (1988).

Along the topic of bracket base design, lower bond strengths and more frequent cohesive-type fractures were seen when using an integral typed base rather than a mesh type (Norevall et al., 1990). In attempts to increase the bond strength between the glass ionomer to the bracket, the effects of sandblasting the meshwork of the bracket pad was investigated (Millet et al., 1993). It was found that by sandblasting the bracket base for three seconds at a distance of 10 mm., a 22% increase in the mean bond strength was observed. The improvement in the observed bond strength, although still approximately one half of those obtained with a resin composite (Right On), was thought to possibly be within the range of clinical acceptability. In this study, the teeth bonded with glass ionomer received a pumice prophy only and were air dried prior to bonding. Ketac-Cem was used. Similar results concerning the sandblasing of bracket pads were obtained by Deidrich and Dickmeiss (1983) whereby they observed a 34% increase in bond strength when using an unfilled acrylic adhesive. Contrary to all this however, Smith and Reynolds (1991) proposed that the bracket mesh surface structure is not a significant factor in producing optimal bond strength but rather the morphology and size of the bracket base is the key factor.

A technique for bonding orthodontic brackets with glass ionomer cements has been reported (White, 1986). White strongly supports the use of glass ionomer cements. In his practice, he reports an equivalent amount of bond failures with glass ionomer as he does with resin composite. The glass ionomer White used in his study was conventional Fuji II. He favors the conventional type of glass ionomer over the newer generation water hardened types as White claims these cements set faster and were shown by Prosser et al (1984) to be weaker than the conventional types. In White's report, he comments on the amalgamated versions of glass ionomers used as core build-up materials. These amalgamated versions (Chelon), have been shown to have a 30% increase in strength over conventional glass ionomers. In a report by Klockowski et al (1989), the bond strengths obtained with Chelon were not significantly greater than those obtained with Ketac-Cem and Ketac-Fil. These investigators encouraged further research, however, because the adhesion Chelon was less affected by thermocycling.

White comments that virtually every bond failure he does encounter with the glass ionomer cements occurs at the bracket/adhesive interface. White pointed to the fact that glass ionomers are stronger in bulk and that their existed the need for a new bracket design to optimize the effectiveness of glass ionomers as orthodontic bonding agents (White, 1986).

The effect of enamel surface preparation has also been examined as possibly influencing the bond strengths obtained with glass ionomer cements. In a study by Fajen and coworkers (1990) and an earlier study by Cook and Youngson (1988), different enamel surface preparations were investigated as part of their experimental design. In the study by Cook and Youngson, a no mix resin composite (Right On) was compared to Ketac-Cem. The bond of Ketac-Cem was tested on a wet tooth surface, an acid etched surface, a surface cleansed with a dentin cleanser (40% polyacrylic acid), and simply a dry tooth surface. Of course, all surfaces tested had received a prophylactic polish. For the glass ionomer groups, the highest bond strength was obtained when the tooth received a prophylaxis and was lightly dried with a cotton pellet. In this study, the shear/peel bond strength was measured. The results showed the resin composite to have significantly higher bond strength (73.9 N), but the Ketac-Cem with just the prophy and light drying was only slightly lower (60.9 N). These authors concluded the benefits obtained when using a glass ionomer cement encouraged further investigation and improvement with the material for the purpose of bonding orthodontic brackets.

In the study by Fajen and coworkers, no significant difference was found in the bond strength of glass ionomer cements to teeth which had been polished with pumice, pumiced and washed with 45% polyacrylic acid, or pumiced followed with the application of 1.23% APF gel. An interesting note from this study however, was the fact that Ketac-Cem, a "water hardened type of glass ionomer, produced greater bond strengths over conventional Fuji I and Precise. However, the bond strength of Ketac-Cem was significantly less (3.91 MPa) as compared to Concise (11.27 MPa). The authors concluded however, that based upon the array of bond strengths proposed as requirements for orthodontic bonding, Ketac-Cem appeared to be adequate for clinical use.

Recently light cure glass ionomers used as fluoride releasing bases and liners have become available. Their use as an orthodontic bonding agent has been investigated by McCourt, Cooley, and Barnwell (1991). The material they investigated is known as Vitrabond. Vitrabond is a light cure glass ionomer in which the powder portion is an ion-leachable fluoroaluminosilicate glass powder which is made photosensitive by its chemistry. The liquid portion consists of a light curable polymer, water, 2-hydroxymethylmethacrylate (HEMA), and a photosensitizer (Rezk-Lega et al., 1991). Timeline, another brand of light cure glass ionomer, was also tested. The shear bond strengths were examined and compared to a resin composite control (Transbond) after 24 hours. Of the glass ionomers, Vitrabond was far superior. Actually, after 24 hours, the shear bond strength of Vitrabond (11.58MPa) was greater than that of the resin control (11.35 MPa). However, after one month, the bond strength of Vitrabond dropped significantly to 5.39 MPa as compared of 10.80 MPa for Transbond. The authors attributed the loss in bond strength seen in Vitrabond to the fluoride exchange mechanism by which fluoride is released from the adhesive as the probable cause. They concluded the material was therefore inadequate as an orthodontic bonding agent since it failed to maintain their clinically suggested minimal bond strength of 10.0 MPa. Examining the method in which the experiment was conducted revealed that even the glass ionomer groups received an acid etch prior to bonding. This may have influenced their results as previous studies have indicated weaker bond strengths when the teeth are etched (Cook & Youngson, 1988).

