Orthodontic Bond Strength Comparison Between Two Filled Resin Sealants

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ORTHODONTIC BOND STRENGTH COMPARISON BETWEEN TWO FILLED RESIN SEALANTS

by

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A Thesis submitted to the Faculty of the Graduate School,
Marquette University,
in Partial Fulfillment of the Requirements for
the Degree of Master of Science

Milwaukee, Wisconsin

August 2018

ABSTRACT

ORTHODONTIC BOND STRENGTH COMPARISON BETWEEN TWO FILLED RESIN SEALANTS

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Marquette University, 2018

Introduction: Sealants are used in orthodontics to help prevent demineralization during treatment. The objective of this study was to determine if there is a difference in the shear bond strength (SBS) between two different resin sealants bonded to teeth.

Materials and Methods: Extracted human premolars (n=20/group) were randomly divided and prepared by acid etching, followed by application of primer or sealant. Group 1, the control group, used Transbond XT Primer (3M Unitek). Groups 2 and 3 were prepared with the sealants L.E.D. Pro Seal (Reliance Orthodontic Products) and Opal Seal (Opal Orthodontics) respectively. Transbond XT Adhesive was applied to a stainless steel bracket and bonded to each tooth. Each group was stored in distilled water at 37°C for 48 hours prior to debonding. Shear bond strength (SBS) was measured via a universal testing machine, and the Adhesive Remnant Index (ARI) was scored.

Results: The SBS (MPa) of the groups were as follows: Group 1 (Transbond): 20.1 ± 6.0; Group 2 (Pro Seal): 16.5 ± 4.8; and Group 3 (Opal Seal): 15.7 ± 3.9. The SBS with Transbond XT Primer was significantly greater than Opal Seal ($P < 0.05$/ANOVA-Tukey), while Pro Seal and Opal Seal sealants were not significantly different from each other ($P > 0.05$). The Opal Seal group had significantly greater ARI scores, indicating more adhesive remained on the teeth after debonding.

Conclusion: Opal Seal and Pro Seal sealants have similar SBS but generally exhibit lower bond strengths compared to the use of an adhesive primer.

ACKNOWLEDGMENTS

James Kolstad, D.D.S.

I would like to thank my thesis director Dr. David Berzins for all his guidance, encouragement, and support throughout this process.

I would like to thank Dr. Ostertag for helping me to formulate this idea for a thesis project and for being a part of the whole process.   I would also like to thank my thesis committee- Drs. B. Ahuja, D. Liu, and G. Nimeri.

Lastly, I would like to thank my parents and fiancé, Cecilia Kolstad, Lon Kolstad, and Anna Kirchner for all of their love, support, and guidance!

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CHAPTER 1
INTRODUCTION

A common problem in orthodontic treatment is the formation of white spot lesions or enamel decalcification on the tooth. The prevalence of white spot lesions in orthodontic patients has been shown to be from 34% to up to 97%, whereas the incidence of such lesions during orthodontic therapy has been shown to be 23% to 76%.[1] White spot lesions are considered to be unhealthy, irreversible, and unesthetic.[2-4] Patients, parents, orthodontists and dentists agree that white spot lesions detract from the overall appearance of the orthodontic patient and that the patient is primarily responsible for the prevention of these lesions.[4] Nevertheless, white spot lesions are easily detectable and can be arrested by preventative treatment[5], or even prevented altogether.

Over the years, orthodontists have tried many different ways to prevent enamel demineralization in their patients.[2,3,5-11] Prevention methods have included oral hygiene instruction, fluoride mouth rinses, application of fluoride varnishes, and sealants. Other than fluoride varnish and sealants, all of the preventative methods require patient compliance during treatment.[2] It has been shown that a relationship may exist between patient compliance and the formation of white spot lesions.[4,5,11] One way to combat the need for patient compliance and reduce decalcification is the application of a sealant on the facial aspect of the tooth prior to bonding the bracket.[3,9] Opal Seal (Opal Orthodontics, South Jordan, UT) and L.E.D. Pro Seal (Reliance Orthodontic Products, Itasca, IL) are two different brands of orthodontic sealants.

Pro Seal is described by the manufacturer as a fluoride-containing, light-cured filled sealant that completely sets without an oxygen-inhibited layer, creating a smooth, hard surface that prevents leakage and protects enamel.[12] Opal Seal is 38% filled with proprietary glass ionomers and nano fillers, and is also light-curable and contains fluoride.[13] Both sealants contain a fluorescing agent that can be illuminated by a black light to determine if the sealant is still present on the tooth surface.[12,13] Recent independent in vitro studies have evaluated Pro Seal and Opal Seal sealants for their surface, mechanical, and esthetic properties.[3,7,10] Results from these studies have shown that each sealant may have advantages over the other. Opal Seal was found to be significantly harder, allowed less *S. mutans* adherence, and had better color stability.[7,10] On the other hand, Pro Seal was found to be more wear-resistant and released significantly greater amounts of fluoride.[7,10] In terms of efficacy, Pro Seal and Opal Seal sealants both provide reductions in enamel demineralization when compared to untreated controls.[3,6,14]

Understanding the different properties of each product along with their bond strength can play an important role in deciding which product to use clinically. While some of the physical and esthetic properties of each sealant have been compared to each other, their orthodontic bond strengths have not been compared. Research has been conducted to investigate the bond strength of Pro Seal sealant bonded with different adhesives.[5,9,15-18] For example, Lowder et al.[9] found that Pro Seal sealant produced clinically acceptable bond strengths when coupled with four different adhesives, but its bond strength was lower than two regular primer/adhesive systems. Comparatively, the bond strength of Opal Seal sealant has not been investigated as thoroughly.[19] The objective of this study was to compare the shear bond strength (SBS) between two different resin sealants when used to bond orthodontic brackets to teeth.

