Bracket to Adhesive Bond Strength Using Filled vs. Unfilled Resins

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Abstract

The purpose of this study is to determine which method of attaching a bracket to a tooth results in the highest bond strength: painting the pad of a foil mesh bracket base with unfilled resin prior to placing the filled resin, applying filled resin into the undercuts of a foil mesh bracket base with an instrument, or placing filled resin directly on the bracket base and immediately pressing onto the tooth.

The samples were broken down into four groups: in the control group the bonding material was handled according to the manufacturer's instructions; in group A the bonding material was handled according to the manufacturer's instructions, with the exception that the liquid resin was applied to the bracket base, thinned with compressed air, and light cured prior to the placement of the adhesive; in group B the bonding material was handled according to the manufacturer's instructions, with the exception that the liquid resin was applied to the bracket base, thinned with compressed air, and not light cured prior to placement of the adhesive; in group C the bonding material was handled according to the manufacturer's instructions, with the exception that prior to placing the bracket on the tooth the filled resin was adapted to the bracket base using a Gregg instrument in an attempt to force the adhesive into the mesh undercuts.

When the results were analyzed, we found no statistical difference for bond strength between any of the four study groups. The groups bonded with unfilled resin on the

bracket base did show a higher percentage of resin attached to the bracket bases after debond then the other two groups.

These results do not support applying unfilled resin to the bracket base, nor forcing the filled resin into the bracket pad mesh with a hand instrument, for the purpose of increasing mean bond strength over following manufacturers directions to bond brackets to teeth.

Introduction

One of the greatest advances in orthodontics occurred when the ability to directly bond orthodontic brackets to teeth was made possible. This development has made orthodontics less time consuming, less painful, and more esthetic by eliminating the band that encircles the tooth. The process of bonding an orthodontic bracket to a tooth involves etching the enamel surface with an acid (usually 37% phosphoric acid) followed by a water rinse and application of a primer (consisting of an unfilled resin material) on the tooth, and occasionally the bracket pad. After this, a filled resin is applied to the bracket pad and the bracket is placed on the tooth. This is then allowed to set either chemically or through light activation at 460 nm.

Since the bonding of orthodontic appliances was introduced, bond failures in an orthodontic practice have been an unwanted problem. They result in longer treatment times, frustrated patients and clinicians, and ultimately lost revenues. This is one reason why so much effort has been put into finding ways to increase bond strength and decrease bond failures.

It is a practice of some orthodontists to paint unfilled resin on the bracket mesh prior to placing the filled resin. The idea is that the unfilled resin will flow into the undercuts provided by the mesh covered bracket base better than a filled resin. By filling these undercuts more completely, a stronger bond may be formed resulting in fewer failures.

The other way of thinking is that by flowing an unfilled resin into these undercuts, a weaker bond may be formed. This is because a filled resin shows greater strength than does the unfilled resin. When the unfilled resin fills the undercuts, no filled resin gets in and the bracket is held by unfilled resin only. This may result in weaker bond strengths and increased bond failures.

Another common practice among some orthodontists is to place the filled composite directly onto the back of the bracket, but then using a hand instrument to force the filled resin further into the undercuts. This may result in a stronger bond than simply placing the filled composite onto the bracket base and placing it onto the tooth.

We would like to decide which of the above arguments is true, resulting in increased bond strength.

Literature Review

In 1955 Buonocore laid the foundation for adhesive restorative and preventive dentistry[2] when he proposed that the surface of enamel could be altered through the use of acids. By altering the enamel with acids he felt, because of its commercial use of bonding acrylic paints to metal surfaces, that he could increase the bond between tooth and acrylic resins. He found this hypothesis to be true and proposed many uses for this new technique including Class III and V restorations, and pit and fissure sealants. Gwinnett, Matsui, and Buonocore found in 1968[3] that the increase in bond strength was due to the formation of resin tags. The acid etch removes a layer of enamel about 10 um deep creating a porous layer of 5-50 um into which the unfilled resin flows. When the resin cures, it then forms a micro-mechanical bond with the enamel.

In 1960 Mitchell developed the earliest known bonded orthodontic appliance.[14] He did not widely publicize his work because he used acid to gain retention for his appliance. At that time this was definitely not an accepted practice, but shortly after others took over and the bonded orthodontic appliance became a reality. Before this time, patients were treated with bands carrying orthodontic brackets in which the bands were cemented on all teeth. While effective for tooth movement, the banded appliance had many drawbacks. These included separation of all teeth, loss of arch circumference due to interproximal band and cement space, poor esthetics, and increased gingivitis.[4]

Light Cure Adhesives

Originally the bonded appliance used chemical cure acrylic resin adhesives. These and subsequent chemical cure composite resin adhesives had the disadvantage of a definable working time. Orthodontic bonding via the use of visible light cure adhesives was first described in 1979 by Tavas.[20] He described an adhesive that was cured by transillumination through the tooth. Laboratory[21] and clinical investigations[15] suggest that light cured materials have similar failure rates to chemical cured materials in both direct and indirect bonding techniques. Light cured materials offer the advantage of a longer working time to place the appliance,[19] and less residual adhesive debris following bracket removal.[16]