Vitrabond was also examined by Rezk-Lega and Ogaard (1991). In this study, the tensile bond strength of Concise (composite control), and the following glass ionomers: Ketac-Cem, Aqua Cem, and Vitrabond (light cured GI). Only a prophylaxis was performed prior to bonding with the glass ionomers. Their results showed the tensile bond strength of Concise to be 152.5 N, Vitrabond 27.53N, Ketac-Cem 10.75 N and Aqua Cem 5.5 N. Bond failure sites were recorded. The Ketac-Cem, Aqua Cem and Concise had a considerable amount of adhesive remaining on the tooth surface while those teeth bonded with Vitrabond had very little remaining to the tooth. These investigators concluded Vitrabond may be adequate for bonding orthodontic brackets.

In a separate study by Minnich (1992), the use of Vitrabond after a 60 second phosphoric acid etch gave bond strengths not significantly less than Transbond (a light cure composite adhesive) but significantly greater bond strengths than those seen with Ketac Cem ($p<.05$). From these results, this investigator felt Vitrabond showed promise as an orthodontic adhesive.

Thus, we find a number of studies which support further investigation into the use of glass ionomers as orthodontic bonding agents. The aim of this study was to compare the bond strengths of Vitremer (light cure glass ionomer), Fuji II (conventional glass ionomer), and Concise (resin composite). The effect of increasing the cement thickness was also examined.

## Materials and Methods

Extracted teeth were used in this study for the debonding procedures. The crowns of the teeth were mounted in acrylic cylinders. The labial surface of enamel was exposed through the acrylic for bonding with the various materials. Ten of these mounted specimens were made and re-used throughout the experiment. Each of the bonding/debonding procedures using the various cements was carried out on these ten teeth. Following debonding, the enamel surfaces were sanded with fine grit wet/dry sandpaper to ensure a clean enamel surface free of any cement from the previous trials. Rocky Mountain mini brackets were used in this study. The brackets were flattened to allow a uniform cement thickness. It should be mentioned here that the Rocky Mountain brackets used in this study were lower cuspid brackets. These brackets were chosen due to the uniformity of the tie wings as their configuration aided in the flattening process. The bracket pads were not square but actually were in the shape of a parallelogram. The dimensions of the brackets were 0.142" X 0.132". For ease in the mathematical calculations, the brackets were assumed to be square with a side length obtained by averaging the true bracket dimension. Thus, 0.137" was taken to be the length of one side of the "square" bracket pad. The total torsional stress was calculated using the following formula:

$$[V]=F/a^2\,(18L^2/a^2 + 6L/a + 1)\,(1/145)^{1/2}$$

where F=debonding force measured in pounds (from Instron print-out)
a=length of the side of the bracket (inches)
L=distance from the center of the bracket to the point of force application (lever arm length)

Shear strength was calculated using the following formula:

$$V=F/a\,(1/145)$$

where "F" was again the debonding force measured in pounds and "a" was the length of the side of the bracket.

For the composite control group, the enamel surface was sanded, then acid etched for twenty seconds. The etchant was rinsed off and the tooth surface dried with an air syringe. Unfilled resin was applied and then the brackets were bonded using the resin cement (Concise). The resin cement layer thickness was controlled by means of a bonding jig calibrated to provide a cement layer of 100 um. Excess cement flash was removed with a razor blade. The samples were then placed into a humidor. The debonding procedure took place approximately thirty minutes after the brackets were bonded to place. This time frame was chosen as it would more accurately reflect the actual clinical setting between bonding and ligation. A new type of debonding method was employed in this study in which the brackets were subjected to a torsional force (see figure I). This type of debonding procedure was developed since it too would more accurately resemble the type of stress exerted on a bracket during the process of ligation.

Two types of glass ionomer cements were used in this study. The first was Fuji II conventional glass ionomer cement. In this portion of the study, the enamel surface was sanded as before. No acid etch procedure was carried out, however the bracket pads were sandblasted with 250 um alumina for approximately five seconds to provide a roughened surface. The cement was mixed according to the manufacture's recommendations. The brackets were cemented to place in the same manner as described above with the bonding jig set to provide a 100 um cement thickness. Debonding was carried out thirty minutes after bonding in the same fashion as before.

Vitremer light cure glass ionomer cement was also used in this study. The bracket pads were sandblasted but the enamel received no acid etch. The cement was prepared according to the manufacturer's recommendations. The brackets were applied to the teeth and the cement was light cured twenty seconds from each angle to ensure polymerization. Once again, a 100 um cement layer was used. The excess flash was removed and the brackets debonded approximately thirty minutes later.