CHAPTER 2
LITERATURE REVIEW

Demineralization and White Spot Lesions

A common problem in orthodontic treatment is the formation of white spot lesions or enamel decalcification on the tooth. Mineral loss and an opacity in enamel help to characterize white spot lesions from healthy enamel.[4] White spot lesions are considered to be unhealthy, irreversible, as well as unesthetic.[5] A negative effect on the oral health and the esthetics of teeth are caused by demineralization of the enamel adjacent to orthodontic brackets.[6] Patients with poor oral hygiene often have the formation of white spot lesions.[7] The potential for demineralization with orthodontic appliances increases in patients with poor oral hygiene.[8] The formation of white spot lesions can occur within a time period of 4 weeks.[7] Patients, parents, orthodontist and dentists all agreed in a study that white spot lesions detracted from the overall appearance of the orthodontic patient and that the patient was primarily responsible for the prevention of the white spot lesions.[7] White spot lesions are easily detectable and arrested by preventative treatment.[8] Patients who have orthodontic treatment are at a higher risk than patients who do not have any treatment.[11] The prevalence of white spot lesions in orthodontic patients has been shown to be from 34% up to 97%[1]. The incidence during orthodontic therapy has been shown to be 23% to 76%.[1]

Prevention Methods

Over the years, Orthodontists have tried many different ways to prevent enamel demineralization in their patients. These methods include fluoride mouth rinses, oral hygiene instruction, fluoride varnishes and sealants.[9] Sealants are a good preventative method against white spot lesions on smooth surfaces especially in high caries risk patients.[8] A study by Premaraj et al. stated that the best preventative method against white spot lesions is by the application of fluoride on the enamel surfaces of teeth through multiple visits.[10] Reduction in the incidence of white spot lesions can be achieved by the use of fluoride varnishes during orthodontic treatment.[4] Fluoride varnish and an orthodontic sealant have been shown to prevent enamel demineralization during orthodontic therapy.[4] A relationship between a compliant patient who follows good oral hygiene protocols and white spot lesions exists.[11] With patient compliance fluoride regimens have been shown to be effective in preventing white spot lesions.[5] All of the preventative methods except for sealants require patient compliance during treatment.[5] One way to combat the need for patient compliance and a reduction of decalcification is the application of a sealant on the facial aspect of the tooth before bonding the bracket.[6] Without patient compliance orthodontic sealants have a promising effect on the prevention of white spot lesions during orthodontic therapy.[6]

Orthodontic Sealants

Eliminating bacterial adherence to enamel, prevention of acid penetration, and their fluoride releasing capabilities are important factors when choosing a sealant.[10] Opal Seal and LED Pro Seal are two different types of Orthodontic Sealants. Pro Seal is a fluoride containing light cured filled sealant.[12] Pro Seal will completely set without an oxygen inhibited layer. This creates a smooth hard surface that prevents leakage and protects enamel.[12] Opal Seal is a 38% filled with proprietary glass ionomers and nano fillers that is light cured and will release fluoride.[13] Both sealants contain a fluorescing agent that can be illuminated by a black light to determine if the sealant is still present on the tooth surface.[12,13] Recent in vitro studies have evaluated Pro Seal and Opal seal for their surface properties, mechanical properties and esthetic properties. Opal Seal when compared to Pro Seal has been shown to be significantly harder, show less adherence to S. mutans, and had better color stability.[3,10] Pro Seal when compared to Opal Seal was shown to be more wear resistant, and releases significantly higher amounts of fluoride.[3,10] Bishara showed that the orthodontic sealant, Pro Seal, when compared to a regular sealant was shown to have similar bond strengths.[8] Pro Seal demonstrated adequate bond strength.[15] Pro Seal sealant showed reliable shear bond strength values.[18] Pro Seal sealant when used with non self etch primer adhesive systems showed no statistical negative influence on the shear peel bond strength.[16] Opal Seal when compared against other primer systems showed to have a similar bond strength.[19] Bond strength studies with Opal Seal have not been investigated as thoroughly as some of the other systems.[19]

Bond Studies

In order to be able to compare new materials in orthodontic bonding studies, Fox et al. proposed a set of protocols to help standardize each study.[33] A list of the protocols from the Fox et al. study include; using premolars from patients who had their premolars extracted for orthodontic reasons. Extracted teeth should be stored in distilled water. Specimens should be stored at 37 degrees Celsius for 24 hours after bonding. Debonding of brackets should take place on an Instron machine with a crosshead speed of 0.1 mm per minute. The site of bond failure should be reported in each study. A statistical analysis should be done and related to clinical application along with measuring bond strengths in either Newtons or MegaPascals.[33] A study by Lowder et al. when comparing the use of an orthodontic sealant with adhesive systems vs not using an orthodontic sealant have been shown to have slightly lower bond strength.[9] Shear bond strengths in the range of 6-8 MPa are required for bonding to enamel.[34] Transbond XT Primer (3M Unitek, Monrovia, Calif) and Transbond XT Light Cure Adhesive (3M Unitek) with a conventional acid etch technique is considered the gold standard for bonding brackets to enamel.[21] A previous study showed that Transbond had a decrease in bond strength after being stored in water between four and eight weeks.[23] The shear bond strength was decreased significantly by thermocycling.[25] The shear bond strength was also shown to decrease when specimens were being stored in water for longer periods of time.[24] Another possible effect on reported bond strengths comes from the cross head speed of the Instron. It is shown that reducing the crosshead speed can increase the bond strength results.[26] A study by Klocke et al. however showed that a cross head speed difference between 0.1 mm and 5 mm per min did not seem to have an effect on force measurements or mode of failure.[27] Another study by Shooter et al. had a similar result showing no significant difference in shear bond strength when using different cross head speeds.[28] Another aspect of the bond study protocols was to look at the site of failure. The ARI is known as one of the most commonly used methods to determine the quality of the adhesion at the bracket adhesive interface and at the tooth adhesive interface.[29] Orthodontic literature has a number of different factors that influence bond strength and ARI. A recent study found that precoated brackets had lower ARI scores than conventional brackets.[30] Failures at the bracket adhesive interface may also likely be caused by the incomplete polymerization of the adhesive, possibly due to lack of light cure behind the bracket.[29] One of the factors that influence in vitro bond strengths is photo curing time of the adhesive.[31] In addition to storage, cross head speed, and storage other factors have been notated as possible effects on bond strengths.[23, 31, 32]