Bonding Agent

Bonding materials are supplied with a bonding agent, which is basically an unfilled resin. This bonding agent is applied following preparation of the enamel surface with an etchant, and prior to placing the filled composite resin.[17] It has been suggested in the literature that this results in increased penetration of the unfilled resin into the enamel pores, which increases bond strength.[13,6]

There is another concept, which states that a resin phase devoid of filler is present in sufficient amounts on the surface of the composite resin to fill the micropores of the etched enamel, making a bonding agent unnecessary.[1,10,12]

Tavas and Watts suggested that the use of an unfilled light cure resin results in a better bond between the adhesive and pad of a photo etched bracket.[21] Other studies found that the use of a bonding agent provided no significant difference in bond strengths to the prepared enamel[10] or the pad (retention from horizontal channels) of a bracket compared with not using a bonding agent.[17] In the study by O'Brien, the authors painted the back of the bracket with unfilled resin, cured it, then applied the filled resin. This effectively excluded any filled resin from entering the retentive areas of the bracket base. Still another study indicates that there is no advantage to using an unfilled resin in bond strength when using integral grooved bracket bases, although no unfilled resin was painted on the back of the bracket base.[8] These studies offer conflicting views and none used the stainless steel mesh pad used most often today because of their high retention abilities compared to other bracket base designs.[8,11]

It has been shown in previous studies that the most common site of failure when bonding a bracket to enamel is the bracket base-adhesive interface when using the foil mesh bracket base design[5,7,8]. It would follow that if the bond at this point can be strengthened then there would be less clinical bond failures.

Purpose

The purpose of this study is to determine which method of attaching a bracket to a tooth results in the highest bond strength:

(1) Painting the pad of a foil mesh bracket base with unfilled resin and curing the unfilled resin prior to placing the filled resin on the pad.

(2) Painting the pad of a foil mesh bracket base with unfilled resin and not curing the unfilled resin prior to placing the filled resin on the pad.

(3) Not painting the pad of a foil mesh bracket base with unfilled resin, but first adapting the filled resin into the undercuts with an instrument prior to pressing the bracket base onto the tooth.

(4) Placing filled resin directly on the bracket base by following the manufacturer's instructions and immediately pressing the bracket base onto the tooth.

Hypothesis: Painting the pad of a foil mesh bracket base with unfilled resin (and curing or leaving the resin uncured) prior to placing the filled resin on the pad, or forcing the filled resin into the mesh undercuts with an instrument prior to bracket placement will result in an increased bond strength compared with simply placing the filled resin on the bracket pad and pressing it onto the tooth.

Null hypothesis: There will be no difference in bond strength between the four groups.

Materials and Methods

A bis-GMA based bonding material, Transbond XT light cure adhesive system (3M Unitek, CA, USA) was used in this study (Figure 1). Victory Series™ upper left central miniature mesh twin brackets (3M Unitek, CA, USA) were bonded to the labial surface of extracted human incisors and canines. Forty extracted maxillary canines and central incisors were prepared for bonding by sectioning the crowns from the roots. The buccal surfaces were sanded flat using 600 grit silicon carbide paper to achieve a uniform flat enamel area large enough to bond a central incisor bracket to the flattened area. Care was taken to avoid exposing any dentin. Gange showed that flattening the enamel surface had no effect on bond strength.[9] The crowns were then placed on the surface of a flat table with the sanded surface toward the table. Plastic cylinders, with the proper diameter to allow for mounting in the Instron machine, were then placed over the crowns and filled with cold-cure acrylic. When the acrylic had set it was removed from the plastic cylinder resulting in a solid cylinder of acrylic with only the flat-sanded enamel surface of the embedded tooth exposed. This resulted in an exposed tooth surface that was exactly 90 degrees to the long axis of the acrylic cylinder, (Figure 2) which would later allow the force from the Instron machine to be applied in shear to the base of the bonded bracket. The prepared tooth samples were then stored in 100% humidity at room temperature.