To examine the effects of increasing the thickness of cement, both the Fuji II and Vitremer cements were examined using a 1000 um cement layer. This was accomplished by re-setting the bonding jig to provide for this amount of cement. Bonding and debonding was carried out in the same fashion as before.

To provide a reference with previous studies, shear bond strengths were examined using both Fuji II and Concise set at 100 um cement thickness (see figure II).

## Results:

The torsional bond strengths from the glass ionomer cements were statistically analyzed and compared to the composite control group (Concise) and to each other. The effect of increasing the cement film thickness was also analyzed. The results from the debonding procedures are shown in Figure III and Figure IV. An analysis of variance (ANOVA) and Newman Keuls multiple comparisons test was performed on the three materials at 100um cement thickness (see table I).

Table I

Independent Group Analysis Summary

Grouping variable is GROUP
Analysis variable is OBS

Group Means and Standard Deviations

| | | |
|---|---|---|
| 1: mean = 9.95 | s.d. = 1.851426 | n = 10 |
| 2: mean = 3.2 | s.d. = .6101002 | n = 10 |
| 3: mean = 4.11 | s.d. = .9209882 | n = 10 |

Analysis of Variance Table

| Source | S.S. | DF | MS | F | Appx P |
|---|---|---|---|---|---|
| Total | 310.15 | 29 | | | |
| Treatment | 268.32 | 2 | 134.16 | 86.59 | < .001 |
| Error | 41.83 | 27 | 1.55 | | |

| Newman-Keuls Multiple Comparisons | | P | Q | Critical q (.05) |
|---|---|---|---|---|
| Mean (1) -Mean (2) = | 6.7500 | 3 | 17.148 | 3.509 |
| Mean (1) -Mean (3) = | 5.8400 | 2 | 14.836 | 2.904 |
| Mean (3) -Mean (2) = | 0.9100 | 2 | 2.312 | 2.904 |

Homogeneous Populations, groups ranked

| | Gp 2 | Gp 3 | Gp 1 |
|---|---|---|---|
| Population 1 | —— | —— | |
| Population 2 | | | — |

This is a graphical representation of the Newman-Keuls multiple comparisons test. At the 0.05 significance level, the Means of any two groups underscored by the same line are not significantly different.

Figure I. Torsional debonding method.