CHAPTER 3
MATERIALS AND METHODS

Sixty extracted human premolar teeth were collected and stored in distilled water. If any large restorations, enamel defects, or any abnormal flaws were found upon examination, the tooth was excluded. The roots were removed from each tooth with a high-speed hand piece and diamond bur. The cut was made about six millimeters below the cementoenamel junction. Each crown was then placed back into a container of distilled water.

The teeth were randomly divided into three groups (n=20/group). Group 1 was bonded with Transbond XT Primer (Figure 1; 3M Unitek, Monrovia, Calif) and Transbond XT Light Cure Adhesive (Figure 2; 3M Unitek). Group 2 was bonded with L.E.D. Pro Seal sealant (Figure 3) and Transbond XT Light Cure Adhesive. Group 3 was bonded with Opal Seal sealant (Figure 4) and Transbond XT Light Cure Adhesive. Stainless steel brackets (universal upper bicuspid, Victory Series, 3M Unitek) with zero torque and tip were used. The surface area of the bracket base was 10 mm^2.

Figure 1. Transbond XT Light Cure Adhesive Primer

Figure 2. Transbond XT Light Cure Orthodontic Adhesive

Figure 3. Opal Seal Orthodontic Sealant

Figure 4. L.E.D. Pro Seal Orthodontic Sealant

Prior to the bonding procedure, each tooth was cleaned with a rubber prophy cup on a slow speed hand piece with pumice paste (nada, Preventive Technologies, Inc., Indian Trail, NC) for five seconds and then rinsed with water. The tooth was then etched using 35% phosphoric acid etching gel (3M Unitek) for 30 seconds, thoroughly rinsed, and dried until the etched buccal surface appeared frosty white. For each group, the primer or sealant was applied to the buccal surface of the tooth following manufacturer instructions. Transbond XT Adhesive was then applied to the bracket base. The bracket was placed in the proper position on the tooth and was pressed firmly to seat the bracket. The excessive resin was removed, and the adhesive was light-cured (Ortholux Luminous

Curing Light, 3M Unitek) for 10 seconds on both the mesial and distal aspects of the bracket. One person prepared all of the teeth (Figure 5). The tooth with the bonded bracket was then placed back into the appropriate container of distilled water and stored at 37^{o}C for 24 hours.

After storage, the teeth were individually mounted in cold-cure acrylic (Great Lakes Orthodontics, Tonawanda, NY). Each tooth was attached to a 0.018 inch stainless steel wire using an elastomeric module and suspended over a small section of PVC pipe (Figure 6). The acrylic was mixed and poured into the pipe to the level of the cusp tip of the suspended tooth, assuring each tooth was mounted in the acrylic in a repeatable way (Figure 7). After the acrylic set, each bonded and mounted tooth was placed back into distilled water and stored at 37^{o}C for 24 hours (Figures 8 & 9).

