Comparison of Bracket Failure Using a Hydrophilic and Hydrophobic Primer

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Introduction: The most common problem during fixed orthodontic treatment is bond failure, caused by either excessive forces or poor bond preparation. Hydrophilic primers were introduced to decrease bond failures due to moisture contamination by allowing the ability to bond on both wet and dry enamel. The main objective of this study is to investigate whether using a hydrophobic or hydrophilic primer will affect bracket failure rates. **Methods**: Patients who met the inclusion and exclusion criteria were recruited from University of Pittsburgh School of Dental Medicine Department of Orthodontics. Participants were sequentially assigned an alternating contralateral bonding pattern and their teeth were prepared using both hydrophobic (Transbond XT primer) and hydrophilic (Assure Plus) primers. Patient chart reviews were completed six months post-bonding for bracket failures. **Results**: Overall, there were no statistically significant bracket failure rate differences between Transbond XT and Assure Plus. In addition, there were no differences when comparing failure rates between the maxillary and mandibular arches. However, Assure Plus showed a statistically significant difference when comparing bracket failure rates in the anterior (4.44%) and posterior (1.67%) segments. **Conclusions**: After six months, Transbond XT had a failure rate of 4.67% and Assure Plus had a failure rate of 2.67%. There was a significantly higher anterior failure rate for Assure Plus compared to the posterior, 4.44% and 1.67% respectively. Overall, Assure Plus is a comparative

alternative to conventional hydrophobic primers. A longer evaluation period of 9 – 12 months should be considered in future research.

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Preface

My last seven years, completing both my DMD and Orthodontic residency, at the University of Pittsburgh School of Dental Medicine has been an absolute pleasure. And this final chapter will be bittersweet. I want to acknowledge and thank everyone in my thesis committee and the Orthodontics Department for their encouragement and limitless patience. Without them, my MDS research would not have been completed, much less even possible.

I am forever grateful to my parents, and my favorite brother for their unconditional love and support. To my fiancé, just a 'thank you' will never be enough for your encouragement throughout the insanity that is dental school and residency.

Lastly, in the great words of Snoop Dogg, "I want to thank me for believing in me, I want to thank me for doing all the hard work… I want to thank me for never quitting."

1.0 Introduction and Statement of the Problem

Prior to the introduction of acid-etch and bonding techniques, orthodontic brackets had no way of staying attached onto enamel. In the 1900s, Edward Angle, the "father of American orthodontics," used wires, tubes and brackets welded onto gold or stainless-steel bands to straighten teeth. Fitting these banded appliances was time-consuming, and often traumatized the gingiva when inserted [1]. Every tooth had to be separated before the band fitting and cementation. In 1955, the development of the acid-etch technique by Buonocore revolutionized the field of orthodontics [2]. With the introduction of composites and bonding materials, orthodontic brackets could be placed directly onto the tooth enamel. This process was quickly adopted because of its convenience, increased esthetics, reduction in chairside time, and decreased gingival irritation.

Contemporary traditional orthodontics follow a bonding protocol typically utilizing three products: (1) acid-etch, (2) primer and (3) composite resin. To prepare the enamel for bonding, an acid is placed to etch and create micro-porosities directly in the enamel. After rinsing off the acid and drying the enamel, a primer is rubbed onto the prepared enamel to create resin tags within the enamel rods. Resin tags act as micro-mechanical retention areas for the primed enamel to bond with the composite on the bracket. A dry working environment is ideal for bonding traditional composite to enamel because any source of moisture from within the oral cavity, such as saliva or blood, will deposit organic particles into the micro-porosities created by the etch [3]. Once contamination occurs, the bond integrity between the enamel and the bracket is compromised. However, if any exposure was washed with water within 1 minute of

contamination, then re-etching may not be required [4]. The best clinical practice would be to re-etch if contamination was suspected. Bonding to a compromised enamel surface will decrease bond strength, which will ultimately lead to bracket failure.

The most common problem during fixed orthodontic treatment is bond failure. The terms bracket failure, broken bracket, or loose bracket are all often synonymous with bond failure. Clinically, they all refer to a bracket that is off the tooth. Bond failures are often caused by excessive forces, poor bonding strength due to tooth anomalies, bonding materials, bonding protocols, and moisture contamination [5]. Maintaining a dry field in the oral cavity is often difficult, especially when attempting to bond adjacent to the gingiva or hard to reach second molars. To reduce bond failures caused by moisture contamination, hydrophilic bonding resins were introduced in 1998 that marketed the ability to bond on both wet and dry enamel [1]. The terms hydrophilic primers and moisture-insensitive are often used interchangeably. A primer containing hydrophilic monomers should negate the negative effects of moisture contamination and allow for adequate bonding strength between the bracket and the enamel surface. The benefits of using a hydrophilic primer are expected to be clinically advantageous compared to using a traditional hydrophobic primer. And bond failure rates caused by moisture contamination should be lowered by using a hydrophilic primer.

