# INFLUENCE OF BRACKET TYPE COMBINED WITH DELAYED LIGHT ACTIVATION ON BRACKET-ADHESIVE SHEAR BOND STRENGTH

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INFLUENCE OF BRACKET TYPE COMBINEDWITH DELAYED

LIGHT ACTIVATION ON BRACKET-ADHESIVE

SHEAR BOND STRENGTH

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University of Missouri-Kansas City, 2016

ABSTRACT

This study examined the effect of bracket type and varying delayed polymerization times in combination with bracket manipulation on adhesive temperature change, shear bond strength (SBS), degree of conversion (DC), and adhesive remnant index (ARI) score when using a resin adhesive. Specimens from four bracket types: stainless steel with a mesh base (SSm), polycrystalline with a dovetail base (PCd), polycrystalline with a micro-shard base (PCsh), and monocrystalline with a micro-sphere base (MCsp), were divided into three groups of clinically relevant delay times (0.5, 5, 10 min) to simulate the delay that frequently occurs between bracket placement and manipulation followed by light polymerization.

Based on an analysis of variance ($\alpha=0.05$), bracket type was not a significant factor in mean temperature change of the resin cement; however, delay time was found to be a significant factor ($p<0.05$). There was no significant difference in SBS as a function of delay time. The PCsh bracket type had higher SBS values than other bracket types. Delayed polymerization time and bracket type were not significant factors in DC or ARI. A Spearman correlation ($\alpha=0.05$) showed a positive correlation between SBS and ARI at the 0.5 min time delay across bracket types.

The results of this study suggest that clinically relevant delay times of 0.5, 5, and 10 min do not negatively impact the SBS of a resin adhesive. A majority of brackets fell into the ARI 1 category, meaning that >50% of the resin adhesive remained on the bracket base. The PCsh bracket type showed significantly higher SBS, and thereby may be more appealing to clinicians.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Dentistry have examined a thesis titled “Influence of Bracket Type Combined with Delayed Light Activation on Bracket-Adhesive Shear Bond Strength,” presented by Whitney N. D. Hewitt, candidate for the Master of Science degree, and certify that in their opinion it is worthy of acceptance.

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# CHAPTER 1

# INTRODUCTION

## Orthodontic Brackets

Orthodontic tooth movement is a controlled process whereby a force is applied to the crown of the tooth resulting in movement of the tooth through the alveolar bone. Different types of orthodontic appliances may be utilized in order to control the amount and direction of this applied force, the most common being bonded bands and brackets. Ligating a wire into the slot of bands and brackets to produce a desired force has shown to aid in accurate tooth positioning as well as limit the need for patient compliance. (Zachrisson 2012). Presently, the use of bands is limited to teeth that will incur higher forces, require both buccal and lingual attachments, or have insufficient clinical crowns (Proffit 2007). With increased frequency of bracket use, manufacturers have been competing to provide a superior product; consequently, an assortment of features are commercially available.

## Orthodontic Bracket Adhesives

Tooth movement is dependent on proper adhesion of the orthodontic bracket to the enamel. In order for the adhesive to incorporate and better adhere to the tooth, an etchant must first be utilized to alter the enamel surface (Buonocore 1955). Two major etching methods are available for use in orthodontics: the total-etch and the self-etch systems. The total-etch process involves two steps whereby the etchant, 37% phosphoric acid, is applied to the tooth surface and rinsed away followed by a primer to secure the adhesive to the enamel (Buonocore 1955; Legler et al. 1989). Alternatively, a self-etching primer is a one step process whereby the solution is applied to the enamel prior to the adhesive. The total-etch system has tended to produce higher bond strengths *in vitro*, but both total-etch and self-etch applications are within clinically acceptable ranges (Korbmacher et al. 2002; Velo et al. 2002; Mansour et al. 2011; Fleming et al. 2012). Though the total-etch method may provide higher bond strengths, its application has been associated with greater technique sensitivity, enamel decalcification, and enamel fracture during the debonding procedure (Brown and Way 1978; Diedrich 1981; Gorelick et al. 1982; Joseph and Rossouw 1990). Due to possible complications with the total-etch system, a significant reduction in chairside time and inventory, and providing clinically acceptable results, the self-etching primers have gained popularity (Fleming et al. 2012).

