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Bonding Orthodontic Brackets to Stainless Steel Crowns

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This is to certify that the thesis prepared by Daniel Stewart D.M.D, entitled Bonding Orthodontic Brackets to Stainless Steel Crowns has been approved by his committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Dentistry.

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Bonding Orthodontic Brackets to Stainless Steel Crowns
A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Abstract

Bonding Orthodontic Brackets to Stainless Steel Crowns
By Daniel Stewart, D.M.D.

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University, 2009

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The purpose of this study was to compare shear bond strengths of brackets bonded to stainless steel crowns using various orthodontic adhesives and surface conditioning techniques. One hundred and twenty mandibular first molar stainless steel crowns were randomly divided into groups: (1): Aluminablasting + Metal Primer + Assure; (2): Aluminablasting + Silane Coupling Agent + Transbond; (3): Diamond Bur Abrasion + Metal Primer + Assure; (4): Diamond Bur Abrasion + Silane Coupling Agent + Transbond; (5: control): Acid Etching + Metal Primer + Assure; (6: control): Acid Etching + Silane Coupling Agent + Transbond. Bond strength was tested using a universal testing machine.

Both aluminablasting and diamond bur abrasion surface preparation techniques, when used in conjunction with metal primer and Assure bonding resin, reached clinically acceptable bond strength values (9.05 and 9.30 MPa, respectively). These techniques seem to offer viable options to bond orthodontic brackets to stainless steel crowns.

Introduction

The introduction of the acid etching bonding technique by Buonocore[1] in 1955 has led to dramatic changes in dentistry. A decade later, Newman[2] used this concept for the use of orthodontic adhesive to bond orthodontic brackets directly onto teeth. Over the past 40 years, continuous developments in dental material sciences and bioengineering resulted in modern orthodontic bonding systems and fixed appliances.[3-5] Today bonding brackets with a composite resin is considered the gold standard in the orthodontic profession.

Direct bonding offers numerous advantages including increased patient comfort by eliminating the need to separate and band teeth, improved esthetics, ability for better plaque removal by patients, minimized soft tissue irritation, and facilitation of bonding attachments to partially erupted teeth.[6, 7]

The principles of the direct bonding of brackets are based on adhesive systems which use 3 different agents: an enamel surface conditioner, a primer solution, and an adhesive resin.[8] The purpose of using surface conditioner is to create microporosity on the enamel that creates a high-energy surface. A primer solution is then flowed into the etched surface to create resin tags so that subsequently a mechanical bond may be provided between the adhesive resin and the tooth surface.[9]

Once bonded onto the tooth surface, brackets should exhibit adequate bond strength to withstand intraoral and orthodontic forces. A bond strength value of 6-8 MPa at 24 hours is considered to be ideal for most clinical orthodontic uses.[10] Any value higher than 14 MPa may cause enamel fracture during debonding,[11,12] whereas less than 4 MPa will likely fail during orthodontic treatment.[13] These data must be interpreted in the context of the clinically acceptable bond failure rate of 1-5%.[13]

Because of the increased number of adult patients seeking orthodontic treatment, clinicians are often challenged by bonding brackets onto metallic or porcelain restorations. In addition, children with stainless steel crowns may also pose a real problem to orthodontists as severely damaged teeth are often restored with this treatment modality. Orthodontic bands instead of brackets have traditionally been used to attach orthodontic appliances to porcelain or stainless steel crowns due to inadequate bond strength between the orthodontic resin and porcelain or metal restoration surface. To date considerable research has been conducted to study the bond strength of the composite resins to enamel. However, fewer studies are available on the bonding characteristics of orthodontic adhesives to restored surfaces, and of these studies porcelain bonding has been the dominant theme.[14-19]

When bonding onto porcelain or metal surfaces it is necessary to modify conventional conditioning techniques due to the inert nature of these materials.[14,17,18,20] Several approaches have been suggested to alter the surface characteristics of the porcelain or metal to improve the bond strength of the composite resin.[15] Surface conditioning prior to bonding may be achieved using chemical means, mechanical means or combination of these two techniques.[15,21]

Chemical alteration of the porcelain surfaces can be obtained by either etching the surface to increase the mechanical retention of the adhesive or by changing the porcelain surface affinity to the adhesive materials. Hydrofluoric acid can be used to etch the porcelain but care must be taken to avoid contact with the soft tissue to prevent damage.[15] Also, it should be kept in mind that the ceramic surface glaze may be lost with this method. Phosphoric acid is another agent used to etch porcelain surfaces and this material does not cause as much damage as hydrofluoric acid. However, adequate and consistent bond strength may not be achieved when used for orthodontic purposes[15].