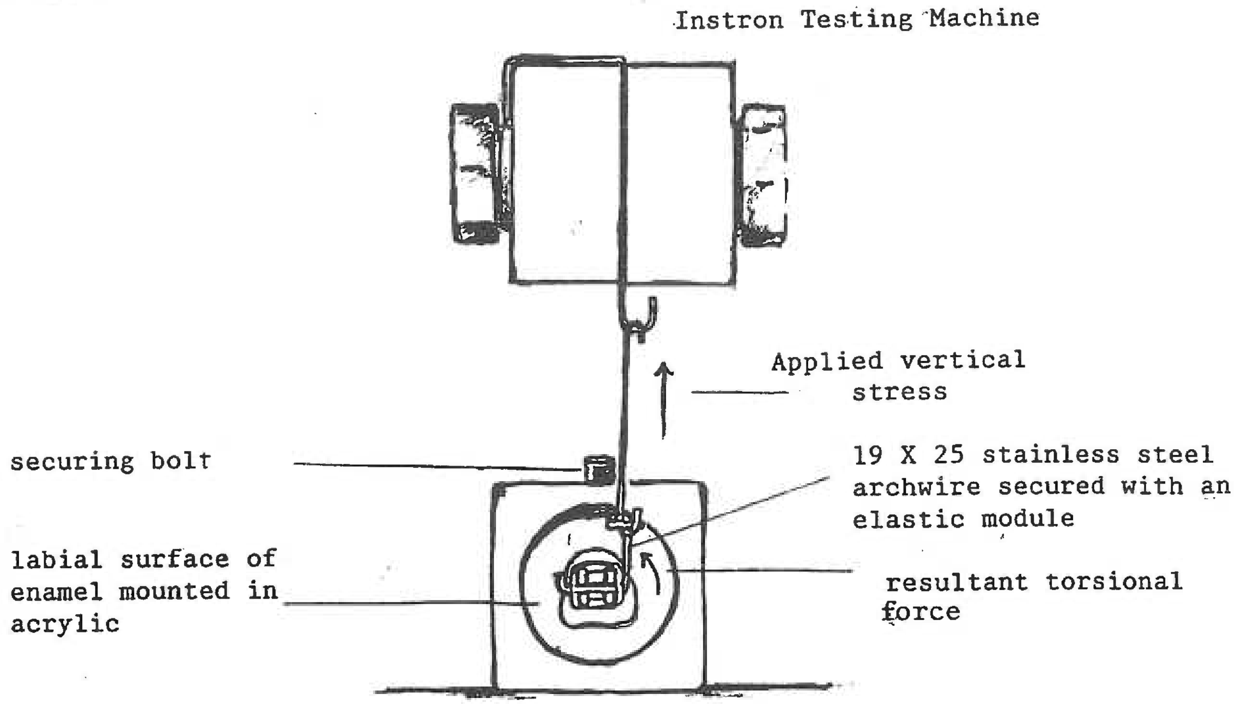



Figure II. Shear debonding method

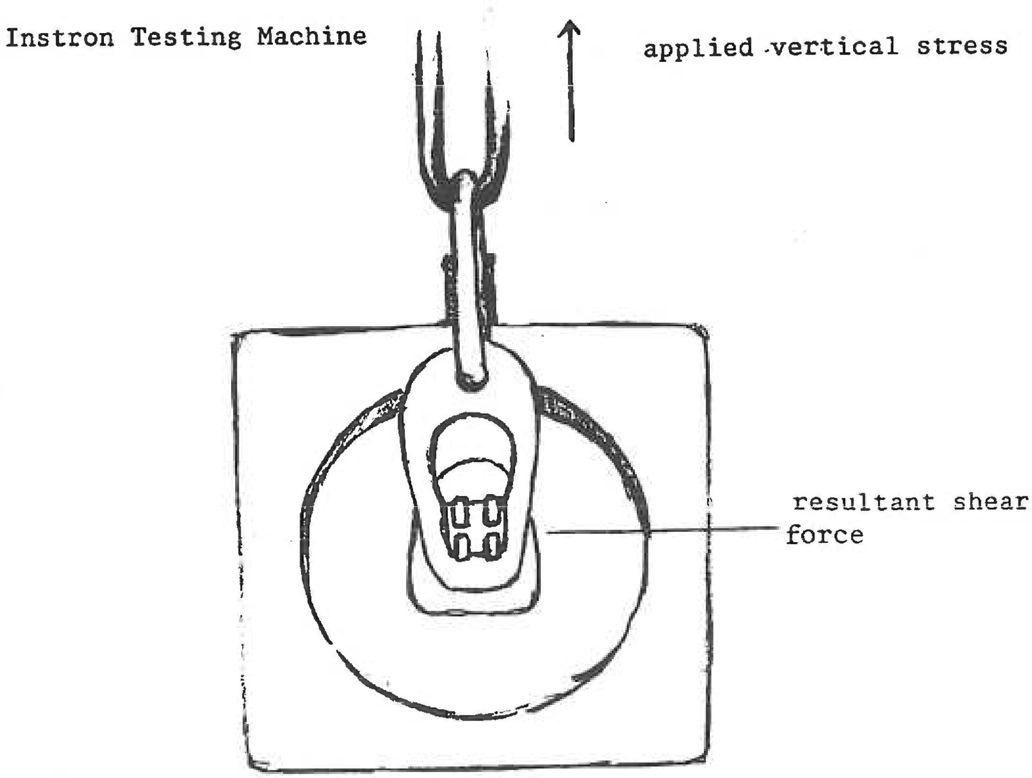


Figure III.

