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POSTGRADUATE DENTAL COLLEGE
SOUTHERN REGION OFFICE
2787 WINFIELD SCOTT ROAD, SUITE 220
JBSA FORT SAM HOUSTON, TEXAS 78234-7510
https://www.usuhs.edu/pdc

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Name of Candidate: Andrew P. Benfield
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30 Jun 20

Dr. Ryan Snyder
TORP PROGRAM DIRECTOR, AIR FORCE POST-GRADUATE DENTAL SCHOOL

30 Jun 20

Dr. Craig Vandewalle
USAF CONSULTANT IN RESEARCH, AIR FORCE POST-GRADUATE DENTAL SCHOOL
Committee Chairperson

30 Jun 20

Dr. Jacob Kitson
DEPARTMENT OF ORTHODONTICS, AIR FORCE POST-GRADUATE DENTAL SCHOOL
Committee Member

Uniformed Services University of the Health Sciences
Manuscript/Presentation Approval or Clearance

Initiator

1. USU Principal Author (Last, First, Middle Initial) Benfield, Andrew, P. Maj
2. Academic Title Orthodontic Resident
3. School/Department/Center AFPDS
4. Phone 210-292-9039
5. Email Andrew.P.Benfield.mil@mail.mil
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Name (Last, First, Middle Initial) Snyder, Ryan, L.

Signature

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Name (Last, First, Middle Initial) N/A

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Service Dean Approval**	
Name (Last, First, Middle Initial) Graver, Jay, D	
School Air Force Postgraduate Dental School	
Higher approval clearance required (for University-, DoD, or US Gov't-level policy, communications systems or weapons review)	
Signature	
Executive Dean Approval**	
Name (Last, First, Middle Initial)	
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The corresponding author must be named___Dr. Andrew P. Benfield _____ [redacted]
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__Dr. Jeremy Scarpate_____

Date:_11 Feb 2020_____

Abstract:

Introduction: The aim of this study is to measure the shear bond strength of 3M Clarity Advanced ceramic brackets with APC Flash Free systems (Ivoclar, 3M Unitek, Ormco) and 3M Victory Series Low Profile Brackets with APC Flash Free systems (Ivoclar, 3M Unitek, Ormco) with and without the use of Opal Seal (Ultradent Products, Inc., South Jordan, UT, USA) an in vitro laboratory study.

Methods: Eighty extracted bovine incisors were divided into sixteen groups of five incisors. The sixteen sets was further divided into four groups corresponding to the different treatment modalities. Group 1 was comprised of sets one through four, twenty teeth in total, and was assigned for bonding with Transbond SEP and 3M Clarity Advanced ceramic brackets with APC Flash Free System. Group 2 was comprised of sets five through eight, twenty teeth in total, and was assigned bonding with Opal Seal and 3M Clarity Advanced ceramic brackets with APC Flash Free System. Group 3 was comprised of sets nine through twelve, twenty teeth in total, and was assigned bonding with Opal Seal and 3M Victory Series Low Profile Brackets with APC Flash Free Systems. Group 4 was comprised of sets thirteen through sixteen, twenty teeth in total, and was assigned bonding with Transbond SEP and 3M Victory Series Low Profile Brackets with APC Flash Free Systems. All brackets were debonded with the Instron Universal Testing machine and shear bond strength and Adhesive Remnant Index (ARI) was recorded for each bracket.

Results: The outcome data for bond strength was normally distributed according to Shapiro-Wilk test ($W = 0.98$, $p = 0.22$). A one-way analysis of variance (ANOVA) was performed to test the group difference. No significant group differences in bond strength was found. The outcome data for ARI are ordinal data. Non-parametric test (Kruskal-Wallis Test) was performed to test the group differences. A Kruskal-Wallis Test showed that there was a statistically significant difference in rank for ARI among the groups. ARI scores for Groups 1 and 2 (Clarity) were greater than ones for Groups 3 and 4 (Victory).

Conclusions: Due to the fracture of the ceramic brackets before debond, no significant differences were achieved in bond strength between bracket types or bonding methods. The significant difference in ARI scores between metal and ceramic brackets was also likely due to the fracture of the ceramic brackets.

Keywords: Bond Strength, Opal Seal, Flash Free Brackets, Adhesive remnant index, orthodontic brackets

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Conflict of interest statement: In accordance with Taylor & Francis policy and my ethical obligation as a researcher, I am reporting that I have no financial or business interests in any company that may be affected by the research reported in the enclosed paper. I am also not aware of any conflicts of interest held by the Air Force Surgeon General's office.