The application of hydrofluoric and phosphoric acid can make the restoration surface more receptive to wetting from primer because of the ability of these acids to remove low-energy contaminants such as oil and grease from the surface.[17] Because of an increase in the substrate surface area, coupled with the removal of contaminants, hydrofluoric and phosphoric acid are found to improve the bond strength between the adhesive and restoration.[21]

Another method to chemically alter the porcelain surface is to change the nature of the surface using a coupling agent such as silane. Silanes, also known as adhesion promoters, once absorbed onto the porcelain surface alter the surface affinity of the porcelain to the resin by either a chemical or physical process. In addition, the portion of the silane molecule that is not absorbed presents a free surface which may be readily wetted by adhesives. It has been shown that the silane coupler actually forms a chemical bond between the acrylic in the composite resin and the porcelain.[15]

The purpose of the mechanical alteration is to increase the surface area and thus improve the mechanical retention between the composite resin and the porcelain/metal surface.[14,15,18,19] Microetching with aluminum oxide (air abrasion or aluminablasting) and diamond bur abrasion are the most popular choices for roughening porcelain or metal surfaces to create mechanical retention, in part, because of the practicality of their use. Although chemical and mechanical roughening are widely used, a combination of mechanical and chemical conditioning known as "tribochemical coating", has recently become popular for surface conditioning.[14,15,22]

During tribochemical coating, silica of the modified aluminum oxide becomes trapped on the porcelain/metal surface due to the aluminablasting pressure. These particles make the surface chemically active to resin in the presence of silane coupling agent and provide a chemicophysical bond between the resin and the porcelain/metal surface. Therefore, the tribochemical coating method is thought to enhance bond strength by providing both mechanical retention and chemicophysical bond.[14-18,23] However, the effectiveness of this method is questionable as it has been reported that there were no statistical differences in the bond strength between the samples that received surface preparation with aluminum oxide and those that received silicated aluminum oxide (tribochemical coating).[18]

In 2003, Nergiz et al.[14] conducted a study to determine how the alloy type and the surface preparation technique affected the bond strength. In that study, discs of different alloy compositions were subjected to various surface preparation techniques including tribochemical coating. It was reported that samples prepared with the tribochemical coating exhibited higher bond strength than the ones that received surface roughening with a diamond bur and aluminablasting. Of the alloys tested, nickel chromium samples were found to exhibit the highest bond strength values. In light of the promising results obtained from that study, it is plausible to expect a higher bond strength between the orthodontic adhesive and stainless steel crowns as both nickel and chromium are present in the composition of the stainless steel alloy.[14,18] However, one drawback of that study was that disk shaped samples did not mimic the actual geometry and contour of the porcelain or stainless steel crowns.

The purpose of this study was to compare the shear bond strength of brackets bonded to stainless steel crowns using various surface preparation technique and orthodontic resin combinations. If a method could be developed to bond brackets to stainless steel crowns with predictable and reliable bond strength, orthodontists would have a true alternative to banding patients with these restorations.

Materials and Methods

One hundred and twenty mandibular first molar stainless steel crowns (3M/Unitek, St. Paul, MN) were randomly divided into four experimental and two control groups: Group 1: Aluminablasting + Metal Primer (Reliance, Itasca, IL) + Assure (Reliance, Itasca, IL); Group 2: Aluminablasting + Silane Coupling Agent (Pulpdent, Wattertown, MA) + Transbond (3M Unitek, Monrovia, CA); Group 3: Diamond Bur Abrasion + Metal Primer + Assure; Group 4: Diamond Bur Abrasion + Silane Coupling Agent + Transbond ; Group 5 (control): Acid Etching + Metal Primer + Assure; Group 6 (control): Acid Etching + Silane Coupling Agent + Transbond. The experimental groups (1-4) differed from the control groups (5-6) based on surface preparation. The samples in the experimental groups were assigned to either an aluminablasting or diamond bur abrasion surface preparation whereas acid etchant was used not as a surface preparation, but as a cleaning agent, in the control groups.

Stainless steel crowns in Groups 1 and 2 were microetched by aluminablasting with aluminum oxide (50µm Ortho Club, Urbana OH) for 4 seconds at a distance of 5mm.[24] Surface roughening of samples in Groups 3 and 4 was achieved with a football shaped diamond bur, by lightly touching the metal crown surface at 30,000rpm. A 38% phosphoric acid gel, Etch Rite, (Pulpdent, Wattertown, MA) was applied for 30 seconds and then rinsed with a copious amount of oil free water spray in order to prepare the samples in Groups 5 and 6 (controls).

Following surface preparation, the bonding agents were applied according to the manufacturer's recommendations. For Groups 1, 3 and 5 one coat of metal primer was applied followed by a thin coat of Assure, a light-cured polyacid-modified composite resin, which was air dried for 5 seconds before bracket placement. Silane was applied to the stainless steel crown surfaces then air dried for 5 seconds followed by a thin coat of Transbond which was also air dried for 5 seconds before bracket placement on the crown surfaces in Groups 2, 4 and 6.