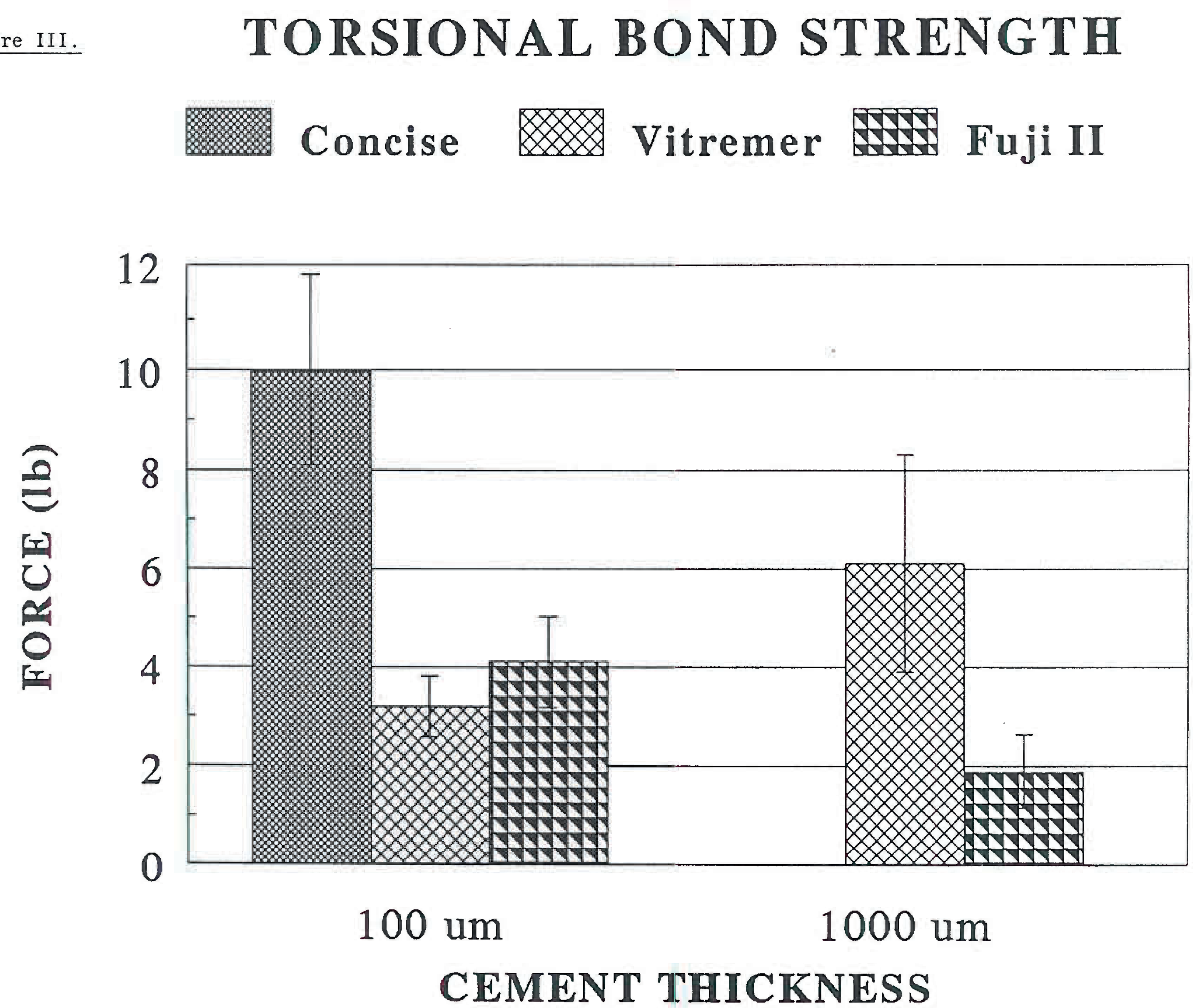
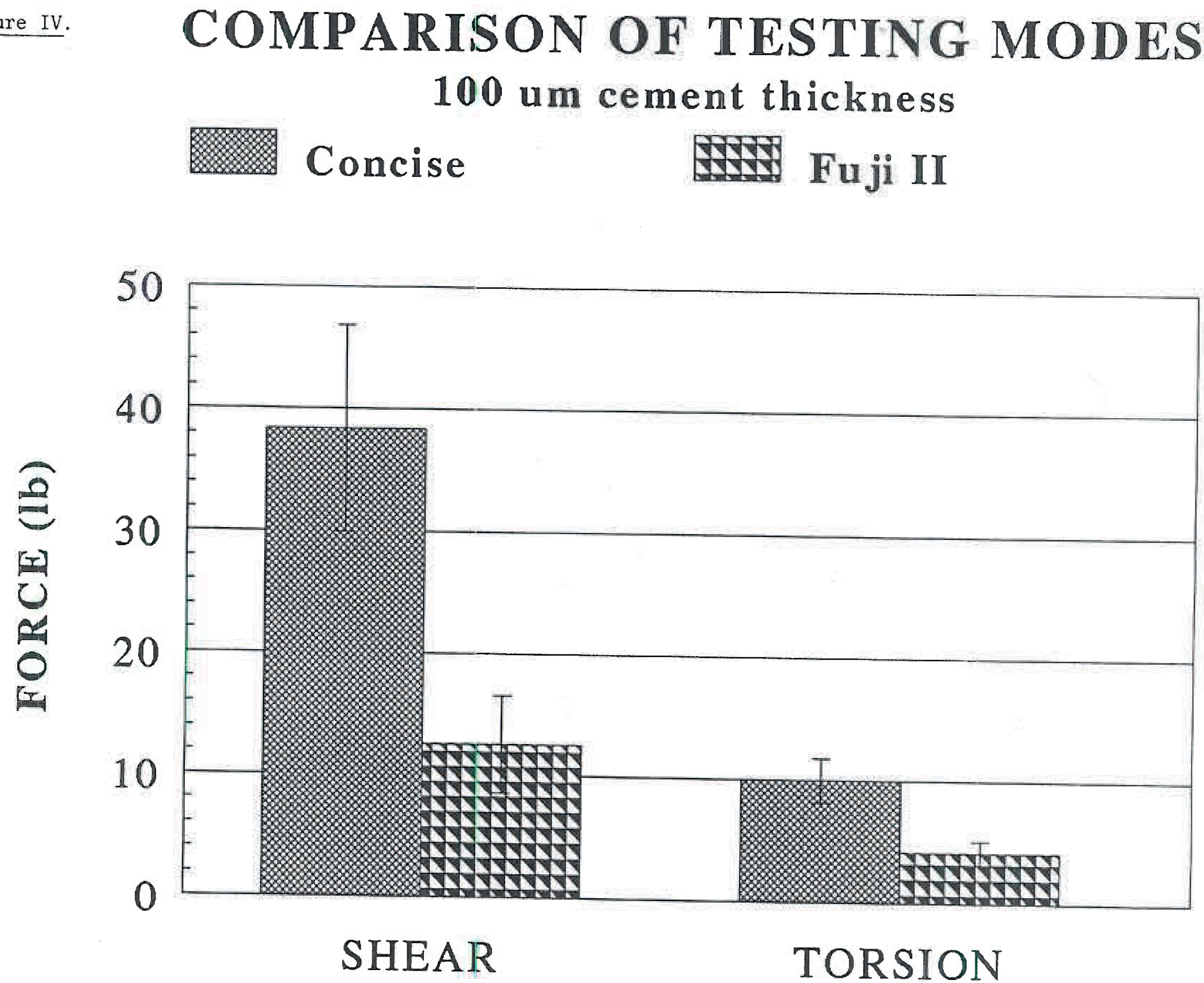