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The experiments reported herein were conducted according to the principles set forth in the National Institute of Health Publication No. 80-23, Guide for the Care and Use of Laboratory Animals and the Animal Welfare Act of 1966, as amended.

Manuscript: Shear Bond Strength Between Opal Seal and Flash Free Brackets

Introduction and literature review

Optimizing the shear bond strength of orthodontic brackets while decreasing the amount of excessive composite during bonding is a major point of interest for orthodontists. As most traditional brackets leave behind flash[1], which creates a site for mature plaque accumulation[2,3] and demineralization[4], flash free brackets are becoming an increasingly popular alternative. Research has shown that flash free brackets have a comparable shear bond strength[5] and adhesive cleanup time[6] when compared to traditional brackets. However, bonding time is shown to be significantly faster[7], which only increases their approval among providers.

In an effort to further decrease demineralization in patient populations, many offices also recommend the use of a fluoride-containing mouth wash in association with daily tooth-brushing to combat decalcification[8,9]. However, this method is entirely patient reliant. Orthodontic practices are thus turning to Opal Seal, a fluoride releasing, resin filled bonding agents to reduce demineralization. The manufacturer states that these filled primers enhance bonding and recharge fluoride uptake.

Although fluoride has been proven to decrease white-spot lesions and decalcification[8], according to research done by Ortiz-Ruiz, fluoride applications prior to bonding have shown to decrease the shear bond strength of orthodontic brackets to enamel.[10] It is then important to investigate how these fluoride releasing resins will influence bonding.

Furthermore, flash free orthodontic brackets are available in ceramic and metal. The literature is conflicting in regards to the shear bond strength between the different materials for orthodontic brackets[11-13]. The differences in these materials must be considered then when debonding brackets from enamel.

There is significant data on shear bond strength between orthodontic brackets and various bonding materials[14-17]. However, due to the novelty of this technology, little research is currently available to determine how the use of fluoride releasing primers in conjunction with flash free brackets effect the shear bond strength of the brackets. It is the purpose of this study to evaluate how the use of a fluoride releasing filled primer (Opal Seal, Ultradent Products, Inc., South Jordan, UT, USA) effects the shear bond strength of flash free brackets (3M Unitek APC Flash-Free Adhesive System).

Material and Methods

This study was performed using bovine incisors. Two hundred fifty bovine incisors were procured and stored in distilled water prior to and throughout the protocol. Eighty teeth were chosen based on a set of inclusion criteria used to ensure suitability with the protocol design and adequate bonding environment. Teeth were excluded if there was evidence of coronal caries, enamel fractures or hypomineralization in the bonding area, gross staining extending into the bonding area, or less than eighty percent of the root remaining.

Following the selection of eighty teeth that met the inclusion criteria, the teeth were divided at random into sixteen sets of five. Each set of five bovine incisors were placed in a plastic bag with distilled water and sealed until ready to be embedded in acrylic. The sixteen sets were further divided into four groups corresponding to the different treatment modalities. Group 1 was comprised of sets one through four, twenty teeth in total, and was assigned for bonding with Transbond SEP and 3M Clarity Advanced ceramic brackets with APC Flash Free System. Group 2 was comprised of sets five through eight, twenty teeth in total, and was assigned bonding with Opal Seal and 3M Clarity Advanced ceramic brackets with APC Flash Free System. Group 3 was comprised of sets nine through twelve, twenty teeth in total, and was assigned bonding with Opal Seal and 3M Victory Series Low Profile Brackets with APC Flash Free Systems. Group 4 was comprised of sets thirteen through sixteen, twenty teeth in total, and was assigned bonding with Transbond SEP and 3M Victory Series Low Profile Brackets with APC Flash Free Systems.

I. Creating the base

Due to the design of the Instron machine mount, a custom base was created to ensure maximum surface area and strength to hold the base while debonding the brackets (Fig. 1 & 2).

The custom stone model was placed in a 700mL plastic storage container. 700mL of Capsil Quickset duplicating material (Great Lakes Orthodontics, Tonawanda, NY) was mixed (350mL of Base, 350mL of Catalyst) for 45 seconds and poured into the storage container until it was full. The duplicating material was allowed to set for 15 minutes. Once the duplicating material was set, the base was removed. This left a negative impression of the base for the acrylic to be poured in and embed the teeth. This process was completed four times to create four different containers for fabricating bases (Fig. 3, 4 & 5).