Subsequently each sample was mounted in a phenolic ring (Buehler, Lake Bluff, Illinois) using a self-curing acrylic. Careful mounting ensured that sample surfaces were parallel with the arm of the testing machine during debonding. Central incisor Victory Series APC brackets (3M Unitek, Monrovia CA) were bonded just mesial of the center of the crowns. The order of bonding was determined by selecting the group number at random and following the protocol listed above. Central incisor brackets were chosen because the contour of the bracket base adapted very well to the surface of the crown and the dimensions of the bracket also facilitated placement of the arm of the universal testing machine. Following bracket placement, flash adhesive was removed from the bracket edges and the resin was cured for 3 seconds on the mesial and distal surfaces using a plasma arc visible light-curing unit (Ortholite, 3M Unitek, Monrovia, CA). Samples were stored in distilled water at room temperature for 24 hours until mechanical testing.[24]

The shear bond strength was tested using a universal testing machine (Instron Corp., Canton MA) at a crosshead speed of 0.5mm/minute. To ensure parallelism between the bracket surface and the testing machine, samples were seated on a custom made holder that could be positioned at different angulations. The force required to shear the bracket was recorded and the bond strength values were calculated in megapascals (MPa) by dividing the shear force by the bracket base area (10.56mm^2). After debonding, stainless steel crown surfaces were evaluated under 10X light microscope by the same operator to determine the location of bond failure using Adhesive Remnant Index (ARI) as follows:[25]

1= all the composite remained on the tooth/crown

2= more than 90% of the composite remained on the tooth/crown

3= between 10-90% of the composite remained on the tooth/crown

4= less than 10% of the composite remained on the tooth/crown

5= no composite remained on the tooth/crown

Statistical Analyses

To account for the possibility of skewed data, the log-transformed MPa values were analyzed using a two-way analysis of variance (ANOVA) to determine whether differences existed between the groups.[26] The two factors were: surface preparation (three levels: Aluminablasting, Diamond Bur Abrasion, Acid etching) and bonding agent (two levels: Metal Primer + Assure, Silane + Transbond) resulting in a two-way interaction of surface preparation and bonding agent. The back-transformed least-squares means (LS means) were determined along with 95% confidence intervals (CI) of the estimated mean bond strength. A Weibull analysis was also used to determine the average bond strength necessary to debond 5% of the brackets with a 95% confidence interval. Differences in ARI scores were analyzed using nominal logistic regression with two-way model.

Results

Outliers in a data set can skew the arithmetic mean. To prevent this, geometric means were calculated from the log-transformed shear bond strength values (MPa). The mean shear bond strength for each of the six groups is shown in Table 1. The six groups were found to be significantly different ($p < .0001$). The mean bond strength values were 5.73 MPa (95% CI = 4.67-7.05 MPa) and 4.94 MPa (95% CI = 4.02-6.07 MPa) for the Aluminablasting + Metal Primer + Assure and Diamond Bur Abrasion + Metal Primer + Assure groups, respectively. For the Aluminablasting + Silane Coupling Agent + Transbond and Diamond Bur Abrasion + Silane Coupling Agent + Transbond groups the values were 3.20 MPa (95% CI = 2.61-3.93 MPa) and 2.40 MPa (95% CI = 1.96-2.95 MPa), respectively. Within the acid etching groups (controls), samples bonded with the metal primer + Assure exhibited higher bond strength (0.76 MPa, 95% CI = 0.62-0.94 MPa) than those bonded with the Silane Coupling Agent + Transbond (0.43 MPa, 95% CI = 0.35-0.53 MPa).

Table 1: Shear bond strength values for the experimental and control groups (MPa)

Group	Mean	Median	95%CI
Aluminablasting + Metal Primer + Assure	5.73	6.25	4.67-7.05
Aluminablasting + Silane + Transbond	3.20	3.53	2.61-3.93
Diamond Bur Abrasion + Metal Primer + Assure	4.94	4.96	4.02-6.07
Diamond Bur Abrasion + silane + Transbond	2.40	2.46	1.96-2.95
Acid etching +Metal Primer + Assure	0.76	0.73	0.62-0.94
Acid etching + Silane + Transbond	0.43	0.43	0.35-0.53

All groups statistically different ($p<0.0001$) from each other

The results indicated that the effect of bonding method did not depend upon the surface preparation. Regardless of which surface conditioning method was used, the Metal Primer + Assure groups were always superior to the Silane Coupling Agent + Transbond groups ($p < 0.0001$). Between the Diamond Bur Abrasion groups, the Metal Primer + Assure bond strength (4.94 MPa, 95% CI = 4.02-6.07 MPa) was nearly double that of the Silane Coupling Agent + Transbond (2.40 MPa, 95% CI = 1.96-2.95 MPa). Similar results were obtained in both the other experimental and control groups. Pooled data (Table 2) showed that the samples in the Metal Primer + Assure group exhibited higher mean bond strength values (2.79 MPa, 95% CI = 2.47-3.14 MPa) than those in the Silane Coupling Agent + Transbond group (1.49 MPa, 95% CI = 1.33-1.68 MPa).