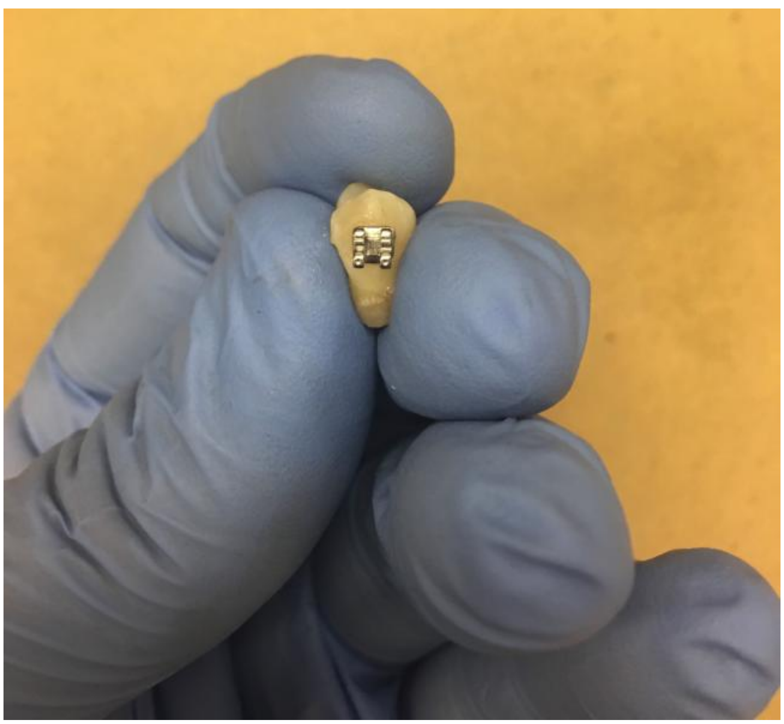

Figure 5. Extracted tooth after being prepared and bracket bonded to enamel

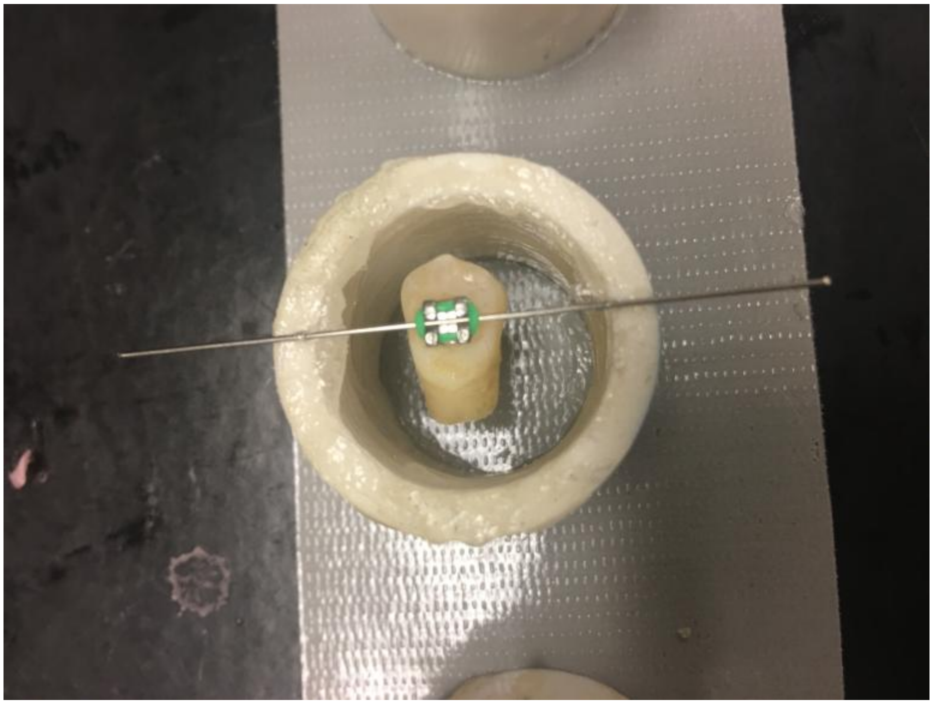

Figure 6. Bonded tooth with 0.018 inch stainless steel wire attached using an elastomeric module and suspended over a small section of PVC pipe attached being prepared to be mounted in cold-cure acrylic

Figure 7. Three bonded teeth in cold-cure acrylic as the acrylic set up

Figure 8. Each bonded and mounted tooth was placed back into distilled water

Figure 9. Each set up separated by primer/sealant being stored at 37°C for 24 hours

A universal testing machine (Instron, Norwood, Mass) was used to measure the shear bond strength of each bracket/tooth specimen. Each mounted tooth was secured in a fixture that allowed a blade attached to the machine crosshead to contact the bracket between its base and gingival tie wings (Figure 10). A shear force at a crosshead speed of 0.5 mm/min was used to debond each bracket (Figure 11). The force was measured in Newtons and converted to MPa by dividing by the bracket base area.