TORSIONAL BOND STRENGTH
Concise
Vitremer
Fuji II
FORCE (lb)
0
2
4
6
8
10
12
100 um
1000 um
CEMENT THICKNESS

Figure IV.


COMPARISON OF TESTING MODES
100 um cement thickness
Concise
Fuji II
FORCE (lb)
50
40
30
20
10
0
SHEAR
TORSION

In the table, group 1 refers to the composite control, group 2 is the group bonded with Vitremer, and group 3 is the Fuji II group. The comparisons made between the three groups revealed no significant difference in bond strengths between the Fuji II and the Vitremer cement (Q=2.312, q(.05)=2.904). However, there was a significant difference between the Concise and the Fuji II (Q=14.836, q(.05)=2.904) and also between the Concise and the Vitremer (Q=17.148, q(.05)=3.509); the Concise being much stronger than either the Fuji II or the Vitremer.

Student's t tests were performed on other aspects of the data. The following information was discovered: Vitremer @(1000um) was significantly stronger than Fuji II @(1000um), (P<.01). Vitremer @(1000um) was significantly stronger than Vitremer @(100um), (P<.01). Fuji II @(100um) was significantly stronger than Fuji II @(1000um), (P<.01). In the shear test comparison between Fuji II and Concise (100um cement thickness), Concise was significantly stronger than the Fuji II (P<.01). When comparing the shear debonding force of Concise to its strength in torsion, the material was shown to be significantly stronger in shear than in torsion (P<.01). The same was true for Fuji II.

It is important to realize that while the force obtained in the torsional debonding procedure were less than those obtained for shear debonding when measured in pounds, the stresses in torsion are actually greater than those in shear. This is due to the force amplification effect of using a lever arm in the debonding mechanism and manifests itself when converting to stress. For this reason, the values obtained in the debonding procedure are recorded in both pounds and in MPa (see table II).

Table II

Bond strengths of the materials in pounds (lbs) and MPa, (100um cement thickness).

| | torsion (lb) | torsion (MPa) | shear (lb) | shear (MPa) |
|---|---|---|---|---|
| Concise | 9.95 | 20.89 | 38.4 | 14.11 |
| Vitremer | 3.2 | 6.72 | - | - |
| Fuji II | 4.11 | 8.63 | 12.5 | 4.59 |

## Discussion:

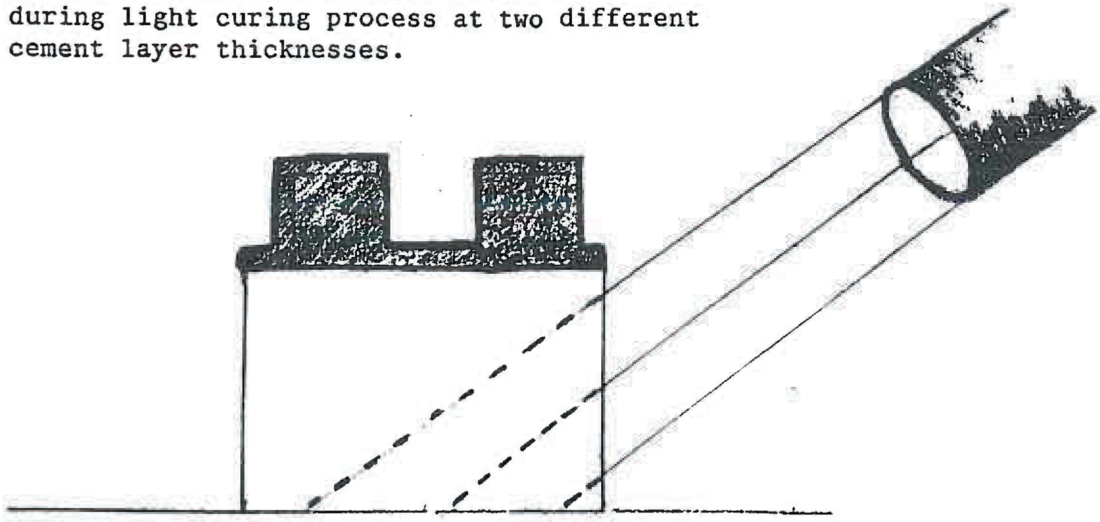
The purpose of this study was to examine the bond strengths of glass ionomer cements, compare these strengths to a standard resin composite, and evaluate their potential for regular use as orthodontic bonding agents.