Table 2: Shear geometric means for the bonding groups (MPa)

Group	Mean	95% CI
Silane + Transbond	1.49	1.33-1.68
Metal Primer + Assure	2.79	2.47-3.14

(p<0.001)

When compared by the type of surface preparation, each group was found to be different (p<0.0001). Overall, higher shear bond strengths were obtained with aluminablasting (4.29MPa, 95% CI = 3.70-4.96 MPa) than the diamond bur abrasion (3.45 MPa, 95% CI = 2.98-3.99 MPa) but this difference was not significant (ratio = 1.24, 95% CI = 0.97-1.59). However, the bond strengths achieved in both of these groups were higher than the acid etching groups (0.57 MPa, 95% CI = 0.50-0.66 MPa), (Table 3).

Table 3: Shear geometric means for the surface preparation techniques (MPa)

Group	Mean	95% CI
Aluminablasting	4.29	3.70-4.96
Diamond Bur Abrasion	3.45	2.98-3.99
Acid etching	0.57*	0.50-0.66

* Statistically different than the other groups (p<0.0001)

Weibull analyses showed that regardless of the surface conditioning technique used, samples in the Metal Primer + Assure groups exhibited higher bond strength values than those in the Silane Coupling Agent + Transbond groups (Table 4).

Table 4: Bond stress necessary to debond 5% of brackets (MPa)

Group	MPa	95% CI
Aluminablasting + Metal Primer + Assure	1.88	1.45-2.42
Aluminablasting + Silane + Transbond	1.10	0.84-1.43
Diamond Bur Abrasion + Metal Primer + Assure	1.67	1.28-2.17
Diamond bur abrasion + Silane + Transbond	0.91	0.69-1.20
Acid etching + Metal Primer + Assure	0.33	0.25-0.43
Acid etching + Silane + Transbond	0.16	0.13-0.21

Figure 1 illustrates the distribution of bracket failures in each group. As indicated by the square markers, more than half of the brackets in the Aluminablasting + Metal Primer + Assure group failed at or above clinically acceptable bond strengths (6 MPa).