The main objective of this study is to investigate whether using a hydrophobic or hydrophilic primer will affect bond failure rates. If there is a difference in bond failure rates when using different primers, then using the appropriate primer may decrease the number of “emergency” orthodontic visits from bracket failures. Orthodontic practices run on efficiency

and a tight schedule due to a large patient volume; rebonding a bracket takes time away from both the patient and doctor. However, if brackets are left off the teeth, treatment time is extended.

2.0 Specific Aims

Aim 1. Examine bond failure rate differences between hydrophobic (Transbond XT primer) and hydrophilic (Assure Plus) primers.

Aim 2. Determine if there are bond failure patterns with either primer.

Aim 3. Assess clinical implications of bond failure rates.

3.0 Background and Literature Review

3.1 Bracket failure rate and pattern

Previous literature showed that there was a higher bracket failure rate in the mandibular arch compared to the maxillary arch. and also the posterior compared to the anterior region [6]. These observations could be attributed to greater difficulty maintaining moisture control in the mandibular arch and occlusal forces during mastication. However, other studies have shown contradictory results sharing no difference in bracket failure rates between maxillary and mandibular arches [7]. These findings indicate that occlusal forces may not be a factor for bond failure, and bracket failure was related to other variables.

The brackets in the posterior region traditionally showed a higher failure rate than the anterior [8]. The bracket failure rate of first and second premolar brackets was three times higher than those on the anterior teeth, incisors and canines [9]. The high incidence may be attributed to poor moisture control as saliva pools towards the back of the mouth and heavier mastication forces. However, this finding was not collaborated and other studies found that there were no statistically significant differences between anterior and posterior teeth bracket failures [10]. It can be concluded that there is not a common pattern amongst bracket failure that can be universally agreed upon.

3.2 Hydrophobic primer bracket failure rate

Primers help adhere composite to the enamel surface. Multiple studies have been done using Transbond XT primer as a control. The failure rate over 12-months using a primer (Transbond XT) was 11.1% while without a primer was 15.8%, which was not statistically significant [11]. However, when dealing with a high volume of patients, 4.7% increase in bracket failure can be argued as clinically significant in terms of time and resources spent rebonding a failed bracket. In another study, the bracket failure rate over a 6-month period using Transbond XT was 2.0% and the rate continued to increase as treatment duration progressed [12]. In a study by Cal-Neto et al., the bracket failure rate of Transbond XT primer over a 12-month period was found to be 4.78% [13]. Overall, there was a wide range of reported bracket failure rates using Transbond XT primer.

3.3 Bond strengths of hydrophilic primers under dry conditions

In an *in-vitro* study by Littlewood et al., brackets bonded with a hydrophilic primer under dry conditions had significantly lower bond strengths and higher risk of bond failure compared to a conventional hydrophobic primer [14]. These results were confirmed by a clinical study where there was “an overall bond failure of 6.8% for conventional adhesive and 18.8% for the hydrophilic primer” [15]. However, those results were contradicted by Grandhi et al., which found that conventional Transbond primer and Transbond moisture-insensitive primers (MIP) had similar bond strengths on both dry and wet etched enamel conditions when performed on

bovine teeth [16]. This study indicated there were no bond strength differences between hydrophobic and hydrophilic primers.

3.4 Bond strengths of hydrophilic primers under wet conditions

When contaminated with blood or saliva, the hydrophobic primer Transbond XT had the weakest bond strength compared to hydrophilic primers; however, there were no differences when comparing hydrophobic and hydrophilic primers under dry environments [3].

In an *in vitro* study using 240 extracted human premolars, it was found that the two different moisture-insensitive primers, Assure and Transbond MIP, provided adequate bond strengths, but more frequent bracket failures, when saliva contamination occurred both before and after the application of a primer [2]. In addition, the study showed that Transbond MIP and Assure had greater shear-peel bond strength when saliva contamination occurred after the primer application than before. Overall, the organic contaminants in blood and saliva decreased the bond strength of primers. And the timing of when contamination occurs, especially if prior to the application of the primer, can prevent the complete bonding between the hydrophilic primer to the enamel and further decreasing bond strength.

Even though hydrophilic primers are designed to be moisture insensitive, proper moisture control should still be maintained, similar to bonding with a hydrophobic primer. This observation was made in a study using 90 extracted human premolars that found significantly

higher bond strengths for brackets bonded with a hydrophilic primer in a dry state compared to a water and blood contamination state [17].

3.5 Assure Plus (Reliance Orthodontic Products, Inc) hydrophilic primer

Launched in 2015 by Reliance Orthodontic Products, Inc , Assure Plus was marketed as the most versatile resin ever developed. It is a light cured hydrophilic bonding primer with an added enhancer adhesion booster. According to manufacturer instructions, Assure Plus was indicated for all bonding surfaces to include “normal, atypical (wet or dry) enamel surfaces, amalgam, gold, stainless steel, porcelain, zirconia, composite restorations, acrylic, temporary/pontic teeth” [18].