The minimum shear bond strength of 3MPa quoted by Voss and coworkers was met in this experiment (4.59 MPa Fuji II 100um). McCourt and coworkers established a minimum bond strength of 5 MPa for successful bonding. In this case, the results obtained in this study indicate inadequate bond strengths when using glass ionomer cement. The new torsional debonding method demonstrated consistency in the bond failure results in the sense that during the torsional debonding procedure, Fuji II was approximately 60% weaker than Concise while in the shear test, Fuji II was 66% weaker than Concise.

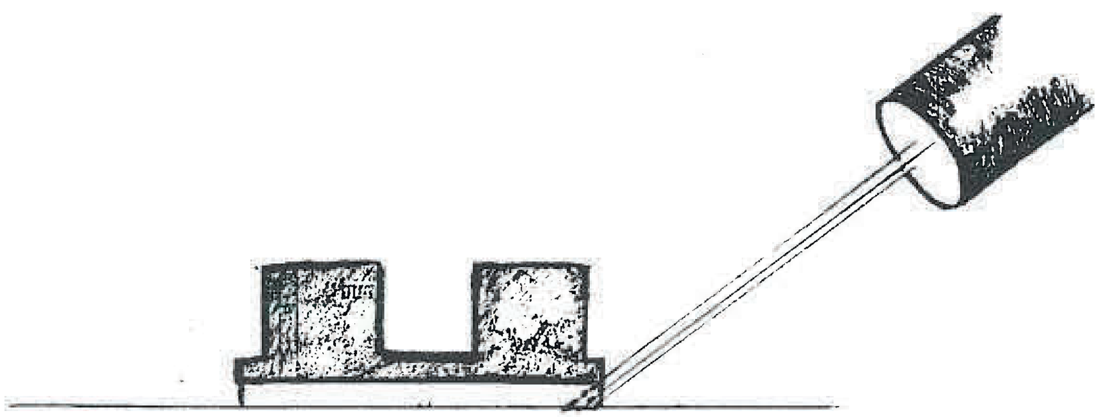
Addressing the issue of increasing the amount of glass ionomer cement for increased bulk of material as suggested by Voss and coworkers, mixed results were obtained. The Vitremer cement showed a 48% increase in bond strength when the cement thickness was increased from 100um to 1000um. However, the Fuji II cement showed a 55% decrease in bond strength. The reason for the increase in Vitremer's bond strength with the thicker layer is thought to be related to increased light penetration during the light curing process (see fig. V). The decrease in the bond strength of the Fuji II cement could be related to an increase in internal defects within the cement as a result of having a greater bulk of the material.

In the mind of this examiner, the larger cement layer is impractical if conventional brackets are to be used. The noticeable increase in cement thickness would undoubtedly lead to less patient comfort and less esthetic acceptance by the patient as the brackets appear much more prominent. Furthermore, some sort of bonding jig would become necessary in order to clinically place the brackets at the correct depth which could complicate the bonding procedure.

Figure V. Differences in direct light penetration during light curing process at two different cement layer thicknesses.



A. 1000 um cement thickness (note increased direct light penetration).



B. 100 um cement thickness (less direct penetration by curing light).

## Conclusion:

While it was again shown that glass ionomer bonding systems produce inferior bond strengths when compared to resin composite cements, it remains to be shown if they produce inferior clinical performance. Perhaps the best way to evaluate the effectiveness of glass ionomer cements for bonding orthodontic brackets is to actually use them in a clinical situation, just as Dr. White has done. In this way, the actual performance of the glass ionomer bond can be evaluated and compared to resin bonding systems regardless of what laboratory values are obtained relating to minimum bond strengths. The idea here being that do we need to drive a tank when a light truck can do the same job? One's main concern is to know if the material will provide the same amount of reliability as the resin cements do. For this reason, more clinical studies are definitely called for.

In a recent study by Fricker (1994), a twelve month clinical evaluation of a light activated glass ionomer cement (Fuji II LC) was compared to a standard resin composite bonding adhesive (System I). His results indicated no significant difference in bond failures between the two materials. It was concluded from this study that the glass ionomer proved itself to be an adequate adhesive for bonding orthodontic brackets. In light of this and previous studies, glass ionomer cements may be considered to be the bonding material of choice in those cases where the brackets are less apt to encounter occlusal trauma. The benefits obtained when using a glass ionomer cement would certainly encourage myself to use this material in carefully selected cases.

The torsional debonding mechanism employed in this study, while more accurately simulating the stresses encountered in a clinical setting, does not seem to change any of our perceptions regarding how the materials compare to one another. Therefore, it is felt that shear bond strength testing provides an accurate (and easier) picture of a material's performance in a clinical situation.

## References:


Brown L. A study of the effects of orthodontic appliances on the oral microbial flora. Oral Surg Oral Med Oral Pathol 1964;17
Bloom R., B:658-67.

Brown CRL., Way DC. Enamel loss during orthodontic bonding and subsequent loss during removal of filled and unfilled adhesives. Am J Orthod 1978;74:663-671.