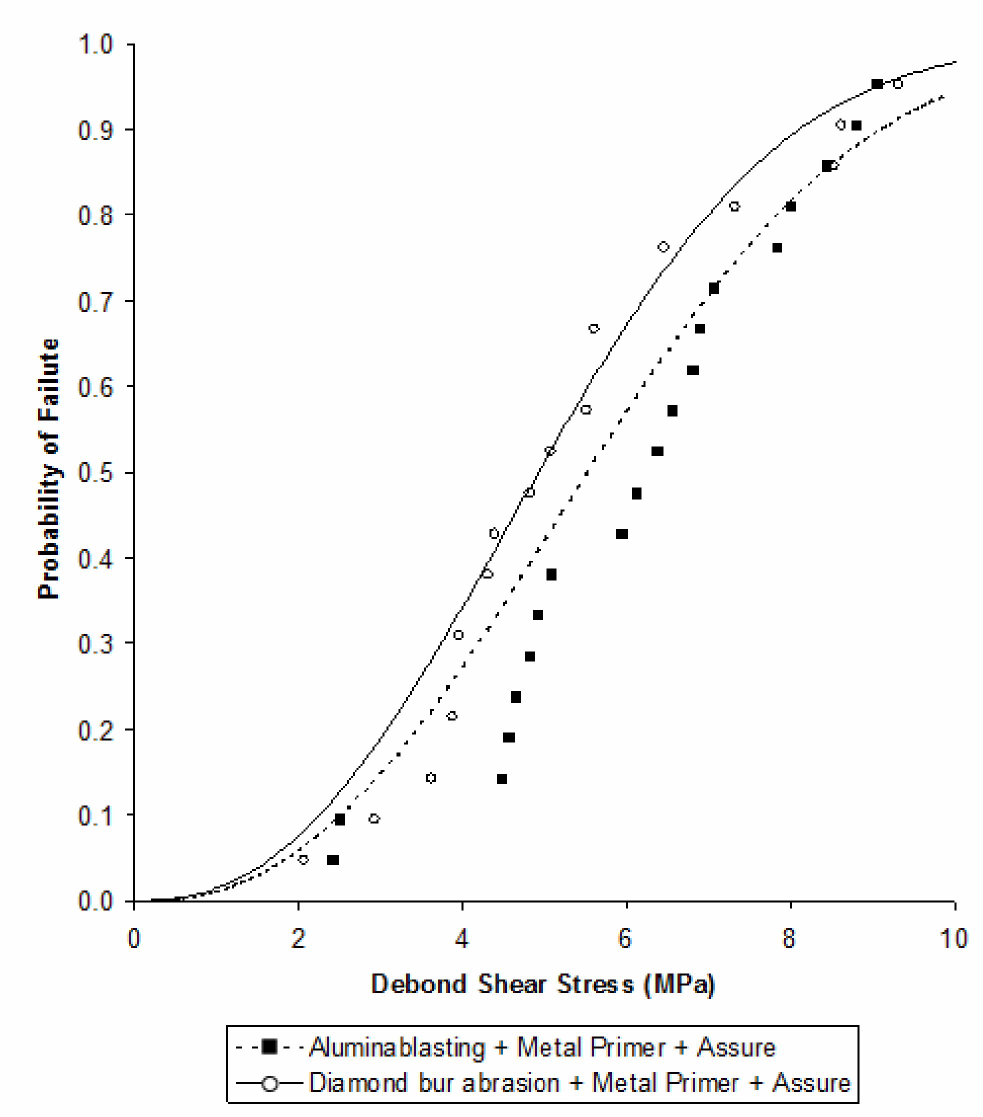

Figure 1: Probability of bracket failure at various bond stresses

The results of the ARI are provided graphically in Figure 2 and numerically in Table 5. Statistical analyses showed that there were significant differences among the groups ($p < .0001$). The Acid Etching + Metal Primer + Assure (control) and the Acid Etching + Silane Coupling Agent + Transbond (control) groups had predominantly ARI scores of 3 and 4 indicating a cohesive bond failure mode. The remaining samples in these groups had an ARI score of 5 with no composite left on the crown surface. The experimental groups (Groups 1-4) had mostly ARI scores of 1 indicating that aluminablasting and diamond bur abrasion techniques resulted in an adhesive bond failure mode. The data did not reveal a correlation between ARI score and bond strength.

Table 5: Frequency of ARI scores for each group

Group	*ARI 1*	*ARI 2*	*ARI 3*	*ARI 4*	*ARI 5*
Aluminablasting + Metal Primer + Assure	15	4	1	0	0
Aluminablasting + Silane + Transbond	14	0	6	0	0
Diamond Bur Abrasion + Metal Primer + Assure	12	3	5	0	0
Diamond Bur Abrasion + Silane + Transbond	3	2	9	4	2
Acid etching + Metal Primer + Assure	0	1	6	8	5
Acid etching + Silane + Transbond	1	0	5	5	9

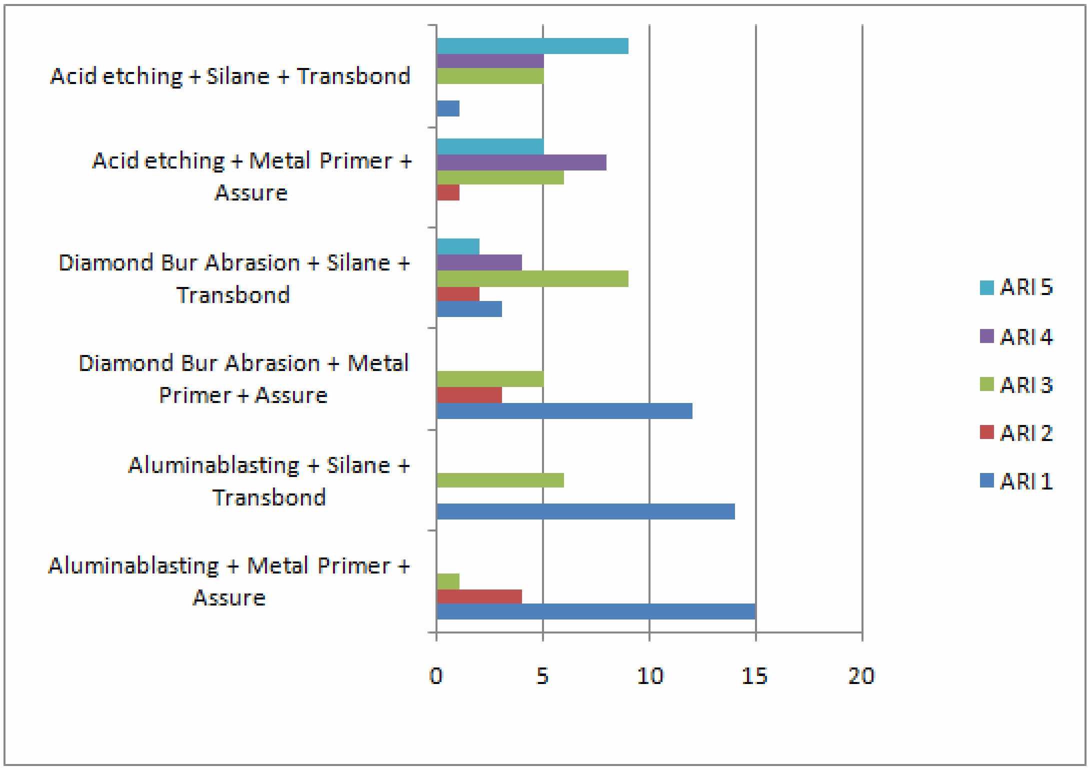

Figure 2: Distribution of ARI scores for each group

Discussion

This study investigated various surface preparation techniques and adhesives to determine which, in combination, would exhibit the highest bond strength when orthodontic brackets were bonded onto stainless steel crowns. In addition, the results were compared to the clinically required bond strength values of 6-8MPa.[10] Two groups served as controls, Acid Etching + Metal Primer + Assure and Acid Etching + Silane + Transbond. The experimental groups used the same bonding agent combinations (Metal Primer + Assure and Silane Coupling Agent + Transbond) but varied in their surface preparation with one group using aluminablasting with aluminum oxide and the other using surface roughening with a diamond bur.