Figure 1

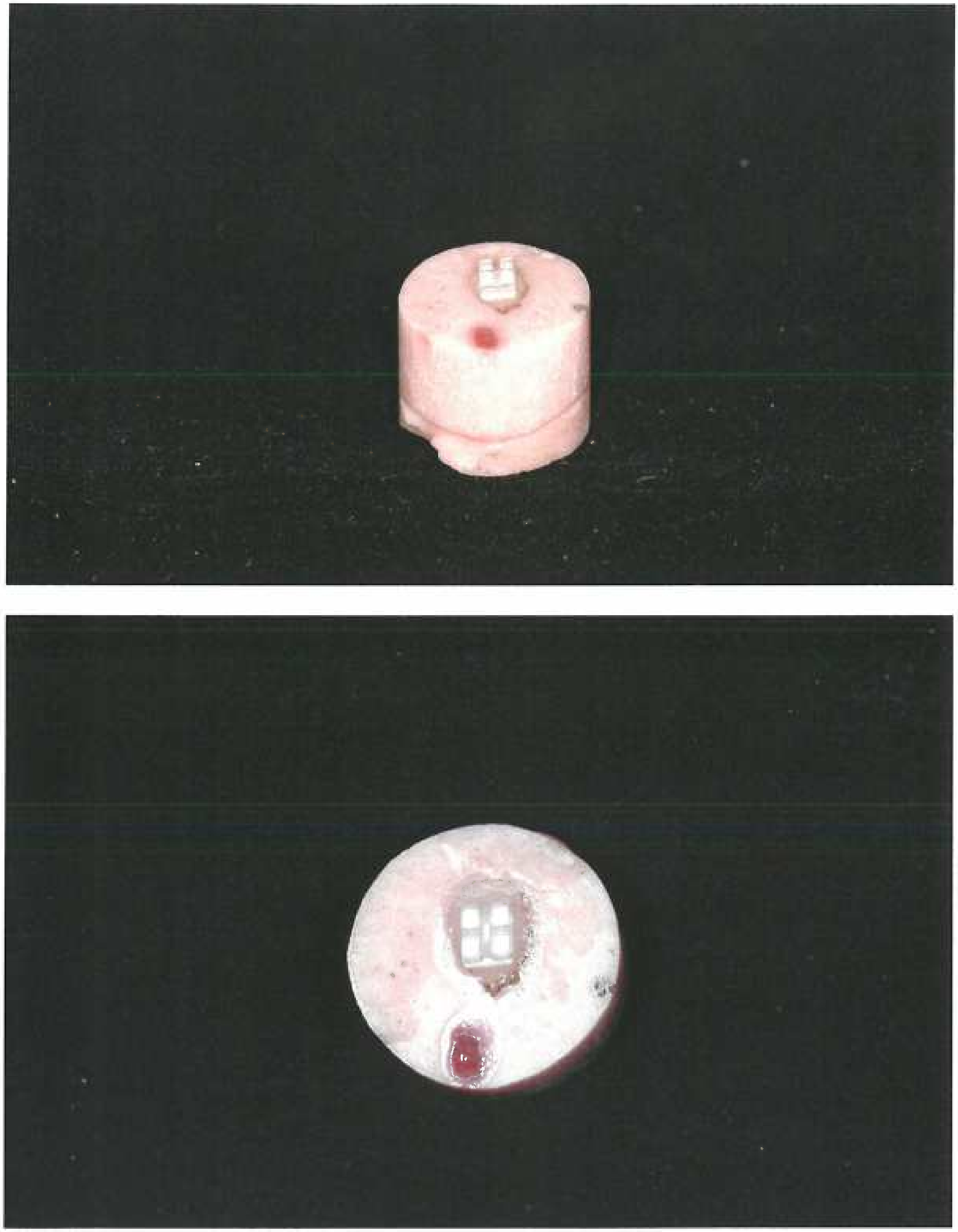

Figure 2

The brackets were then bonded to the prepared teeth in the following four ways:

- Control group: The bonding material was handled according to the manufacturer's instructions.

- Group A: The bonding material was handled according to the manufacturer's instructions, with the exception that the liquid resin was applied to the bracket base, thinned with compressed air, and light cured prior to the placement of the filled adhesive.

- Group B: The bonding material was handled according to the manufacturer's instructions, with the exception that the liquid resin was applied to the bracket base, thinned with compressed air, and not light cured prior to placement of the filled adhesive.

- Group C: The bonding material was handled according to the manufacturer's instructions with the exception that prior to placing the bracket on the tooth, the filled resin was adapted to the bracket base using a Gregg instrument in an attempt to force the adhesive into the mesh undercuts.

A sharp scaler was then used to remove the excess bonding material before light curing. A light-curing unit (3M Unitek Ortholux XT visible light curing unit) was used to cure the bonding adhesive. Its output was monitored by its own self-contained radiometer.

Experimental Design

Victory Series™ upper left central miniature mesh twin brackets were used in the bonding process. All samples were thoroughly cleansed, rinsed with water, and dried. Samples 1 through 10 (control group) were prepared for bonding by first etching the enamel surface for 30 seconds using the Ultra-Etch 35% phosphoric acid gel (Ultradent, South Jordan, UT) and then rinsing the surface thoroughly with water for ten seconds and dried with air. A thin layer of unfilled resin bonding agent Transbond XT light cure adhesive primer was then applied to the enamel surface with a brush and light cured with the Ortholux light for 20 seconds. Transbond XT light cure adhesive was then placed on the bracket pad and the bracket was placed on the prepared enamel surface. The excess was removed with a sharp scaler. The adhesive was then light cured using the Ortholux light for 40 seconds (20 gingival, and 20 incisal), as recommended by Oesterle.[18] Each sample was then stored in 100% humidity for 24 hours.

Samples 11 through 20 (group A) were prepared for bonding by first etching the enamel surface for 30 seconds using the Ultra-Etch 35% phosphoric acid gel (Ultradent, South Jordan, UT) and then rinsing the surface thoroughly with water for ten seconds and dried with air. A thin layer of unfilled resin bonding agent Transbond XT light cure adhesive primer was then applied to the enamel surface and the bracket base with a brush and each was light cured with the Ortholux light for 20 seconds. Transbond XT light cure adhesive was then placed on the bracket pad and placed on the prepared enamel surface. The excess was removed with a sharp scaler. The adhesive was then light cured using the Ortholux light for 40 seconds (20 gingival, and 20 incisal), as recommended by Oesterle.[18] Each sample was then stored in 100% humidity for 24 hours.