II. Setting Up the Teeth

Once the negative bases were created, the teeth were air dried and randomly selected and aligned so that the incisal edges were at approximately the same level (Fig. 6).

Acrylic (Great Lakes Orthodontics, Ltd., Tonawanda, NY) was then added by mixing monomer and polymer in a separate mixing bowl and pouring it into the container until the roots of the teeth were covered and the facial surfaces of the teeth were left exposed for bonding. The acrylic was then cured in a pressure pot at 20 psi for twenty minutes. Upon removal from the pressure pot, the teeth and acrylic were removed and stored in distilled water until bonding (Fig. 7, 8 & 9).

Once the bases and teeth were created, they were distributed into separate groups for bonding. Groups 1 and 2 were for ceramic brackets with flash free system bonded with transbond and opal seal, respectively. Groups 3 and 4 were for the metal brackets and bonded with opal seal and transbond, respectively.

III. Direct bonding the teeth

Group 1

The facial surfaces of the teeth to be bonded were cleaned using pumice and rinsed completely (Fig. 10). Thirty-four percent phosphoric acid etchant gel (Caulk, Dentsply International) was then placed on the facial surfaces and allowed to work for twenty seconds (Fig. 11). The etched teeth were rinsed for ten seconds and dried thoroughly for fifteen seconds. The facial surfaces of the teeth were painted with Transbond Self-Etching Primer (3M Dental Products, St Paul, Minnesota) for 3-5 seconds and then the primer was air thinned (Fig. 12). One 3M Clarity Advanced ceramic bracket with APC Flash Free System was placed on the facial surface of each tooth. The bracket was placed into its final position and fully seated. Each bracket was cured (VALO, Ultradent Products Inc, South Jordan, UT) for a total of twelve seconds each, three seconds per side (incisal, gingival, mesial, distal). All the procedures listed above were performed for one set at a time (Fig. 13).

Group 2

The facial surfaces of the teeth to be bonded were cleaned using pumice and rinsed completely. Thirty-four percent acid etchant gel was then placed on the facial surfaces and allowed to work for twenty seconds. The etched teeth were rinsed for ten seconds and dried thoroughly for fifteen seconds. The facial surfaces of the teeth were painted with Opal Seal using the provided syringe brush tip for 3-5 seconds and then the primer was air thinned. One 3M Clarity Advanced ceramic bracket with APC Flash Free System was placed on the facial surface of each tooth. The bracket was placed into its final position and fully seated. Each bracket was cured for a total of twelve seconds each, three seconds per side (incisal, gingival, mesial, distal). All the procedures listed above were performed for one set at a time.

Group 3

The facial surfaces of the teeth to be bonded were cleaned using pumice and rinsed completely. Thirty-four percent acid etchant gel was placed on the facial surfaces and allowed to work for twenty seconds. The etched teeth were rinsed for ten seconds and dried thoroughly for fifteen seconds. The facial surfaces of the teeth were painted with Opal Seal using the provided syringe brush tip for 3-5 seconds and then the primer was air thinned (Fig. 14 and 15). One 3M Victory Series Low Profile Bracket with APC Flash Free System was placed on the facial surface of each tooth. The bracket was placed into its final position and fully seated. Each bracket was cured for a total of twelve seconds each, three seconds per side (incisal, gingival, mesial, distal). All the procedures listed above was performed for one set at a time.

Group 4

The facial surfaces of the teeth to be bonded were cleaned using pumice and rinsed completely. Thirty-four percent acid etchant gel was placed on the facial surfaces and allowed to work for twenty seconds. The etched teeth were rinsed for ten seconds and dried thoroughly for fifteen seconds. The facial surfaces of the teeth were painted with Transbond Self-Etching Primer for 3-5 seconds and then the primer was air thinned. One 3M Victory Series Low Profile Bracket with APC Flash Free Systems was placed on the facial surface of each tooth. The bracket was placed into its final position and fully seated. Each bracket was cured for a total of twelve seconds each, three seconds per side (incisal, gingival, mesial, distal). All the procedures listed above was performed for one set at a time.

IV. Shear Bond Strength Testing

The bonded acrylic-tooth blocks were mounted in the Instron Universal Testing Machine holder and positioned such that the crosshead contacted the brackets between the bonding pad and the superior tie wings.

The crosshead speed was set to 1 mm/min. When each test was initiated, the crosshead lowered until contact was made with the bracket. The load was then increased until the bracket was debonded from the tooth. The maximum load achieved for each test was recorded on computer software in units of newtons (N).