The results of this study showed that the aluminablasting surface preparation technique is slightly superior to surface roughening with a diamond bur. The bond strength values of the samples prepared with either surface preparation technique were statistically higher than those in the control groups (acid etching groups). This finding is in agreement with previous investigators[14,15] who also found that samples in the aluminablasting group resulted in higher bond strength values than the ones in the diamond bur abrasion group.

Both the aluminablasting and surface roughening with a diamond bur techniques, when used with a metal primer and Assure bonding agent, were able to approach the level of clinically required bond strength values of 6-8MPa. In addition, the Assure resin with metal primer demonstrated higher bond strength values in both the experimental and control groups.

This study did not use the tribochemical system of incorporating silica particles into the metal substrate. Even though several studies reported the tribochemical technique to be successful in increasing bond strength when coupled with silane[14-17] this method may not be appropriate for intraoral applications as silane is found to be unstable in humid conditions. Therefore, a need for a rubber dam to control the moisture of the oral environment would diminish the practicality of the tribochemical coating in clinical orthodontic applications. Besides, one study reported that bond strength was not significantly increased with this method.[18] In contrast, since Assure is recommended to be used in slightly moist environments, the metal primer and Assure bonding resin combination seems to be an ideal and practical method for intraoral use[27] in orthodontics when bonding brackets onto the stainless steel crowns.

Given the results of this study, it may be concluded that neither surface preparation nor bonding agents alone would assure attainment of acceptable bond strength values. However, when used in the correct combination, clinically significant bond strength can be obtained as this was the case when aluminablasting + metal primer + Assure bonding resin were used in combination.

As mentioned earlier a 1-5% clinical failure rate is acceptable in clinical orthodontics.[13] In order to estimate how brackets would perform *in vivo*, Weibull survival analyses were used to evaluate the shear bond strength levels at which 5% of the brackets failed. According to Littlewood et al.[28], the bond strength should be at least 5MPa at a 5% failure rate. In this study, none of the groups met this requirement. Nevertheless, the results were promising as samples in the Aluminablasting + Metal Primer + Assure and Diamond Bur Abrasion + Metal Primer + Assure groups reached values (9.05 and 9.30MPa, respectively) above the suggested level of 6-8MPa. In addition, the majority of samples within the above mentioned groups failed at or near the 5 MPa range. The wide range of values within the groups may be due to normal variations in the manufacturing process of APC brackets, as well as errors introduced during the surface preparation and bonding.

In addition to failure rate, the mode of bond failure is also important to orthodontists. Bond failures can be either cohesive or adhesive in nature. A cohesive fracture occurs if a crack propagates in the bulk composite resin upon debonding. In this case, the surfaces of the tooth and the bracket base are covered by fractured adhesive. On the other hand, the fracture is considered adhesive when debonding occurs between the adhesive and the bracket base surfaces or the adhesive and the tooth surfaces. It has been suggested that an adhesive bond failure is desirable as the potential for enamel damage during adhesive removal is greatly reduced because a minimum amount of resin remains on the tooth/restoration surface after debonding.[11,29] However, it has also been proposed that cohesive failure within the bonding agent, or adhesive failure at the bracket/resin interface is ideal because this type of failure can prevent enamel fracture.[30] The experimental groups had mostly ARI scores of 1 indicating an adhesive failure at the bracket/resin interface. Although the increased amount of the adhesive left on the tooth surface would require additional resin removal time during debonding, the potential for damaging the substrate (stainless steel crown) is greatly reduced.

The current study compared combinations of various surface preparations and bonding agents *in vitro* and therefore may not mimic *in vivo* conditions. Also, it should be kept in mind that statistically significant differences in mean bond strength may not be significant in clinical conditions. Despite the ability of the Weibull analysis to offer clinical failure predictions based on *in vitro* data, it would be more accurate to conduct clinical studies to evaluate the actual *in vivo* behavior of these systems.

Conclusion

The purpose of this study was to alter surface preparation and bonding agent combinations to achieve an adequate bond of orthodontic brackets to stainless steel crowns. Based on the results, the most effective surface preparations were aluminablasting with aluminum oxide followed by surface roughening via diamond bur abrasion. When either of these surface preparations was used in combination with a metal primer and Assure bonding resin, the shear bond strength values approached the suggested level (6-8MPa) considered adequate for orthodontic bonding.[10] The results of the ARI scores indicated primarily adhesive failures within Groups 1-4. The adhesive nature of the bond failure suggests that the bond at the bracket and composite resin interface failed prior to the bond of the composite and stainless steel crown interface. This type of failure can be favorable for orthodontics as it minimizes the damage to the bonded surfaces (enamel or restoration). Despite the encouraging results obtained in this study, *in vivo* tests are necessary to determine the true clinical effectiveness of direct bonding to stainless steel crowns.