Many different types of adhesives are available for bracket bonding, but all must provide adequate strength to prevent bond failure prior to the completion of orthodontic treatment. In addition, bracket adhesives should be dimensionally stable, fluid enough to adapt to both enamel and bracket surfaces, and clinically manageable (Proffit 2007). Several orthodontic adhesive products are commercially available, including glass ionomers and resin cements. Glass ionomer cements are enticing due to their ability to release fluoride, but any advantages in shear bond strength with comparison to resin adhesives are still uncertain (Sfondrini et al. 2001; Hegarty and Macfarlane 2002; Mickenautsch et al. 2012). The most commonly used adhesive to bond orthodontic brackets are resin cements. Two types of dental resins, acrylic and diacrylic resins, are available for use. Acrylic resins are self-curing polymers that are rarely used today for orthodontic bracket bonding. Diacrylic resins are the most commonly used orthodontic adhesive materials and are available in light-cured applications. Diacrylic resin adhesives are comprised of bis-GMA that produces a three-dimensional crosslinking network of bonds when polymerized thereby increasing bond strength (Zachrisson 2012).

Self-curing resins polymerize via a chemical process that occurs when the monomer comes in contact with the chemical initiator, thereby giving the clinician a predetermined amount of time to manipulate the bracket into the desired location. For this reason, light-cured adhesives have become more prevalent, as it allows for a more controlled working time (Zachrisson 2012). Polymerization of a light-cured resin begins with activation of a photoinitiator, camphoroquinone, when exposed to a blue light source in the visible light range with a wavelength of approximately 470 nm (Zachrisson 2012). An acceptable dental curing light can range in wavelengths between 400-500 nm and produce an output as low as 400 mW/cm$^2$ (Strydom 2002). These low output units necessitate longer curing times, up to 40 seconds per bracket, and therefore extended appointment time for the clinician (Finnema et al. 2010). Fortunately, advancements in technology have produced light emitting diode (LED) curing units that provide high intensity beams up to 1600 mW/cm$^2$ with minimal heat production and are compact, cordless, and quiet (3M Unitek 2009; Zachrisson 2012). These units can cure a single bracket in as little as 3-6 seconds (3M Unitek 2009).

### Bracket-Adhesive Shear Bond Strength

Bracket bond failure is an inconvenient complication for both the patient and clinician during orthodontic treatment that results in increased total treatment time, chair time, and overhead costs (Powers et al. 1997; Finnema et al. 2010). For these reasons, investigations have focused on developing a system that provides a bond strength that is both adequate for tooth movement and limits bond failure during treatment, while also preventing enamel damage during the debonding procedure which has been observed with excessive bond strengths (Pickett et al. 2001; Verma et al. 2013). It has been reported that during mastication, forces between 40-120 N are sustained to the brackets and it has been speculated that bond strengths in the range of 6-8 MPa are required to overcome these forces (Reynolds 1975). Furthermore, bond strengths greater than 13.5 MPa have been shown to result in enamel fracture (Verma et al. 2013). Bond strength can be assessed by measuring the tensile forces or the shear forces encountered during the bracket debonding procedure. Both tests are valid for studying orthodontic bond strength, but shear bond strength is more commonly recorded. Although it would be more clinically relevant to obtain *in vivo* shear bond strengths, no standardized protocols or instruments have been established (Powers et al. 1997). A systematic review reported *in vitro* bond strengths ranging from 3.5-27.8 MPa (Finnema et al. 2010). Observed differences in bracket bond strength have been linked to storage medium, type or quality of enamel surface, method of debond, site of adhesive failure, analysis of procedure, as well as numerous other factors (Fox et al. 1994; Finnema et al. 2010).