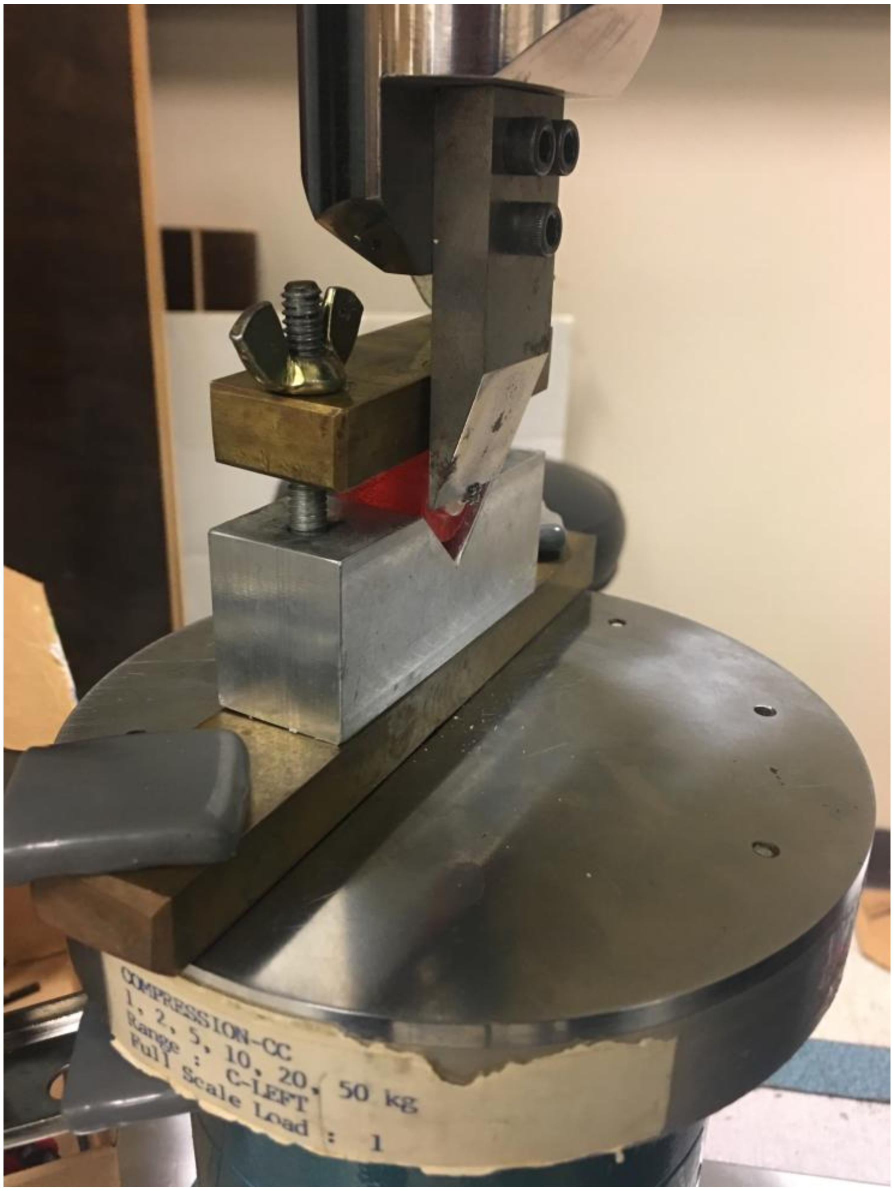

Figure 10. Each tooth secured in the universal testing machine to test the shear bond strength

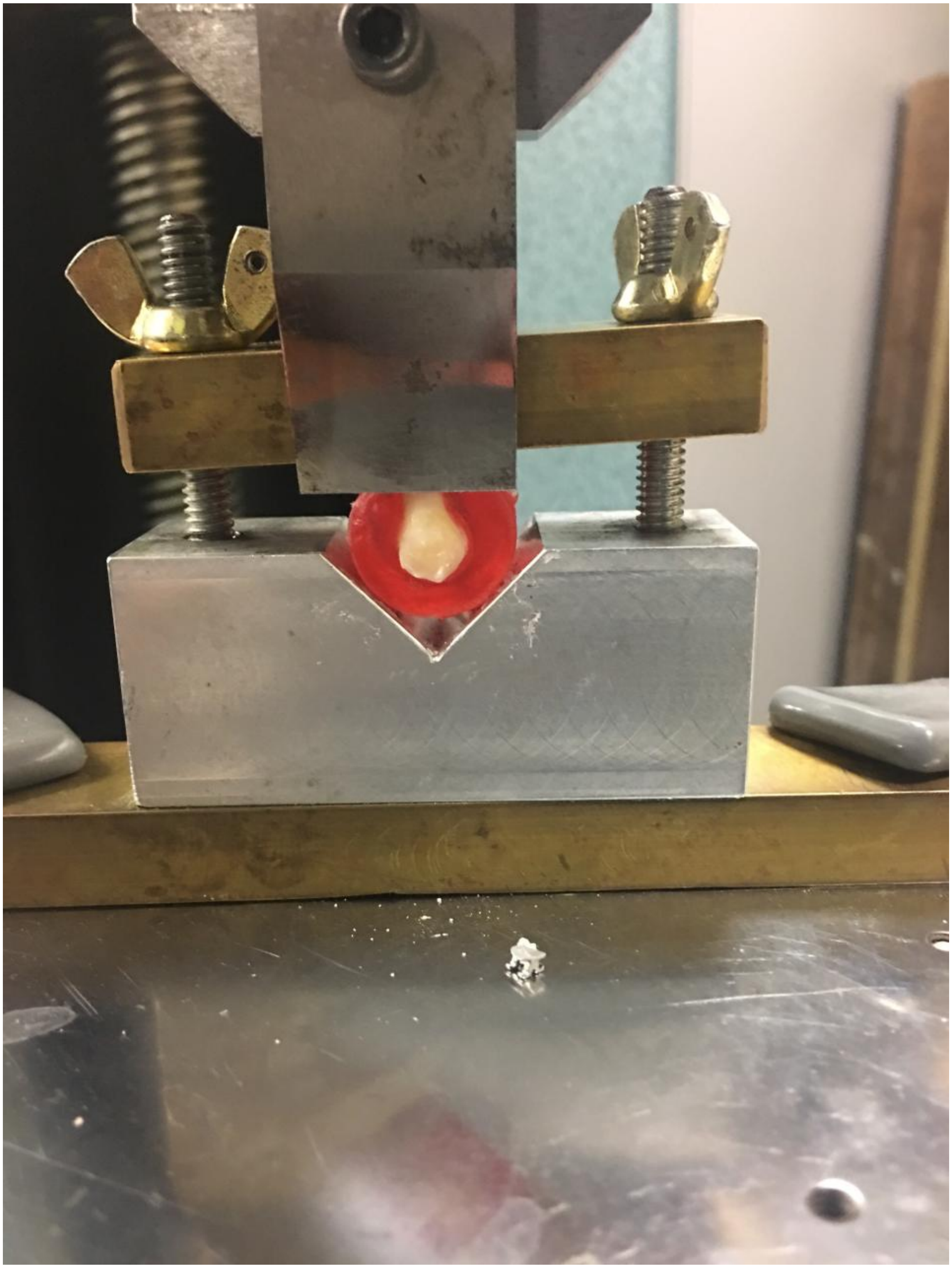

Figure 11. Bracket debonded via the Universal Testing Machine

After each bracket was debonded, the enamel surface and bracket were examined using an optical microscope and scored using the Adhesive Remnant Index (Figures 12, 13, & 14; ARI).[20] The ARI score represents the amount of adhesive remaining on the enamel after debonding the bracket. There are four possible ARI scores: 0 = no adhesive left on the tooth, 1 = less than fifty percent of the adhesive left on the tooth, 2 = more than fifty percent of the adhesive left on the tooth, and 3 = all of the adhesive left on the tooth.