The bonding directions for enamel was similar to traditional bonding protocols: (1) using oil-free pumice on the enamel surface (2) rinse and dry, (3) apply etchant, (4) rinse and dry, (5) apply one coat of Assure Plus, (6) lightly dry with air, (7) place bracket with a light cure paste onto primed tooth. However, the bonding protocol for Assure Plus on non-enamel surfaces, such as porcelain or metal crowns, differs from other primers such that it no longer required an etchant if Assure Plus was used after a conditioner. Traditionally, hydrofluoric acid was a required etchant used to ensure proper bonding to porcelain and metal surfaces.

Assure Plus is compositionally different from other primers and contains: Bis-GMA, 2-Hydroxyethyl Methacrylate (HEMA), ethanol, and 10-Methacryloyloxydecyl Dihydrogen Phosphate Monomer (10-MDP Monomer). Bis-GMA is a light cured compound found in various

other dental materials. The material creates a carbon-carbon interaction with enamel, generating a micro-mechanical retention ideal for bonding and minimizing polymerization shrinkage. Ethanol is added as a solvent for the primer to enhance the bond between hydrophobic and hydrophilic materials at the junction of composite-dentin bond [19]. HEMA has hydrophilic properties to assist with moisture control and allow for better penetration into the open enamel rods after etching [5]. MDP Monomer enhances the bonding connection between composite and acrylic resin [5]. With these components, Assure Plus has both hydrophilic properties and the ability to bond onto non-enamel surfaces.

3.6 Assure Plus bond strength

Saliva contamination decreases the overall bond strength of both hydrophobic and hydrophilic primers; Assure Plus (9.22 ± 3.42 MPa) produced clinically acceptable bond strengths with saliva contaminated enamel surfaces on extracted human mandibular molars [20].

4.0 Purpose of Present Investigation

The purpose of this study is to determine whether there is a difference in orthodontic bond failure rates when comparing a hydrophobic and hydrophilic primer in the oral cavity. The hydrophobic primer, Transbond XT Primer (3M^{TM}), will be the control. And the hydrophilic primer, Assure Plus (Reliance Orthodontic Products, Inc), will be used on the experimental quadrant. Previous studies were primarily *in vitro* studies conducted on either extracted human teeth or bovine teeth. Bovine and human enamel are similar in "physical properties, compositions, bond strengths" [3]. An *in vivo* study conducted in the mouth comparing different primers will ideally be more representative of clinical practice.

The null hypothesis states that there will be no difference when comparing bracket failure rates between the two primers. Since hydrophilic primers are marketed to allow brackets to be bonded on dry and wet enamel surfaces, then the teeth bonded with Assure Plus should perform at least the same, and not worse, compared to Transbond XT primer.

5.0 Materials and Methods

5.1 Overview

The University of Pittsburgh School of Dental Medicine Department of Orthodontics and Dentofacial Orthopedics will serve as the only source for participants. This study was reviewed by the University of Pittsburgh Institutional Review Board (IRB) and approved on Feb 01, 2022 to be effective Feb 09, 2022 (STUDY21100085). A continuing review (CR21100085-001) was approved on Dec 06, 2022.

5.2 Eligibility Criteria

Inclusion criteria for this study are patients with the following: (1) Permanent dentition with all incisors, canines, and premolars present (molars are excluded), (2) Treatment with pre-coated 3M Victory Series or Mini Uni-Twin brackets, (3) Comprehensive two-arch fixed orthodontic treatment.

The exclusion criteria will include: (1) Any missing permanent teeth (excluding molars), (2) Large buccal restorations, (3) Porcelain and metal crowns, and other large non-enamel surfaces, (4) Brackets not pre-coated, (5) Flash-Free Adhesive coated brackets.

5.3 Recruitment and Consent

Patients who met the eligibility criteria and were starting orthodontic treatment at University of Pittsburgh School of Dental Medicine Department of Orthodontics and Dentofacial Orthopedics were recruited. Recruitment started from February 09, 2022, and ended on September 30, 2022. On the initial orthodontic bonding day, informed consent for the study was received and any questions regarding the research were answered. Patients were then sequentially assigned a bonding pattern (alternating contralateral pattern) and primed using both Transbond XT and Assure Plus (Figure 1A and B). Patients returned for regular orthodontic visits every 4-6 weeks and bond failures were documented on Axium electronic health record.