Each measurement was converted into megapascals (MPa) using the following equation:

$$1\ N/mm^2 = 1\ MPa$$

The maximum load in newtons was divided by the surface area of the bracket's bonding pad (surface area = 10.52 mm^2) to yield a measurement in megapascals. The shear bond strength of each of the eighty samples was recorded and then subjected to statistical analysis.

Results

The outcome data for bond strength was normally distributed according to Shapiro-Wilk test ($W = 0.98$, $p = 0.22$). A one-way analysis of variance (ANOVA) was performed to test the group difference. No significant group differences in bond strength was found ($F(3, 76) = 2.17$, $p = 0.099$) (Table I) (Fig. 16, 17 and 18).

The outcome data for Adhesive Remnant Index are ordinal data. A Non-parametric test (Kruskal-Wallis Test) was performed to test the group differences. A Kruskal-Wallis Test showed that there was a statistically significant difference in rank for ARI among the groups, $\chi^2(3) = 32.65$, $p < .0001$, with a mean rank score of 53.93 for Group 1, 54.78 for Group 2, 29.38 for Group 3, and 23.93 for Group 4. A post hoc test reveals that the significant group comparisons were between Group 1 and Group 3, between Group 1 and Group 4, between Group 2 and Group 3, and between Group 2 and Group 4. ARI scores for Groups 1 and 2 (Clarity) were statistically greater than ones for Groups 3 and 4 (Victory) (Table II) (Fig 19).

Discussion

Given clinical observations and the data by Ortiz, which states that fluoride interferes with shear bond strength when placed during bonding, one would expect the shear bond strength to be lower in the flash free brackets with Opal Seal. Reasons this study was unable to provide enough evidence to support this hypothesis could be attributed to the fact that opal seal releases significantly less fluoride during bonding than Ortiz used during his materials and methods [10].

The results of the adhesive remnant index were greater on average than what has been recorded in traditional shear bond strength studies of traditional twin brackets, which is consistent with the literature on APC Flash Free brackets. Research by Lee and Grunheid states that ARI is greater in flash free brackets when compared to traditional brackets, meaning they leave more composite on the tooth surface, thus protecting the underlying enamel. Grunheid's article went as far as to say the cleanup time of remaining cement was equivalent to that of traditional brackets making an excellent alternative to traditional brackets when considering debonding [6,7]. Specifically, when metallic and ceramic brackets were compared by Fernandes, he found there was significantly greater ARI scores in the metallic brackets. So, considering Fernandes data and the results of this study having an ARI score higher in the ceramic bracket, we can then conclude that the change in ARI scores must be due to the flash free system and it's interaction with the ceramic base and mesh [12].

A few of the limitations of this study must be addressed due to their potential influence on the results of the study. One such limitation of this study was the position of the crossarm when debonding the brackets. In order to only test the shearing strength of the bracket, it is necessary to have the crossarm between the base of the bracket and the superior wings (Fig. 20). When the cross arm is positioned against the superior wings and not between the base and the wings, the arm creates a torqueing force as opposed to true shear forces (Fig. 21).

Another shortcoming is that ceramic clarity brackets were not meant to be debonded by pressing on the superior wings. It was observed that some of the wings fractured prior to debond. This could have caused an inadvertent increase in the ARI scores for the ceramic brackets because the composite was left on the tooth on these teeth due to the remainder of the bracket. So, then what would need to be done differently in a future study to get a more accurate representation of the force required to remove a ceramic bracket during debond as well as the proper adhesive remnant index (ARI) score?

The manufacturers created a stress concentration line that runs incisal-gingivally along the base of the ceramic bracket. So, the bracket was designed to be debonded by applying mesial and distal pressure to the bracket causing the bracket to fracture along the concentration line.

The pliers recommended to debond ceramic APC Flash free brackets. A future study it is recommend that debonding the brackets should be accomplished using appropriate pliers and recording the strength required for debond. This would give a more accurate representation of Adhesive Remnant Index as well as the force required to debond all of the groups tested.

Conclusion

There is no difference in shear bond strength of flash free brackets when using Opal Seal compared to flash free brackets without the use of Opal Seal. The results also indicate there is no difference in the amount of force required when debonding metal vs ceramic brackets with APC Flash Free systems. The lack of significant difference in shear bond strength between brackets types is consistent with prior shear bond strength studies as the data is highly variable with some studies stating that metallic brackets have a higher shear bond strength and others reporting no statistically significant differences[11-13,18]. The outcomes indicate

that there is no statistical difference when debonding brackets with the use of Opal Seal or Transbond self-etching primer.

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