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Appendix (Raw Data)

Crown Sample	Surface treatment and bonding agent combination	Debond shear force (Mpa)	ARI score	Debond shear force(lbs)
A1	Aluminablasting + Metal Primer + Assure	9.05	3	21
A2	Aluminablasting + Metal Primer + Assure	8.02	1	18.6
A3	Aluminablasting + Metal Primer + Assure	2.50	2	5.8
A4	Aluminablasting + Metal Primer + Assure	5.95	1	13.8
A5	Aluminablasting + Metal Primer + Assure	4.65	1	10.8
A6	Aluminablasting + Metal Primer + Assure	4.48	1	10.4
A7	Aluminablasting + Metal Primer + Assure	6.81	1	15.8
A8	Aluminablasting + Metal Primer + Assure	4.91	1	11.4
A9	Aluminablasting + Metal Primer + Assure	5.08	2	11.8
A10	Aluminablasting + Metal Primer + Assure	6.89	1	16
A11	Aluminablasting + Metal Primer + Assure	6.38	1	14.8
A12	Aluminablasting + Metal Primer + Assure	6.12	2	14.2
A13	Aluminablasting + Metal Primer + Assure	4.57	1	10.6
A14	Aluminablasting + Metal Primer + Assure	7.07	1	16.4
A15	Aluminablasting + Metal Primer + Assure	8.79	1	20.4
A16	Aluminablasting + Metal Primer + Assure	8.45	2	19.6
A17	Aluminablasting + Metal Primer + Assure	2.41	1	5.6
A18	Aluminablasting + Metal Primer + Assure	6.55	1	15.2
A19	Aluminablasting + Metal Primer + Assure	4.83	1	11.2
A20	Aluminablasting + Metal Primer + Assure	7.84	1	18.2
B1	Aluminablasting+ Silane+ Transbond	2.15	1	5
B2	Aluminablasting+ Silane+ Transbond	2.67	3	6.2
B3	Aluminablasting+ Silane+ Transbond	3.53	1	8.2
B4	Aluminablasting+ Silane+ Transbond	3.79	1	8.8
B5	Aluminablasting+ Silane+ Transbond	5.17	1	12
B6	Aluminablasting+ Silane+ Transbond	3.62	1	8.4
B7	Aluminablasting+ Silane+ Transbond	3.62	3	8.4
B8	Aluminablasting+ Silane+ Transbond	1.38	1	3.2
B9	Aluminablasting+ Silane+ Transbond	2.07	3	4.8
B10	Aluminablasting+ Silane+ Transbond	3.53	1	8.2
B11	Aluminablasting+ Silane+ Transbond	2.59	3	6
B12	Aluminablasting+ Silane+ Transbond	4.05	1	9.4
B13	Aluminablasting+ Silane+ Transbond	2.59	3	6
B14	Aluminablasting+ Silane+ Transbond	3.79	3	8.8
B15	Aluminablasting+ Silane+ Transbond	6.98	1	16.2
B16	Aluminablasting+ Silane+ Transbond	1.64	1	3.8
B17	Aluminablasting+ Silane+ Transbond	4.22	1	9.8

B18	Aluminablasting+ Silane+ Transbond	2.84	1	6.6
B19	Aluminablasting+ Silane+ Transbond	3.19	1	7.4
B20	Aluminablasting+ Silane+ Transbond	5.43	1	12.6
C1	Diamond bur abrasion + Metal Primer + Assure	6.46	2	15
C2	Diamond bur abrasion + Metal Primer + Assure	8.62	1	20
C3	Diamond bur abrasion + Metal Primer + Assure	3.88	2	9
C4	Diamond bur abrasion + Metal Primer + Assure	7.33	3	17
C5	Diamond bur abrasion + Metal Primer + Assure	5.08	1	11.8
C6	Diamond bur abrasion + Metal Primer + Assure	2.93	1	6.8
C7	Diamond bur abrasion + Metal Primer + Assure	2.07	1	4.8
C8	Diamond bur abrasion + Metal Primer + Assure	8.53	1	19.8
C9	Diamond bur abrasion + Metal Primer + Assure	3.96	1	9.2
C10	Diamond bur abrasion + Metal Primer + Assure	3.88	3	9
C11	Diamond bur abrasion + Metal Primer + Assure	4.83	2	11.2
C12	Diamond bur abrasion + Metal Primer + Assure	5.60	1	13
C13	Diamond bur abrasion + Metal Primer + Assure	3.62	3	8.4
C14	Diamond bur abrasion + Metal Primer + Assure	5.60	1	13
C15	Diamond bur abrasion + Metal Primer + Assure	4.31	1	10
C16	Diamond bur abrasion + Metal Primer + Assure	9.31	3	21.6
C17	Diamond bur abrasion + Metal Primer + Assure	4.40	1	10.2
C18	Diamond bur abrasion + Metal Primer + Assure	3.96	1	9.2
C19	Diamond bur abrasion + Metal Primer + Assure	5.52	3	12.8
C20	Diamond bur abrasion + Metal Primer + Assure	5.60	1	13
D1	Diamond bur abrasion + Silane + Transbond	1.03	3	2.4
D2	Diamond bur abrasion + Silane + Transbond	2.03	4	4.7
D3	Diamond bur abrasion + Silane + Transbond	5.52	3	12.8
D4	Diamond bur abrasion + Silane + Transbond	1.29	5	3
D5	Diamond bur abrasion + Silane + Transbond	1.72	5	4
D6	Diamond bur abrasion + Silane + Transbond	1.47	3	3.4
D7	Diamond bur abrasion + Silane + Transbond	2.33	3	5.4
D8	Diamond bur abrasion + Silane + Transbond	4.14	4	9.6
D9	Diamond bur abrasion + Silane + Transbond	1.38	4	3.2
D10	Diamond bur abrasion + Silane + Transbond	4.31	2	10
D11	Diamond bur abrasion + Silane + Transbond	2.67	3	6.2
D12	Diamond bur abrasion + Silane + Transbond	2.76	2	6.4
D13	Diamond bur abrasion + Silane + Transbond	2.41	1	5.6
D14	Diamond bur abrasion + Silane + Transbond	6.03	1	14
D15	Diamond bur abrasion + Silane + Transbond	3.36	1	7.8
D16	Diamond bur abrasion + Silane + Transbond	2.59	4	6
D17	Diamond bur abrasion + Silane + Transbond	1.38	3	3.2
D18	Diamond bur abrasion + Silane + Transbond	2.50	3	5.8
D19	Diamond bur abrasion + Silane + Transbond	2.11	3	4.9