Samples 21 through 30 (group B) were prepared for bonding by first etching the enamel surface for 30 seconds using the Ultra-Etch 35% phosphoric acid gel (Ultradent, South Jordan, UT) and then rinsing the surface thoroughly with water for ten seconds and dried with air. A thin layer of unfilled resin bonding agent Transbond XT light cure adhesive primer was then applied to the enamel surface with a brush and light cured with the Ortholux light for 20 seconds. Primer was then painted on the back of the bracket base and blown thin with compressed air without light curing it. Transbond XT light cure adhesive was then placed on the bracket pad and placed on the prepared enamel surface. The excess was removed with a sharp scaler. The adhesive was then light cured using the Ortholux light for 40 seconds (20 gingival, and 20 incisal), as recommended by Oesterle.[18] Each sample was then stored in 100% humidity for 24 hours.

Samples 31-40 (group C) were prepared for bonding by first etching the enamel surface for 30 seconds using the Ultra-Etch 35% phosphoric acid gel (Ultradent, South Jordan, UT) and then rinsing the surface thoroughly with water for ten seconds and dried with air. A thin layer of unfilled resin bonding agent Transbond XT light cure adhesive primer was then applied to the enamel surface with a brush and light cured with the Ortholux light for 20 seconds. Transbond XT light cure adhesive was then placed on the bracket pad, a Gregg composite instrument was used to force the composite into the undercuts on the bracket base, and then the bracket was placed on the prepared enamel surface. The excess was removed with a sharp scaler. The adhesive was then light cured using the Ortholux light for 40 seconds (20 gingival, and 20 incisal), as recommended by Oesterle.[18] Each sample was then stored in 100% humidity for 24 hours.

The Instron Machine (Instron Corp., Canton, Mass.) was then utilized to apply a shear force to each bracket until bond failure (Figure 3). The cross-head speed was set at 2.54 mm per minute. The acrylic mounted teeth were placed in a holding apparatus with the brackets uniformly oriented as much as possible. A debonding jig was fit over the gingival wings of each sample (figure 4) and force was then applied by the Instron machine until failure. Shear bond force and the site of failure were recorded for each sample. Shear bond strength was calculated as the force divided by the bracket area.