SBS was analyzed using one-way analysis of variance (ANOVA) and a post-hoc Tukey HSD test at a $P \leq .05$ level of significance. ARI data were compared by Kruskal-Wallis and Mann-Whitney U tests via statistical software (IBM SPSS Statistics 23, IBM Corp., Armonk, NY).

Figure 12. Microscope used to measure the ARI

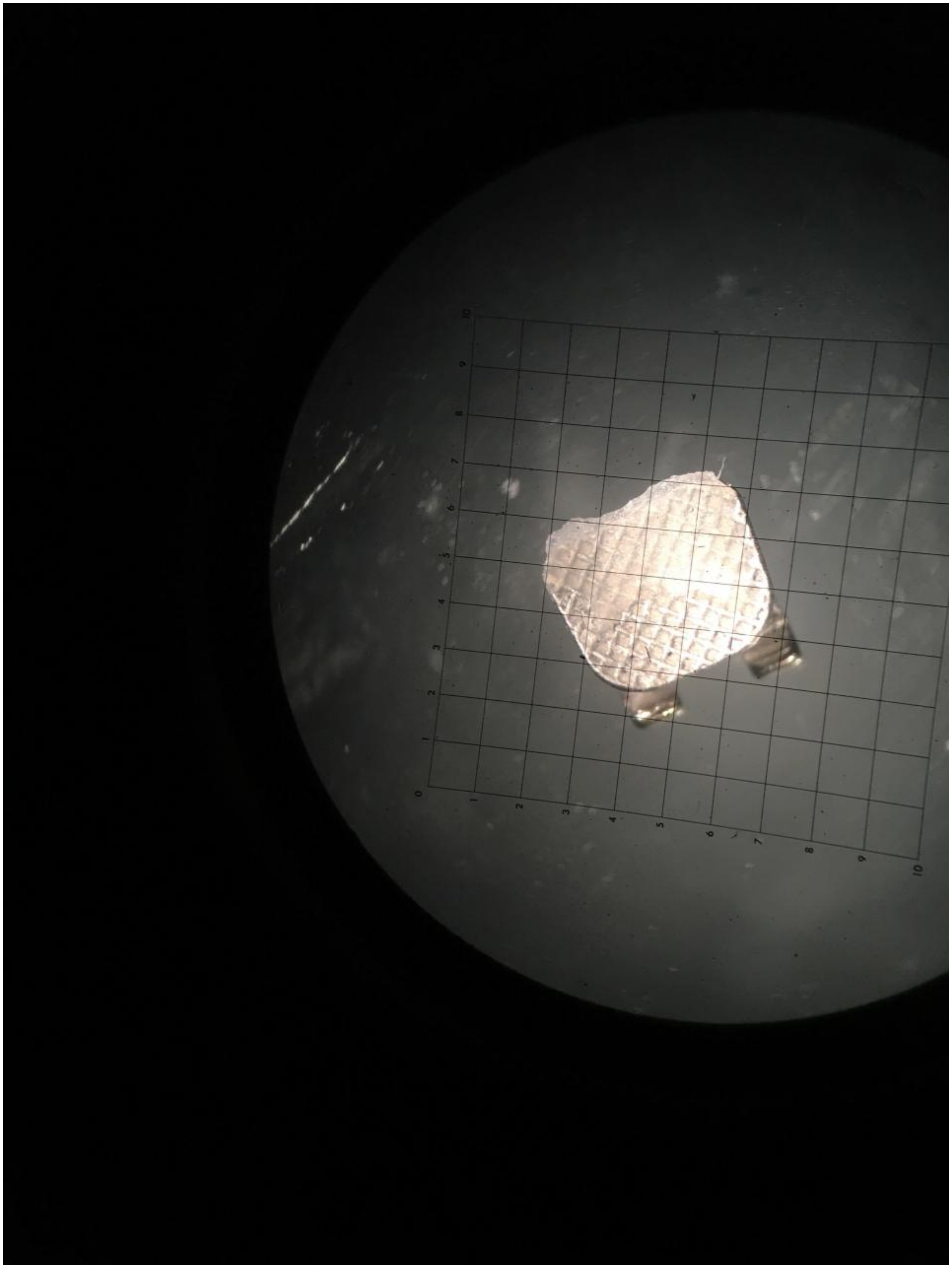

Figure 13. View of bracket in the microscope when used to determine the ARI

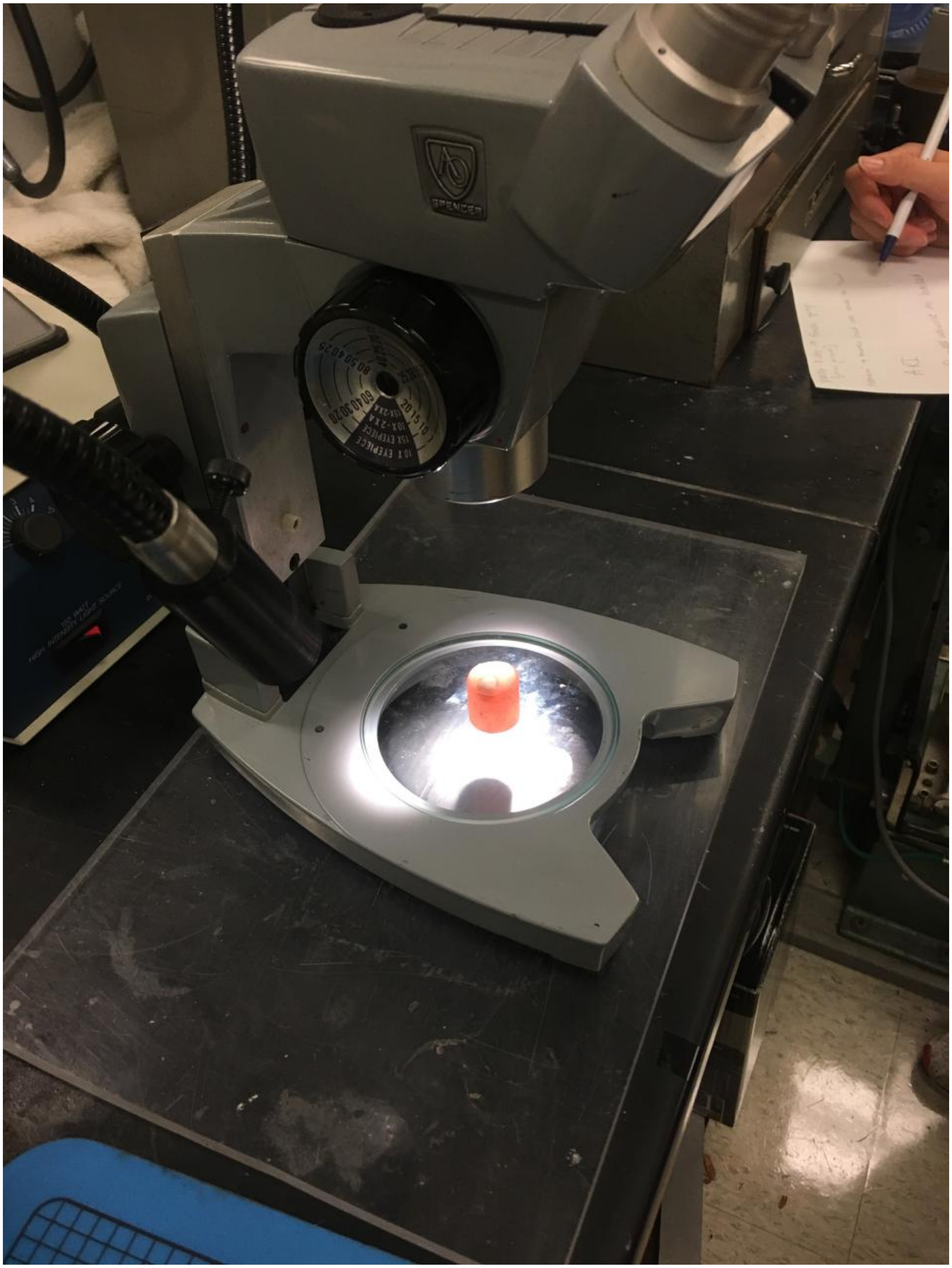

Figure 14. View of debonded tooth when determining ARI

CHAPTER 4
RESULTS

The shear bond strength (MPa) of the groups are listed in Table 1. The SBS when using Transbond XT Primer was significantly greater than Opal Seal sealant ($P < 0.05$), but Pro Seal and Opal Seal sealants were not significantly different from each other ($P > 0.05$). Weibull analysis also indicated the Transbond XT Primer group displayed greater bond strengths. However, Opal Seal possessed the greatest Weibull modulus, indicating a slightly greater reliability between the groups as it had less broadly distributed bond strength values. This is further reflected in the lower standard deviation for the Opal Seal group. Figure 15 displays Weibull curves plotting "Probability of Failure" versus "Shear Bond Strength" that are consistent with Table 1. In terms of bond failure site, the Opal Seal group had significantly greater ARI scores ($P = 0.001$; Table 2), indicating more adhesive remained on the teeth after debonding.

Table 1. Shear Bond Strength and Weibull Analysis

Group	Mean ± Standard Deviation (MPa)*	Weibull modulus (β)	Characteristic Strength (α; MPa)	Shear Bond Strength (MPa) at 10% Probability of Failure	Shear Bond Strength (MPa) at 90% Probability of Failure
1-Transbond	20.1 ± 6.0	3.4	22.2	11.4	28.4
2-Pro Seal	16.5 ± 4.8	3.3	18.3	9.2	23.7
3-Opal Seal	15.7 ± 3.9	4.0	17.2	9.9	21.2

* Via ANOVA and a post hoc Tukey HSD test, Group 1 was significantly greater ($P < 0.05$) from Group 3, but Groups 2 and 3 were not significantly different ($P > 0.05$) from each other.