5.4 Study Design

1. Teeth are cleansed with a mixture of water and fluoride-free pumice using a rubber-polishing cup, rinsed and dried.
2. Patients are fitted with a NOLA dry field retractor for moisture control
3. Teeth are etched for 15 seconds with 37% phosphoric acid gel, rinsed for 5 seconds with water, and then dried with air.
4. Depending on assigned bonding pattern, each quadrant will be primed with either Transbond XT primer or Assure Plus
5. Primers are lightly air-thinned and cured for at least 3 seconds.
6. Pre-pasted brackets (Victory Series or Mini-Uni Twin Series) are positioned and pressed flush onto each tooth

7. Brackets are polymerized for at least 6 seconds on each tooth using a 3M Unitek Ortholux Luminous Curing Light
8. First wire inserted will vary depending on patient's malocclusion

A

	Right	Left
Maxillary Arch:	Transbond XT primer	Assure Plus
Mandibular Arch:	Assure Plus	Transbond XT primer

B

	Right	Left
Maxillary Arch:	Assure Plus	Transbond XT primer
Mandibular Arch:	Transbond XT primer	Assure Plus

Figure 1A and 1B. Bonding Patterns. Figure 1A shows bonding pattern 1. Figure 1B shows bonding pattern 2

5.5 Sample Size

Sample size calculation was based on a maximum difference of 15% between the two groups, Transbond XT and Assure Plus. With a power of 80% and an alpha significance level of 0.05, the sample size calculation was 100 brackets per group. This translated to ten patients with 20 brackets (10 Transbond XT and 10 Assure Plus) to be analyzed per patient.

5.6 Data Acquisition

Maxillary and mandibular arches may be bonded at separate visits. If the arches are bonded separately, then the date of bonding for each arch will be recorded as the starting point and monitored from then. After 6 months, Axium charts will be reviewed and all bracket failures will be recorded on an Excel spreadsheet with the following information: deidentified patient number, quadrant, tooth number, primer, and whether failure occurred within 3 months or between 3 – 6 months. Only the first bracket failure incidence will be recorded per tooth.

Seventeen patients were recruited for this study. Once patients were bonded, the date of bonding was recorded along with the bonding pattern. The last date for data collection was set on March 30, 2023. Two patients who initially had their upper arches bonded were ultimately excluded at the end because their lower arches were not bonded prior to September 30, 2023.

5.7 Statistical Analysis

Bracket failure occurrences were recorded after a period of 6 months post-bonding. Their failure rates were calculated for the control (Transbond XT primer) and experimental (Assure Plus) groups. The failure rates between two groups were also evaluated to compare maxillary to mandibular arches, and anterior to posterior segments. P-values were calculated using proportion tests on STATA (statistical software for data science).

6.0 Results

6.1 Group characteristics

A total of 17 patients were initially recruited. Two patients were disqualified from this study when their lower arches were not bonded prior to March 30, 2023, the final date for data collection. 15 patients had both maxillary and mandibular arches bonded for at least 6 months prior to the data collection date cut-off. Twenty brackets (8 incisors, 4 canines and 8 premolars) were evaluated for each patient. Ten brackets were used for each primer, Transbond XT primer and Assure Plus, in a contra-lateral bonding pattern. A total of 300 brackets were evaluated, 150 per group (Figure 2).

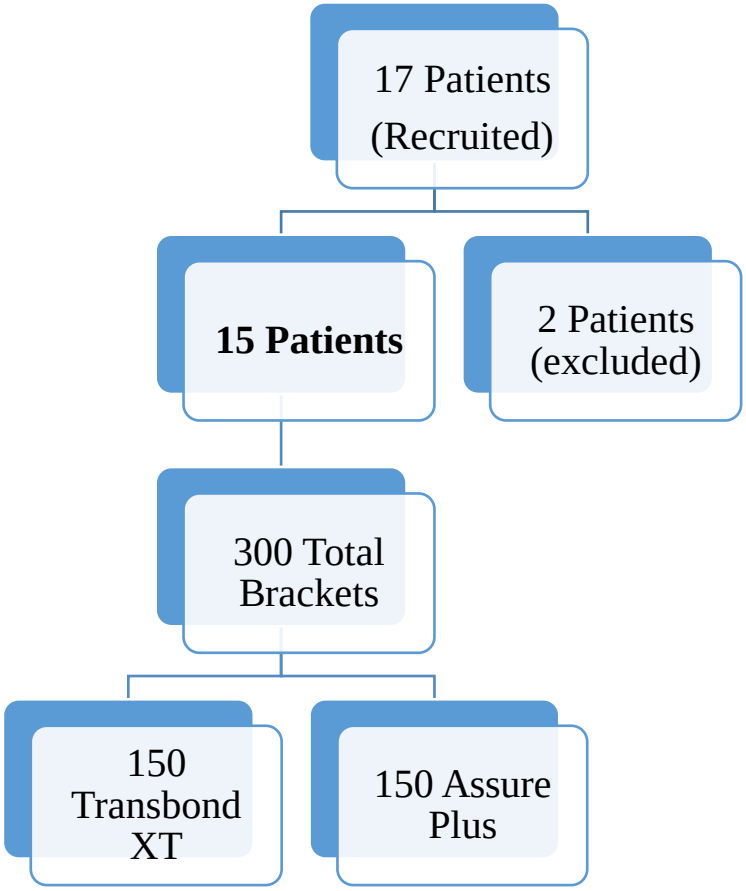


Figure 2. Overview of group characteristics.