Cook PA., Youngson CC. An in vitro study of the bond strength of a glass ionomer cement in the direct bonding of orthodontic brackets. Brit. J Orthod 1988;15:247-253.

Creanor SL., Macfarlane TW., Mackenzie D., Weetman DA., Strang R., Stephen KW. Microbiology and acid/anion profiles of enamel surface plaque from an in situ caries appliance. Caries Res. 1986;20:392-97.

Deidrich P. Enamel alterations from bracket bonding and debonding: a study with the scanning electron microscope. Am J Orthod. 1981;79:500-522.

Deidrich P., Dickmeiss B. Vergleichende physikalische und rasterelektronenoptisache untersuchungen zur adhasion verschiedener metallbrackets. Fortschritte der Keiferorthopaedie. 1983;44:298-310.

Fajen V., Duncanson MG., Nanda RS., Currier G., Angolkar P. An in vitro evaluation of bond strength of three glass ionomer cements. Am J Orthod Dentofac Orthop. 1990;97:316-322.

Fitzpatrick DA., Way DC. The effects of wear, acid etching, and bond removal on human enamel. Am J Orthod. 1977;72:671-681.

Forsten L. Fluoride release from a glass ionomer cement. Scan J Dent Res. 1977;85:503-504.

Fricker, John P. A 12 month clinical evaluation of a light activated polyakenotate (ionomer) cement for the direct bonding of orthodontic brackets. Am J Orthod Dentofac Orthop. 1994;105:502-505.

Garner LD., Kotwal NS. Correlation study of incisive biting forces with age and anterior occlusion. J Dent Res. 1973;52:698-702.

Gwinnett AJ., Gorlick L. Microscopic evaluation of enamel after debonding. Am J Orthod. 1977;71:651-665.

Hallgren A., Oliverby A., Twetman S. Caries associated microflora in plaque from orthodontic appliances retained with glass ionomer cement. Scand J Dent Res. 1992;100(3):140-143.

Keizer S., ten Cate JM., Arends J. Direct bonding of orthodontic brackets. Am J Orthod. 1976;69:318-327.

Klockowski R., Davis E., Joynt R., Wieczkowski G., MacDonald A. Bond strength and durability of glass ionomer cements used as bonding agents in the placement of orthodontic brackets. Am J Orthod Dentofac Orthop. 1989;96:60-64.

Maijer R., Smith DC. A comparison between zinc phosphate and glass ionomer cements in orthodontics. Am J Orthod Dentofac Orthop. 1988;93:273-279.

Maijer R., Smith DC. A new surface treatment for bonding. J Biomed Mater Res. 1979;13:975-985.

McCourt J., Cooley R., Barnwell S. Bond strength of light-cure fluoride-releasing base-liners as orthodontic bracket adhesives. Am J Orthod Dentofac Orthop. 1991;100:47-52.

Millett D., McCabe JF., Gordon PH. The role of sandblasting on the retention of metallic brackets applied with glass ionomer cement. Brit J Orthod. 1993;20:117-122.

Minnich MD. Light-cured glass ionomer as an orthodontic adhesive. Abstract in Am J Orthod Dentofac Orthop. 1992;102:487.

Newmann GV. Epoxy adhesives for orthodontic attatchments: progress report. Am J Orthod. 1965;51:901-912.

Norevall L., Sjogren G., Persson M. Tensile and shear strength of orthodontic bracket bonding with glass ionomer cement and acrylic resin. Swed Dent J. 1990;14:275-284.

O'Reilly MM., Featherstone JDB. Demineralization and remineralization around orthodontic appliances: an in vivo study. Am J Orthod Dentofac Orthop. 1987;92:33-40.

Proffit WR., Fields HW., Nixon WL. Occlusal forces in normal and long face adults. J Dent Res. 1983;62:566-574.

Prosser HJ., Powis DR. Brant P., Wilson AD. Characterization of glass ionomer cements. J Dent. 1984;12:231-240.

Reynolds IR. A review of direct orthodontic bonding. Brit J Orthod. 1975;2:171-178.

Rezk-Lega F., Ogaard B. Tensile bond force of glass ionomer cements in direct bonding of orthodontic brackets: An in vitro comparative study. Am J Orthod Dentofac Orthop. 1991;100:357-361.

Smith NR., Reynolds IR. A comparison of three bracket bases: An in vitro study. Brit J Orthod. 1991l18:29-35.

Voss A., Hickel R., Molkner S. In vivo bonding of orthodontic brackets with glass ionomer cement. Angle Orthodontist. 1993;63:149-153.

Wheeler JJ., Ackerman RJ. Bond strength of thermally recycled metal brackets. Am J Orthod. 1983;88:181-186.

White L. Glass ionomer cement. J Clin Orthod. 1986;20:387-391.

Wilson AD., Crisp S., Lewis BG., McLean JW. Experimental luting agents based on the glass ionomer cements. Brit Dent J. 1977;142:117-122.

Wilson AD., Prosser HJ. Biocompatibility of the glass ionomer cement. J Dent Ass South Africa. 1982;37:872-879.