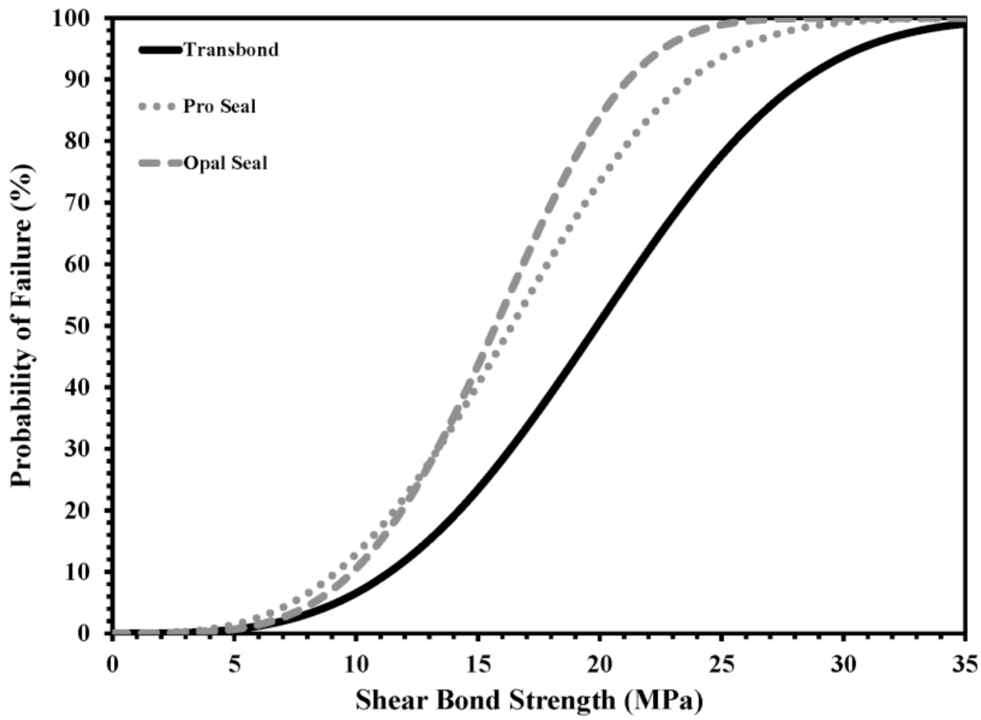

Figure 15. Weibull curves plotting "Probability of Failure" vs "Shear Bond Strength"

Table 2. Adhesive Remnant Index (ARI) Scores by Group

Group	**ARI Scores***			
	0	**1**	**2**	**3**
1-Transbond	0	10	10	0
2-Pro Seal	0	9	11	0
3-Opal Seal	0	0	20	0

*There was no significant difference ($P > 0.05$) between Groups 1 and 2, however Group 3 was significantly different ($P = 0.001$) from Groups 1 and 2.

CHAPTER 5
DISCUSSION

The purpose of this study was to determine if there was a difference in SBS between Pro Seal and Opal Seal sealants. Previous studies have shown that Pro Seal sealant exhibited clinically acceptable bond strength and compared the different properties of Pro Seal and Opal Seal sealants.[3,7,9,10] The literature has shown there is an added benefit to using a sealant in the protection against the formation of white spot lesions in non-compliant patients; however, there has not been a study that has compared the bond strength of Opal Seal sealant to Pro Seal sealant.

Results showed that the two orthodontic sealants performed similarly with respect to SBS, although the adhesive primer (control) group had a statistically greater SBS than Opal Seal sealant. Transbond XT Adhesive with Transbond XT Primer has been regarded as the gold standard when bonding to enamel.[21] Nevertheless, both Pro Seal and Opal Seal sealants had shear bond strengths over 15 MPa, which is considered clinically acceptable.[22] Comparatively, the force levels for debonding brackets in the current study using Transbond XT Primer and Pro Seal sealant were slightly higher than the force levels reported by Lowder et al.[9] In the Lowder et al. study, specimens were stored for 30 days and thermocycled, both of which are factors that have been shown to decrease bond strength.[23-25] Furthermore, the crosshead speed was slower in the current study, although the effect of crosshead speed on orthodontic bond strength has been inconsistent.[26-28]

The ARI is one of the most commonly used methods to determine the quality of the adhesion at the bracket/adhesive and tooth/adhesive interfaces.[29] The ARI results for the Transbond XT Primer and Pro Seal sealant groups were quite evenly split between

ARI 1 and 2 scores, whereas Opal Seal sealant had a significantly greater ARI score, indicating more adhesive consistently remained on the teeth after debonding. Although the exact composition and concentration of all monomers in the products are proprietary, the Safety Data Sheets list Opal Seal sealant and Transbond XT Adhesive as containing BIS-GMA, whereas Pro Seal sealant does not. Opal Seal sealant and Transbond XT Adhesive may have better compatibility, thereby forming a stronger bond and shifting the weak link onto the bracket/adhesive interface compared to the other two groups. More research is needed to confirm this and to investigate other factors. While more adhesive left on the tooth may lower the risk of enamel fracture, it would also increase clean-up time by the orthodontist. This study used standard stainless steel brackets that required the application of adhesive to the bracket base; use of a different bracket system may alter the adhesive failure site. For instance, a recent study found that precoated brackets had lower ARI scores than conventional brackets.[30] This can be attributed to the fact that precoated brackets have a premeasured uniform layer of adhesive. Alternatively, the lower ARI scores may also be the result of the more uniform pressure that is applied in placing the adhesive on the bracket mesh during manufacturing, allowing for better penetration of the mesh.[30] Failures at the bracket/adhesive interface may also be caused by the incomplete polymerization of the adhesive due to lack of light-curing behind the bracket.[29]

Orthodontic literature outlines different factors that influence bond strength and ARI.[23,31] Those factors include operator technique, patient behavior, enamel variations, specimen storage time, enamel conditioning procedures, type of adhesive, and bracket base area/design.[23,31,32] In this study, all of the materials and processes were the same except for the primer/sealants being compared. Protocols from Fox et al.[33] were used to help with standardization of the study. Still, as this was an in vitro study, there are limitations to translating the current research to clinical practice. A clinical comparison of the two sealants is necessary to properly ascertain their demineralization efficacy and bonding durability.

CHAPTER 6
CONCLUSION

Opal Seal and Pro Seal sealants have similar shear bond strengths, but generally exhibit lower bond strengths compared to Transbond XT Primer. Additionally, Opal Seal sealant leaves more adhesive on the tooth when debonding occurs, which could lead to an increase in debond appointment time.

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