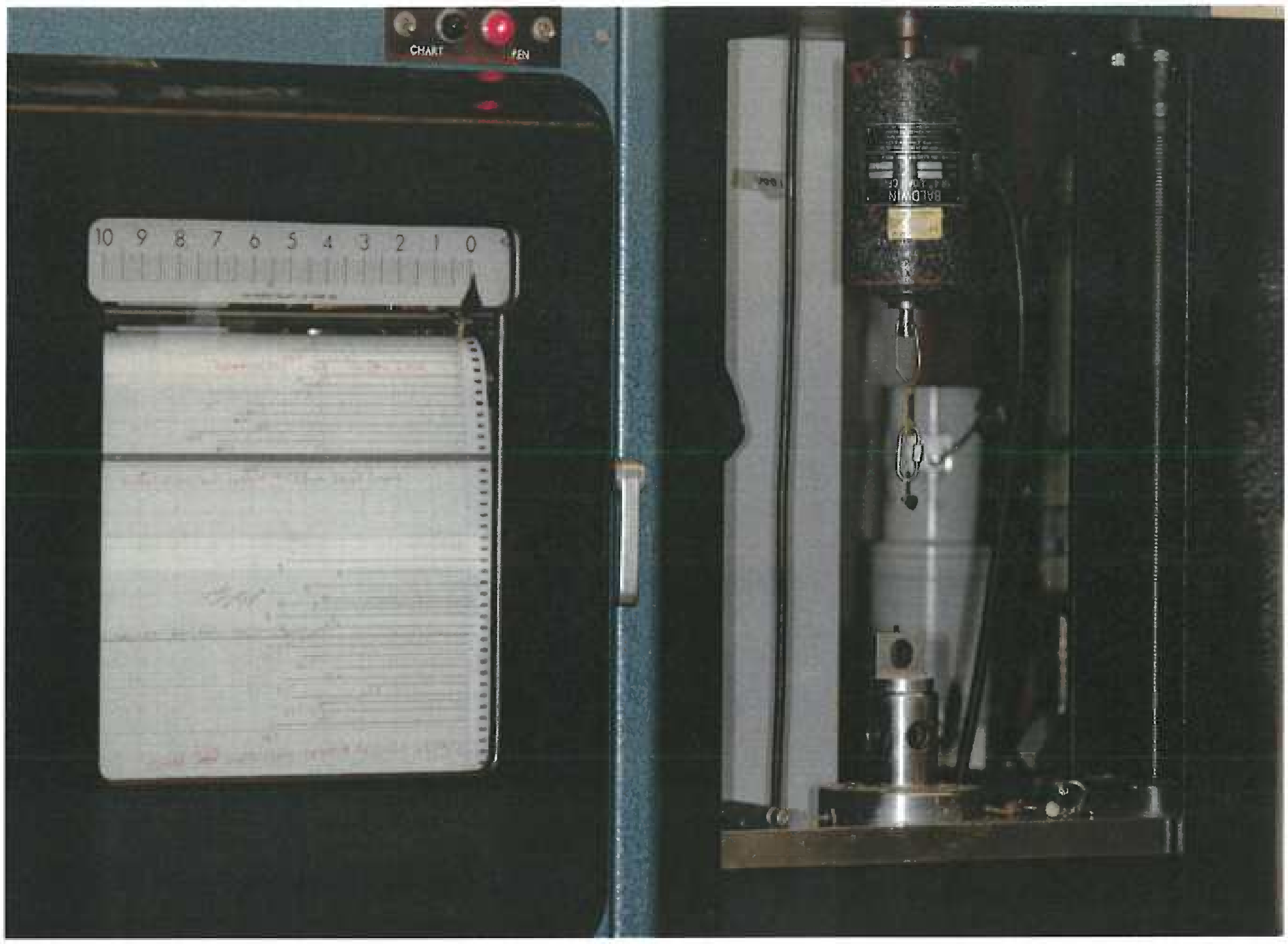

Figure 3

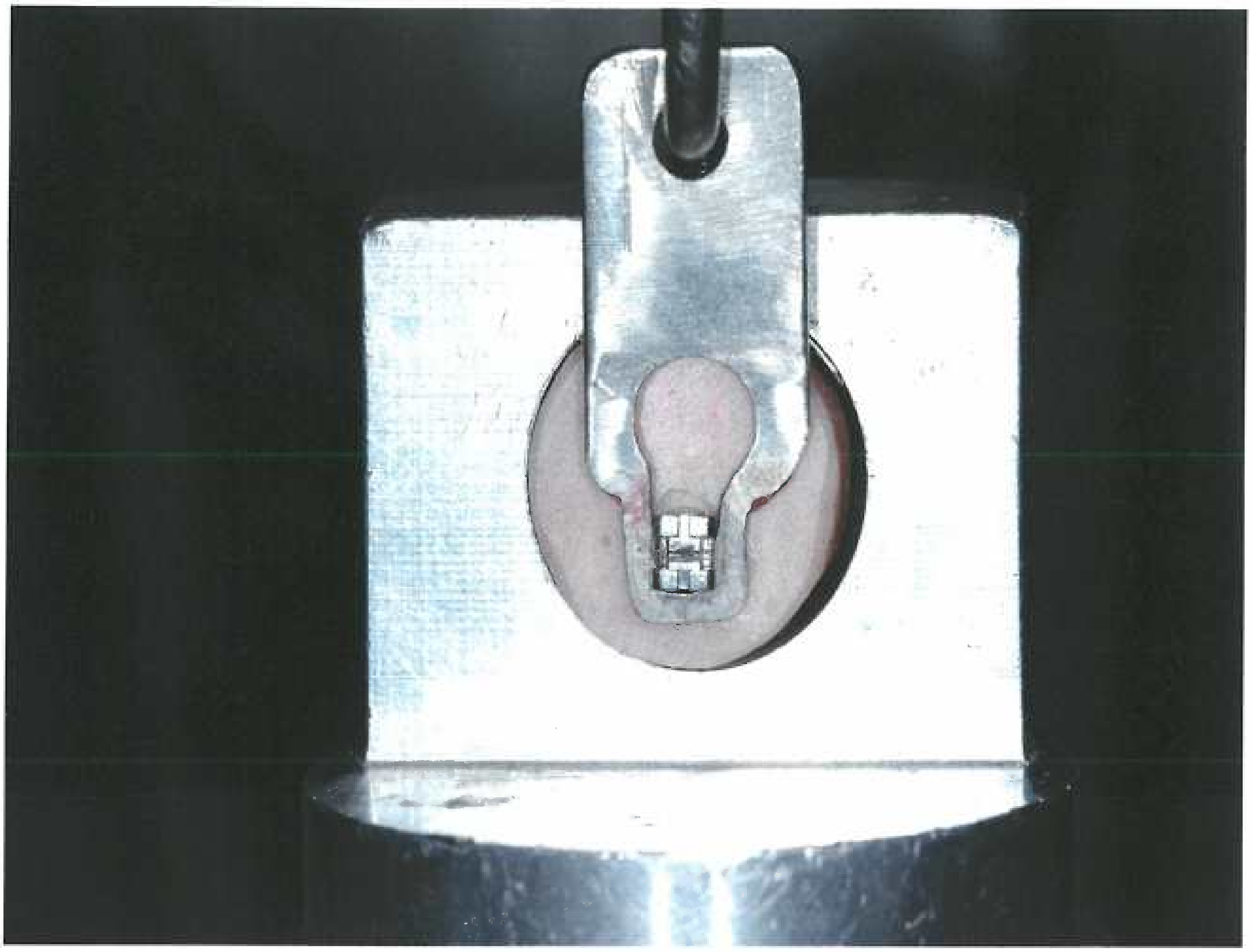

Figure 4

Results

Figure 5 displays the mean shear bond strength and one standard deviation for each group. Debond forces for each sample are displayed in Figure 6. The shear bond strengths between the four groups were statistically analyzed using the one-way ANOVA and the Tukey Multiple Comparison test at the $p \leq 0.05$ level. The ANOVA showed no statistical difference between any of the four groups tested. When the Tukey Multiple Comparison test was applied to the two groups having the largest difference between them (Group B (mean 15.14 MPa) and Group C (mean 16.32 MPa)) there was no statistical difference, and therefore no statistical difference between any of the four groups.