6.2 Overview of Bracket Failure

Each bracket failure occurrence was recorded with the deidentified patient number, quadrant, tooth number, primer (Transbond XT or Assure Plus), and whether failure occurred within 3 months or between 3 – 6 months (Table 1). In this study, 6 out of 15 participants (40%) had at least 1 bracket failure within 6 months of bonding. Out of 11 total bracket failures, 4 of those were from participant #6. Participants #9 and #15 both lost 2 brackets and #5, #10, #14 lost 1 bracket.

A total of 11 failed brackets, out of 300 bonded brackets, were recorded during the 6-month post-bonding period with an overall bond failure rate of 3.67% (Table 2). Seven brackets bonded with Transbond XT failed with a failure rate of 4.67%. Assure Plus had four bracket failures with a failure rate of 2.67%. When comparing Transbond XT and Assure Plus, there were no significant differences between the two bracket failure rates at 6-months (p-value = 0.36).

Within 3 months, Transbond XT had a failure rate of 2.67% and Assure Plus was 2.00%. More than half of the brackets for both groups had failed within 3 months: 4 failures occurred with Transbond XT and 3 failures with Assure Plus. The overall failure rate of the study within 3 months was 2.33%, which was 7 of the 300 brackets.

Table 1: Bracket failure tracker

Participant #	Quadrant	Tooth #	Assure Plus 3 Mo	Assure Plus 6 Mo	Transbond XT 3 Mo	Transbond XT 6 Mo
5	LR	5	-	-	-	1
6	UL	2	1	-	-	-
6	LL	5	-	-	-	1
6	LR	1	1	-	-	-
6	LR	2	1	-	-	-
9	LL	1	-	1	-	-
9	LR	2	-	-	1	-
10	LL	4	-	-	-	1
14	LL	5	-	-	1	-
15	UL	2	-	-	1	-
15	UL	3	-	-	1	-
Total			**3**	**1**	**4**	**3**

Mo = Month

Table 2: Bracket failure rates for Transbond XT and Assure Plus at 3 and 6 months

Adhesive	Brackets	3 Mo failures	3 Mo failure rate	6 Mo failures	6 Mo failure rate	P-value
Transbond XT	150	4	2.67 %	7	4.67 %	0.36
Assure Plus	150	3	2.00 %	4	2.67 %	
Total	300	7	2.33 %	11	3.67 %	

Mo = Month

6.3 Bracket Failure in The Maxillary and Mandibular Arches

Overall, three brackets had failed on the maxillary arch and eight brackets had failed on the mandibular arch, yielding a failure rate of 2.00% and 5.33% respectively (Table 2). Even though the bracket failure rate in the mandibular arch was more than 2 times greater than the maxillary arch, there was not an overall significant difference (p-value = 0.12).

Transbond XT had a maxillary failure rate of 2.67% and a mandibular failure rate of 6.67%. The difference in failure rate between the two arches was not significantly different (p-value = 0.25). Assure Plus had a maxillary failure rate of 1.33% and a mandibular failure rate of 4.00%. The difference in failure rate was also not significantly different (p-value = 0.17).

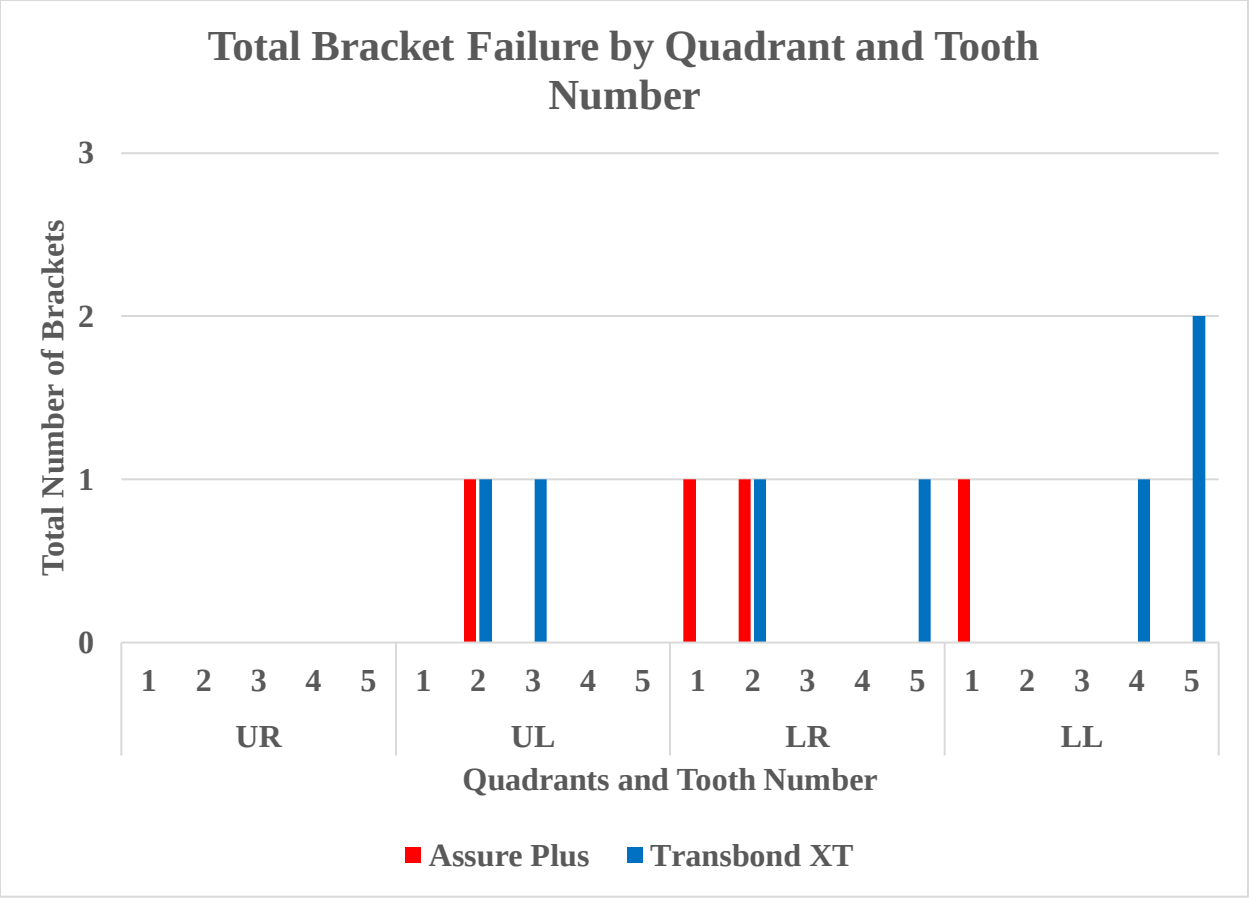
Within the maxillary arch, two brackets bonded with Transbond XT failed and one Assure Plus bracket failed. The failure rates were not statistically significant (p-value = 0.56). In the mandibular arch, five brackets bonded with Transbond XT failed and three brackets had failed with Assure Plus. These failure rate differences were also not significantly different (p-value = 0.46).