D20	Diamond bur abrasion + Silane + Transbond	2.84	3	6.6
E1	Acid etching + Metal Primer + Assure	1.03	3	2.4
E2	Acid etching + Metal Primer + Assure	0.78	4	1.8
E3	Acid etching + Metal Primer + Assure	0.52	4	1.2
E4	Acid etching + Metal Primer + Assure	0.52	5	1.2
E5	Acid etching + Metal Primer + Assure	1.12	4	2.6
E6	Acid etching + Metal Primer + Assure	0.26	5	0.6
E7	Acid etching + Metal Primer + Assure	2.15	3	5
E8	Acid etching + Metal Primer + Assure	0.34	5	0.8
E9	Acid etching + Metal Primer + Assure	1.47	4	3.4
E10	Acid etching + Metal Primer + Assure	0.78	3	1.8
E11	Acid etching + Metal Primer + Assure	2.15	3	5
E12	Acid etching + Metal Primer + Assure	1.55	3	3.6
E13	Acid etching + Metal Primer + Assure	0.65	4	1.5
E14	Acid etching + Metal Primer + Assure	0.43	4	1
E15	Acid etching + Metal Primer + Assure	0.34	5	0.8
E16	Acid etching + Metal Primer + Assure	0.43	5	1
E17	Acid etching + Metal Primer + Assure	0.69	4	1.6
E18	Acid etching + Metal Primer + Assure	1.03	2	2.4
E19	Acid etching + Metal Primer + Assure	0.69	4	1.6
E20	Acid etching + Metal Primer + Assure	1.29	3	3
F1	Acid etching + Silane + Transbond	0.34	5	0.8
F2	Acid etching + Silane + Transbond	0.78	1	1.8
F3	Acid etching + Silane + Transbond	0.39	5	0.9
F4	Acid etching + Silane + Transbond	0.43	5	1
F5	Acid etching + Silane + Transbond	0.17	5	0.4
F6	Acid etching + Silane + Transbond	0.34	4	0.8
F7	Acid etching + Silane + Transbond	0.78	3	1.8
F8	Acid etching + Silane + Transbond	0.26	5	0.6
F9	Acid etching + Silane + Transbond	0.22	4	0.5
F10	Acid etching + Silane + Transbond	0.52	3	1.2
F11	Acid etching + Silane + Transbond	0.22	4	0.5
F12	Acid etching + Silane + Transbond	0.52	4	1.2
F13	Acid etching + Silane + Transbond	0.30	5	0.7
F14	Acid etching + Silane + Transbond	0.56	5	1.3
F15	Acid etching + Silane + Transbond	0.43	3	1
F16	Acid etching + Silane + Transbond	0.82	3	1.9
F17	Acid etching + Silane + Transbond	0.34	5	0.8
F18	Acid etching + Silane + Transbond	0.86	4	2
F19	Acid etching + Silane + Transbond	0.43	5	1
F20	Acid etching + Silane + Transbond	1.03	3	2.4

Vita

Daniel Stewart was born in Naples, Florida on December 25th 1980. He graduated as the valedictorian of Estero High School in 1999. From there he proceeded to The University of Florida where he received both his B.S. in Nutrition and D.M.D. He graduated cum laude with his B.S. and in the top 10% of his dental class. He is currently a postgraduate resident in the Orthodontics program at Virginia Commonwealth University and will receive a certificate in Orthodontics along with a Master of Science degree in Dentistry.