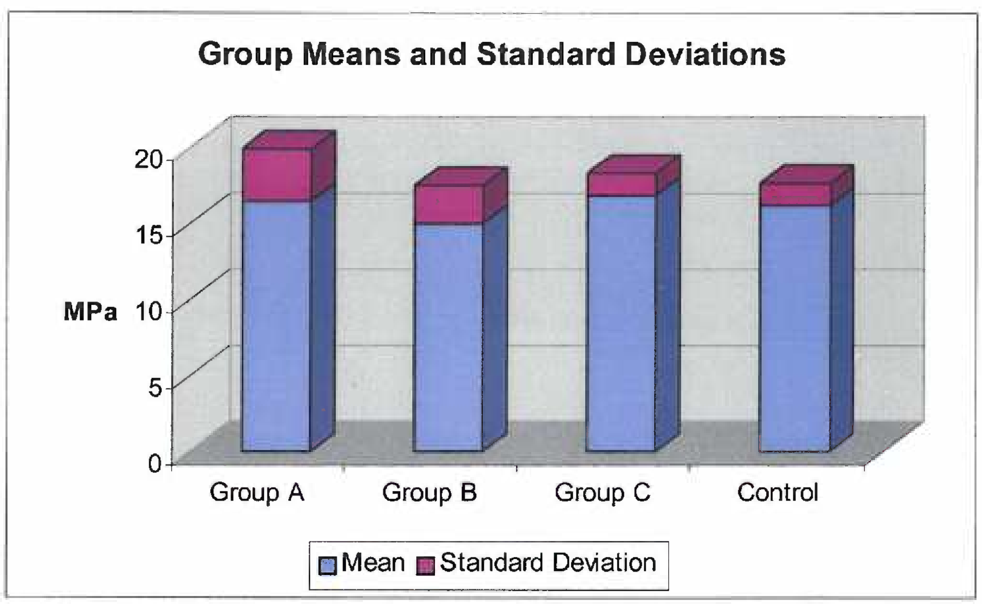

Figure 5

Group A		Group B		Group C		Control	
lean	16.47827	Mean	15.13569	Mean	16.86186	Mean	16.31912
tandard Error	1.126327	Standard Error	0.771079	Standard Error	0.47876	Standard Error	0.448164
ledian	16.22118	Median	15.13977	Median	16.67007	Median	16.8537
lode	20.52642	Mode	#N/A	Mode	#N/A	Mode	#N/A
tandard Deviation	3.561759	Standard Deviation	2.438367	Standard Deviation	1.513971	Standard Deviation	1.417219
ample Variance	12.68613	Sample Variance	5.945632	Sample Variance	2.292109	Sample Variance	2.00851
urtosis	-0.58231	Kurtosis	-1.02395	Kurtosis	1.622799	Kurtosis	0.541009
kewness	-0.45722	Skewness	-0.29716	Skewness	-0.8256	Skewness	-1.07028
ange	10.44685	Range	7.1414	Range	5.386656	Range	4.652112
linimum	10.07958	Minimum	11.26301	Minimum	13.58906	Minimum	13.46664
laximum	20.52642	Maximum	18.40441	Maximum	18.97572	Maximum	18.11875
um	164.7827	Sum	151.3569	Sum	168.6186	Sum	163.1912
ount	10		10		10		10