Of the factors listed for affecting bracket bond strength, site of adhesive failure is the one factor that lies outside the investigator's control. Adhesive fracture pattern is measured via visual assessment using the Adhesive Remnant Index (ARI) (Artun and Bergland 1984) and is included in studies measuring bracket bond strength to evaluate the quality of the bond (Fox et al. 1994; Montasser and Drummond 2009). The ARI tells the location of the bond failure, whether it predominantly occurs at the bracket base-adhesive interface, within the adhesive, or at the adhesive-enamel interface. Ideally, the clinician would prefer failure to occur at the adhesive-enamel junction to limit the need for adhesive removal and reduce chairside time at the debonding appointment (Fox et al. 1994; Verma et al. 2013). The ARI was originally developed using a 4-point scale ranging from 0 to 3, where the criteria are as follows: 0 = all adhesive remained on the bracket base; 1 = >50% of the adhesive remained on the bracket base; 2 = <50% of the adhesive remained on the bracket base; and 3 = no adhesive is present on the bracket base (Artun and Bergland 1984). Later, the Modified Adhesive Remnant Index (MARI) was developed that uses a 5-point scale ranging from 1 to 5, where: 1 = no adhesive is present on the bracket base; 2 = <10% of the adhesive remained on the bracket base; 3 = >10% but <90% of the adhesive remained on the bracket base; 4 = >90% of the adhesive remained on the bracket base; and 5 = all of the adhesive is present on the bracket base (Bishara and Trulove 1990). Many studies report high ARI scores of 4 or 5, which suggests that bond strength of the adhesive to the bracket is stronger than that between the adhesive and the enamel (Finnema et al. 2010; Verma et al. 2013). Variances in ARI scores have been related to bracket type in addition to bracket bond strength (O'Brien et al. 1988).

## Factors Affecting Bracket Bond Strength

### Bracket Adhesive Degree of Polymerization

During adhesive polymerization, bonds are formed within the adhesive resin giving strength to the interactions between bracket base, adhesive resin, and enamel surfaces. The degree of polymerization, also known as degree of conversion, is a reflection of the setting process during which the adhesive monomer is converted to a polymer in the light-initiated polymerization process (Watts 2001; Miletic and Santini 2008). If areas within the resin composite are unable to completely polymerize, water may diffuse into the resin and weaken bracket bond strength (Verma et al. 2013). An increase in photophosphorylation has been proven to enhance bond strength, where each additional second of proper light exposure raises bond strength 0.077 MPa (Finnema et al. 2010). Therefore, an impediment to light exposure may lead to incomplete polymerization and limit long-term success of the bracket bond strength (Finnema et al. 2010).

**Bracket Types and Relevant Properties for Adhesive Polymerization**

**Stainless steel brackets.** Traditionally, stainless steel is used to fabricate orthodontic brackets and remains the most commonly used bracket (Proffit 2007). A typical stainless steel bracket is composed of 50-80% iron, 13-23% chromium, 3-14% nickel as well as trace amounts of silicon, manganese, molybdenum, copper, and niobium (American Orthodontics 2014a). Stainless steel brackets are produced via a casting process that gives accurate results and allows for very precise expression of the bracket prescription providing predictable tooth movement (Proffit 2007). Another important feature of stainless steel brackets is the manner in which it can transfer energy. Stainless steel brackets are impervious to light transmission which may impede light curing and prevent complete polymerization of the subjacent resin cement. Therefore, it is recommended to cure stainless steel brackets interproximally to increase the light exposure at the margins of the bracket where the cement is visible (3M Unitek 2012). Although impermeable to light, stainless steel brackets, like all alloys, are thermal conductors and therefore have the capability to transfer heat. The thermal conductivity of stainless steel ranges between 12-30 W/m°C for ambient temperature (American Orthodontics 2014a). Studies have suggested that if the temperature of the adhesive is increased, adhesive degree of polymerization may be enhanced and potentially improve bracket adhesive bond strength (Freedman and Krejci 2004; Trujillo et al. 2004).