Table 3: Bracket failure rates after 6 months: maxillary versus mandibular arch

	Maxillary			Mandibular			
Adhesive	**Brackets**	**Failures**	**Failure rate**	**Brackets**	**Failures**	**Failure rate**	**P-value**
Transbond XT	75	2	2.67 %	75	5	6.67 %	0.25
Assure Plus	75	1	1.33 %	75	3	4.00 %	0.17
Total	150	3	2.00 %	150	8	5.33 %	0.12
P-Value	0.56			0.46			

6.4 Bracket Failure by Quadrant and Tooth Number

When separating the data into quadrants and individual tooth bracket failures, the only quadrant without any bracket failures was the upper right (UR) quadrant (Figure 2). The upper left (UL) quadrant had three failures, two Transbond XT brackets (UL2 and UL3) and one Assure Plus bracket (UL2). In the lower right (LR) quadrant, two brackets failed for both Assure Plus (LR1 and LR2) and Transbond XT (LR2 and LR5). Four brackets failed in the lower left (LL) quadrant, one LL1 bracket with Assure Plus and three Transbond XT brackets (LL4, LL5, and a different LL5).



UR = Upper Right
UL = Upper Left
LR = Lower Right
LL = Lower Left

Figure 3. Total bracket failure by quadrant and tooth number

6.5 Bracket Failure in The Anterior and Posterior Dentition

In this 6-month study, the anterior segment included incisors and canines, and the posterior segment comprised of the first and second premolars (Table 3). Six out of 180 anterior brackets had failed with a failure rate of 3.33%. A higher failure rate of 4.17% was observed in the posterior segment, with five failed brackets out of 120 total brackets. However, there were no significant differences when comparing the overall failure rates (p-value = 0.70).

With just Transbond XT, the anterior segment had a failure rate of 2.22% and the posterior segment had a failure rate of 6.67%. There was not a significant difference between anterior and posterior bracket failure rate for Transbond XT (p-value = 0.17).

Anterior brackets bonded with Assure Plus had a failure rate of 4.44% while posterior brackets had a failure rate of 1.67%. There was a significant difference between the anterior and posterior bracket failure rate for Assure Plus (p-value = 0.035).

For just anterior brackets, the failure rate of Assure Plus was 4.44%, which was double the failure rate of Transbond XT at 2.22%. However, there were no significant differences (p-value = 0.41). For the posterior brackets, Transbond XT had a failure rate of 6.67%, which was four times greater than the failure rate for Assure Plus, 1.67%. However, there were no significant differences (p-value = 0.17). Overall, Assure Plus had a greater failure rate in the anterior and Transbond XT had a greater failure rate in the posterior.