Table 1

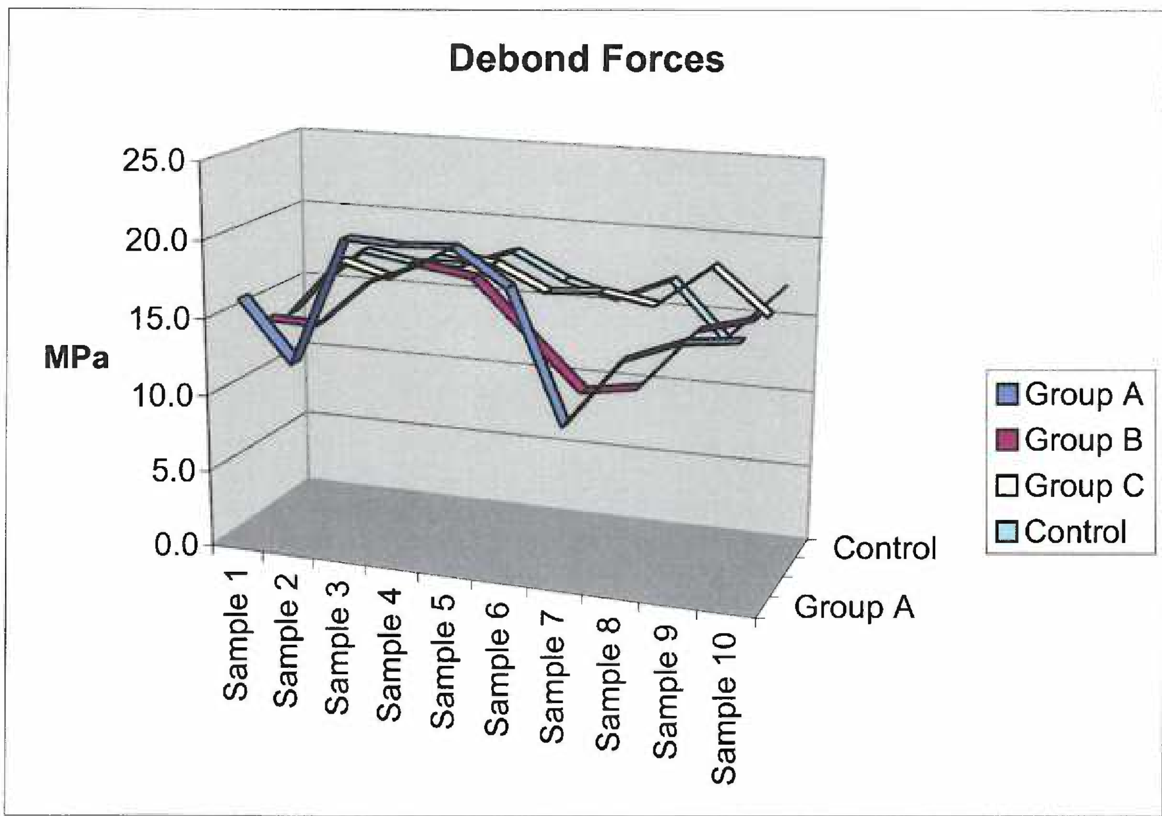

Figure 6

	Group A	Group B	Group C	Control
Sample 1	16.2	14.0	13.6	14.5
Sample 2	12.3	13.9	17.4	17.3
Sample 3	20.5	17.0	16.5	16.8
Sample 4	20.3	18.4	18.4	16.9
Sample 5	20.5	17.9	18.0	18.1
Sample 6	18.3	14.6	16.5	16.5
Sample 7	10.1	11.3	16.8	15.5
Sample 8	14.4	11.8	16.2	17.1
Sample 9	15.8	15.7	19.0	13.5
Sample 10	16.2	16.7	16.1	17.0

Table 2

Site of failure

Figure 7 demonstrates graphically the site at which bond failure (at the bracket vs. at the tooth) was initiated for each of the four groups. All of these numbers were determined from visual examination of the bracket pad and tooth. Group A demonstrated 50% of the samples having total failure of the adhesive at the bracket and 20% of the samples with total fracture at the tooth. 30% of the failures of group A were mixed showing a combination of failure of the adhesive at the bracket and at the tooth. Of the mixed failures an average of 86.7% of the failure took place at the bracket (or 86.7% of the resin remained on the tooth). In this group, 80% of the failures actually started at the bracket.

In Group B, 10% of the samples had total failure of the adhesive at the bracket, while another 10% showed total failure at the tooth. 80% of the failures of group B were mixed showing a combination of failure of the adhesive at the bracket and at the tooth. Of these mixed failures an average of 59.4% of the failure took place at the bracket. In Group B, 90% of the failures started at the bracket.

In Group C, 80% of the samples had total failure of the adhesive at the bracket, while no samples had total failure at the tooth. 20% of the failures of group C were mixed showing a combination of failure of the adhesive at the bracket and at the tooth. Of these mixed failures an average of 85% of the failure took place at the bracket. In this group all of the failures started at the bracket.

In the control group, 80% of the samples had total failure of the adhesive at the bracket, while no samples had total failure at the tooth. 20% of the failures of the control group were mixed showing a combination of failure of the adhesive at the bracket and at the tooth. Of these mixed failures an average of 95% of the failure took place at the tooth. All of the samples in the control group showed failure initiating at the bracket.