Table 4: Bracket failure rates after 6 months: anterior versus posterior dentition

	Anterior (Incisors & Canines)			Posterior (Premolars)			
Adhesive	**Brackets**	**Failures**	**Failure rate**	**Brackets**	**Failures**	**Failure rate**	**P-value**
Transbond XT	90	2	2.22 %	60	4	6.67 %	0.17
Assure Plus	90	4	4.44 %	60	1	1.67 %	0.035*
Total	180	6	3.33 %	120	5	4.17 %	0.70
P-Value	0.41			0.17			

7.0 Discussion

7.1 Study design

Numerous studies, using extracted bovine and human teeth, have been completed on individual bond strengths and bracket failure rates of Transbond XT primer. However, research on the bonding strength of Assure Plus is limited. Even so, majority of studies with primers are completed outside of the mouth in controlled environments. The conditions inside the mouth throughout orthodontic treatment cannot be replicated by coating samples in saliva. There are other factors, that cannot be standardized, in consideration that affect bonding efficiency, such as the patient's functional pattern, diet, salivary flow, and oral hygiene.

In the current study, the patient's teeth are isolated from moisture in accordance with current clinical practice and primer bonding guidelines. Despite best efforts of isolation, gingival crevicular fluid, salivary pooling, and blood from inflamed gingiva can still potentially contaminate the surface of prepared teeth since we are not individually isolating every tooth.

A contra-lateral study design was used so that both primers can be used for each patient rather than designating one primer per participant. Compared to a split-mouth design, this design removes the possible variable of a patient favoring one side of their mouth only. Both primers are represented in both arches on different sides of the mouth; therefore, the variability of patient selection and compliance should have limited influence on the results.

7.2 Bond failure rates

In the present study, the overall bond failure rate was 5.33%. The bond failure rate of Transbond XT was 4.67% and Assure Plus was 2.67%. Bond failure rates under 10% are considered clinically acceptable [9]. Even with a 2% difference, there were no statistically significant differences in failure rates comparing Transbond XT and Assure Plus. Both primers performed similarly, and their bond failure rates were well within the range of clinically acceptable.

Bond failure rates reported in previous studies using Transbond XT primer had differing results ranging from 2.54% to 17.6% [21]. This large range may be explained such that studies with longer observation periods had more bond failures and therefore higher failure rates [22]. Previous studies describing bond failure rates of Assure Plus were limited. Even so, the shear bond strength of Assure Plus was found to be statistically greater than Transbond XT, 15.077 ± 6.701 and 8.231 ± 2.328 respectively [23]. This observation reflects the overall lower bracket failure rate seen with Assure Plus in comparison to Transbond XT.

In this study, 64% of all brackets (7 out of 11 total bracket failures) failed within 3 months of bonding. 40% of the patients (6 participants) in this study reported at least 1 bond failure within 6 months post-bonding. And 50% of those patients reported more than 1 bond failure incidence. The findings in this study was found to be higher than previous studies that reported less than 30% of patients reported a single bond failure [24]. Another study found that two-third of bracket failures happened within the first 6 months after bonding during the leveling

and aligning phase [24]. More brackets are expected to fail as the orthodontic treatment progresses.

The findings of this study was consistent with previous clinical studies that found there were no differences in bond failure rates between the maxillary and mandibular arches [9]. However, other studies have shown that bond failure was twice as common in the mandibular arch compared to the maxillary arch [22]. In contrary, there are also studies that showed a higher percentage of bond failure in the maxillary arch [25]. No common bracket failure pattern with either arches could be discerned.

Overall, there were no statistically significant differences between anterior and posterior bracket failure rates, which was consistent with previous studies [10]. However, there was a statistically significant difference between bond failure rates of anterior and posterior brackets bonded with just Assure Plus. The anterior brackets bonded with Assure Plus was 2.66 times more likely to experience bond failure than the posterior teeth. This finding with Assure Plus was contrary to previous clinical studies that showed a three times increase in posterior bracket failure compared to anterior brackets [9]. Studies attributed those findings to poor moisture control, partial eruption of premolars and heavy occlusal forces. No common pattern between anterior and posterior segments could be agreed upon.

Anterior bracket failure may be caused by anterior occlusal bracket interferences. It was observed that patients with an increased overbite, deep bite cases, have an increased bracket failure rate [24] [22]. Associated with an excessive overbite are heavier forces of mastication and

anterior bracket occlusal interferences. Often, the bite must be vertically opened to prevent bond failure from occlusal interferences in the anterior region. In addition, constant occlusal interferences on a bracket can cause traumatic occlusion and mobility on the affected teeth.

Poor patient compliance may also be a possibility to account for the statistically significant difference seen between anterior and posterior bond failure in brackets with Assure Plus. Participant #6 had lost three anterior brackets primed with Assure Plus all within 3 months after bonding. It was observed in another study that "multiple bracket failures are clustered in certain patients with a median of three failed brackets per patient" [26]. This patient had another bond failure before the end of the 6-months observation period. Participant #6 self-reported poor compliance and had been eating hard candies despite prior orthodontic bracket care instructions that included types of foods to avoid. Despite losing three anterior Assure Plus brackets, this patient did not lose any anterior Transbond XT brackets. Because of this observation, it can be accepted that participant #6's results were not an anomaly and Assure Plus did have a greater bond failure rate in the anterior region than Transbond XT. However, the sample in this study was small and a larger sample of at least 30 participants may either mask this conclusion or possibly even further reinforce it.