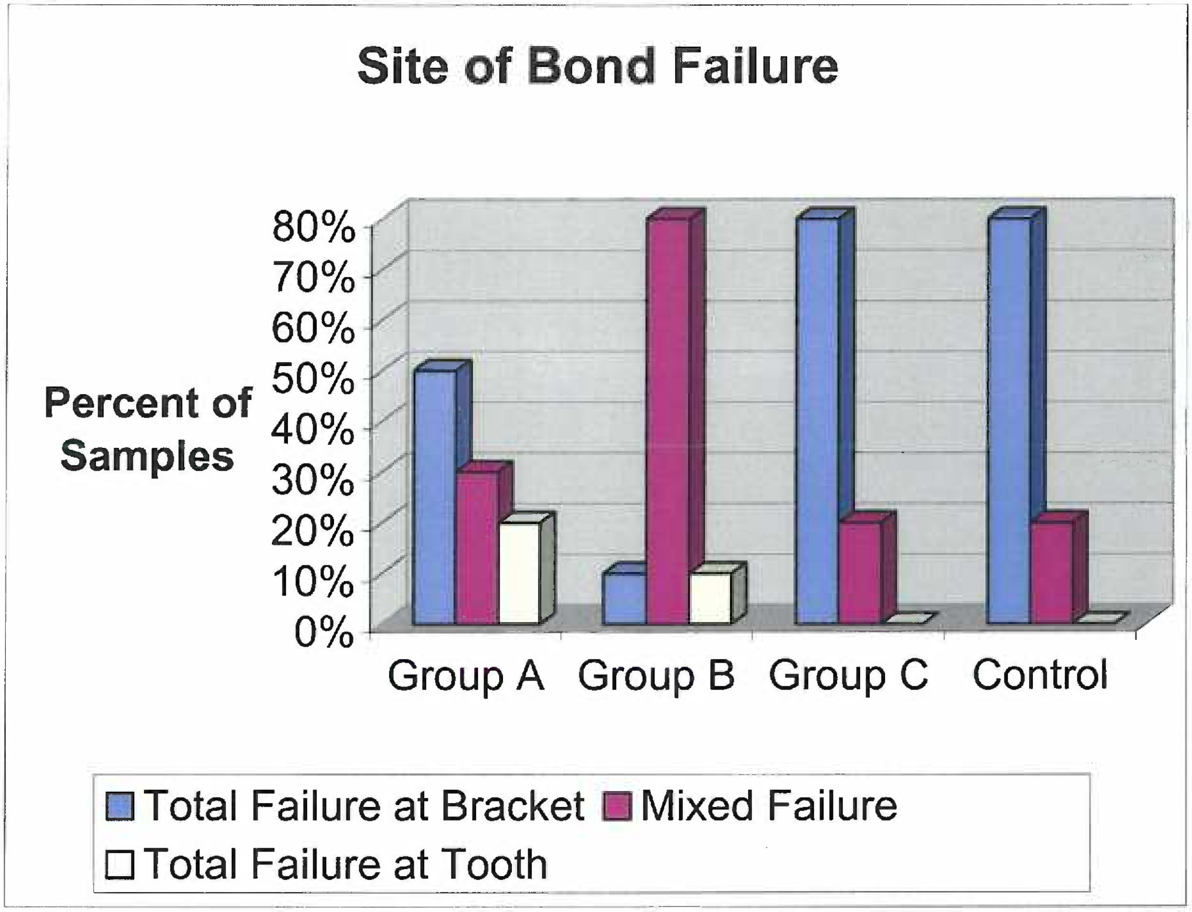

Figure 7

	Group A	Group B	Group C	Control
Total Failure at Bracket	50%	10%	80%	80%
Mixed Failure	30%	80%	20%	20%
Total Failure at Tooth	20%	10%	0%	0%

Table 3

Summary of results

1. When the mean bond strengths of the four different groups were measured and compared, no statistical differences were found between any of the groups.
2. The use of unfilled resin on the bracket pad (whether cured prior to filled resin placement or not) showed no statistical increase in bond strength versus using no unfilled resin.
3. There were differences in the location at which the bond failure occurred between the four groups. It was observed that the groups with the unfilled resin applied to the bracket base (groups A and B) showed less failures occurring at the bracket base, while those groups with filled resin applied directly to the bracket base showed higher failure rates at the bracket base.

Discussion

The idea that unfilled resin will flow into the undercuts provided by the mesh covered bracket base (the most widely used bracket base today) better than a filled resin alone may in fact be true, but does that increase the bond strength of the bracket to the tooth? Or by using an unfilled resin are we in fact decreasing the bond strength of the bracket to the tooth? Can we then increase the bond strength by forcing composite into the undercuts of the mesh by pushing the filled adhesive into the bracket mesh with a hand instrument? If these things do not increase bond strength then why should we take extra time to do them?

The results of this study show that whether we paint the bracket with an unfilled resin prior to placement of the bracket on the tooth with a filled resin, or simply apply the filled resin directly to the bracket base makes no difference in the bond strength of the bracket to the tooth. Light curing the unfilled resin prior to placement also had no impact on the resulting bond strength, and neither did forcing filled resin into the undercuts with a hand instrument.

One reason for finding no difference between the groups could be that in all cases, regardless of if unfilled resin was painted on the bracket pad or not, only unfilled resin may have found its way into the undercuts of the mesh pad. This concept was presented by a few researchers[1,10,12] in reference to the necessity of using an unfilled resin when bonding to enamel. They indicated that a resin phase devoid of filler particles is present in sufficient amounts on the surface of the composite resin to penetrate the pores created by the acid etch in the enamel making a bonding agent (unfilled resin) unnecessary. This may be occurring with the bracket pad as well. Perhaps this resin phase devoid of filler is all that is getting into the undercuts when a filled resin is used. If no filled resin gets into the undercuts on the bracket base then it would make sense that there would be no difference between the four groups.

Therefore, if we do paint unfilled resin on the bracket base or force filled resin into the bracket base routinely we must have another reason for incurring the extra time associated with these practices. One reason may be the difference in location of the bond failure. Painting the back of the bracket with an unfilled resin first (especially without light curing), then applying the filled resin and adapting it to the tooth resulted in less resin left on the tooth surface for reasons unknown. This could result in less time spent during the debond appointment removing the resin from the tooth surface.

The results of this experiment show that painting the bracket base with an unfilled resin, or forcing filled resin into the undercuts with a hand instrument, resulted in bond strengths that were not statistically different from those achieved by following the manufacturer's instructions (as done in the control sample).

Conclusions

1. No statistical difference was found for bond strength between any of the four study groups, and the null hypothesis is accepted.

2. The groups bonded with unfilled resin on the bracket base showed a higher percentage of resin attached to the bracket base after debond then the other two groups.

These results do not support the use of unfilled resin applied to the bracket base, nor forcing the filled resin into the bracket pad mesh with a hand instrument for the purpose of increasing mean bond strength over following manufacturers directions to bond brackets to teeth.

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