In addition to wide ranges of failure rates for primers in previous studies, bonding failure trends were also inconsistent. Previous studies often had contradictory results, and conclusions could not be easily interpreted from comparative clinical studies due to a lack of standardization. Variables such as malocclusion classification, masticatory forces, oral hygiene status, compliance, and observation time frame can affect the results.

7.3 Other variables associated with bond failure

In literature, patients with poor oral hygiene are associated with an increased bracket failure rate [25]. Plaque accumulation prolongs acidic environments on the tooth surface, reducing the pH of the oral cavity and consequently weakening bracket adhesion and increasing risk of demineralization [22]. Decreased salivary pH from poor OH or acidic beverages can lead to increased orthodontic bond failure at the bracket-adhesive interface by creating enamel defects around the bracket, reducing bonding strength and shearing force resistance [27] [28]. Patients with poor oral hygiene are often also non-compliant in other aspects related to orthodontic treatment, such as appointments, elastic wear, and oral habits.

7.4 Clinical implications

Even though this study had clinically acceptable bond failure rates of below 10%, a failure rate difference of 2% (Transbond XT 4.67% and Assure Plus 2.67%) affects doctor time, chair time, and treatment time. If the findings of this study were translated to clinical practice, the implications can be large. For every 100 patients bonded with Transbond XT at a failure rate of 4.67%, there would be 94 bond failures. If these patients were bonded with Assure Plus, with a failure rate of 2.67%, there would be 54 bond failures. That is a difference of 40 more bond failures. And this is not taking into consideration molar brackets, which traditionally has an even greater bond failure rate. If a patient was to be seen for a broken bracket ‘emergency’ on a non-scheduled day, it would take at least 15 minutes to untie the wire, clean composite off the tooth, etch, bond, retie, and then flip the chair for another patient. Rebonding 40 broken brackets for

every 100 patients translates to approximately ten hours of additional chair time. In a retrospect study by Stasinopoulos et al., it was found that treatment duration was extended by 0.6 months for each additional failed bracket [26]. This is not uncommon because an ignored broken bracket prevents the next wire succession, delaying treatment completion.

8.0 Limitations

This master's thesis project was conducted at the graduate orthodontic clinic in the University of Pittsburgh School of Dental Medicine. The study was limited by the number of participants available for recruitment. The population at the school is variable and non-traditional cases with missing teeth or large edentulous spans are not uncommon. Depending on the faculty overseeing each patient case, the bracket system and treatment philosophy may be different. Patients who needed extractions, used Damon or ceramic brackets were excluded, decreasing the already small recruitment pool. Damon brackets and other not pre-coated brackets required an individual to pack composite at the back of the bracket pads, introducing a possible variable. There has been an increasing trend in adult patients seeking orthodontic care. However, when aligner treatment was not an option, they preferred ceramic over metal brackets. Ceramic brackets in the clinic were pre-coated with a Flash-Free composite that differed from the pre-coated brackets and had to be excluded from selection. It would have been difficult, and the recruitment size would have further decreased, to only select for one type of bracket system in this study. To reduce other variables, only patients who were to be bonded with pre-coated 3M metal brackets were recruited.

In some cases, maxillary and mandibular arches were not bonded on the same day due to an interfering malocclusion or time constraints in the graduate clinic. Two recruited patients were excluded because their mandibular arches were not bonded 6 months prior to the designated Axium collection date. In an ideal study, data collection should continue throughout treatment, but due to the time limitation set by this master's project, the observation period could only be 6

months. Because of the time constraints, potential patients were not recruited past a certain date if both arches were not bonded together.

9.0 Future Research

Future research should focus on recruiting more patients. A larger sample of at least 30 patients would provide more accurate results and be a better representation of the population. In addition, bracket failure rates should be observed past 6 months because normal orthodontic treatment averaged between 18 to 24 months.

A common orthodontic emergency is from a loose terminal molar bracket that resulted in a long, poking wire. Future studies can investigate the bond failure differences of molar brackets using Transbond XT and Assure Plus.

Another research project can explore repeating the same research design with Transbond XT and Assure Plus but utilizing the indirect bonding technique for bracket placement. In traditional orthodontics, brackets are individually placed by the doctor. Once on the teeth, brackets are light cured after each arch or segment rather than right after placement. With the indirect bonding method, brackets are placed into a stent in advance, put over the teeth, and then light-cured. This reduces the time brackets are left uncured on the tooth and reduces the chance of surface contamination.

10.0 Conclusions

1. After 6 months, Transbond XT primer (hydrophobic) had a failure rate of 4.67% and Assure Plus (hydrophilic) had a failure rate of 2.67%. However, there were no statistically significant differences between those two failure rates.
2. There was a significantly higher anterior failure rate for Assure Plus compared to the posterior, 4.44% and 1.67% respectively.
3. Overall, Assure Plus is a comparable alternative to conventional hydrophobic primers.
4. A longer study should be completed, ideally to monitor 9 – 12 months after bonding.

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