**Ceramic brackets.** In an effort to deliver a more esthetic option for patients, ceramic materials were introduced into bracket design. Their high strength resists deformation during tooth movement and makes ceramics a good option for bracket fabrication (Proffit 2007).

Ceramic brackets are composed of sapphire crystal, namely aluminum oxide, which can be produced from a single crystal, termed monocrystalline brackets, or a conglomeration of individual crystals or grains, known as polycrystalline brackets (American Orthodontics 2014a). Unlike the stainless steel brackets, ceramic brackets transmit light, and it is recommended to light cure the bracket adhesive through the ceramic bracket surface for optimal polymerization of the resin adhesive (Unitek 2012). However, it should be noted that the monocrystalline bracket has greater light transmittance over the polycrystalline bracket structure with light scatter occurring at the individual grain boundaries thereby decreasing light transmittance (Eliades 2012; American Orthodontics 2013). In terms of heat transfer, in contrast to stainless steel, ceramics are insulators and thus unable to transfer heat that might enhance the degree of polymerization of the bracket adhesive.

**Bracket Base Design**

One potential area for failure is between the adhesive resin and the base of the bracket. The interaction between these two surfaces is very important, and may be attributed to purely mechanical bonding or may also have chemical component contribution. When ceramic brackets were first introduced, a silane coupler was incorporated to increase bond strength by producing chemical interactions between the adhesive and bracket base (Zachrisson 2012). Unfortunately, this resulted in excessively high shear bond strengths with frequent enamel fracture during bracket debonding procedures. Today, chemical bonding via a silane coupler is not recommended for ceramic orthodontic bracket bonding (Proffit 2007; Zachrisson 2012).

Mechanical bonding of orthodontic brackets occurs when the resin adhesive flows into undercuts within the bracket base and locks the adhesive into the base structure upon adhesive polymerization. Mechanical retention on the base of stainless steel brackets can be achieved with a mesh structure as well as an etched foil base (American Orthodontics 2012). Since a mesh cannot be incorporated onto the base of a ceramic bracket, many designs have been developed to create undercuts on the bracket base surface. These designs include microscopic spheres, irregular shards, and dovetails (3M Unitek 2014; American Orthodontics 2014b). Differences in adaptation of the resin adhesive to these undercuts may play a role in bracket shear bond strength. A less viscous adhesive may adapt to the bracket base as it is able to flow easier into the bracket base undercuts. Viscosity is altered by amount of filler materials incorporated by the manufacturer as well as the temperature of the adhesive composite resin (Proffit 2007; Cantoro et al. 2008; Deb et al. 2011)

**Bracket Bonding Techniques**

According to manufacturer recommendations, five steps should be taken when bonding brackets with a light cure resin cement: tooth preparation, acid etching, priming teeth, adhesive application, and bracket placement and curing. During tooth preparation, proper isolation of teeth should be performed followed by prophylaxis with an oil-free pumice, after which excess water is rinsed from the enamel surface (3M Unitek 2012). After activation of the self-etching primer, the saturated applicator is actively rubbed onto the enamel surface for 3-5 seconds, and thinned with a gentle burst of air for 1-2 seconds (3M Unitek 2008). A thin layer of adhesive is immediately applied to evenly cover the bracket base, and the bracket is lightly placed onto the tooth surface until it is manipulated into proper positioning. Once in the desired location, the bracket is firmly pressed onto the tooth surface and excess flash is removed without disturbing the bracket positioning. Finally, the bracket is cured appropriately and the process is repeated for the next tooth (3M Unitek 2012).

**Delayed Adhesive Polymerization and Manipulation of Brackets**

Despite the recommended process of executing all five steps of bracket bonding for each individual bracket, this is not the typical bracket bonding process used in clinical practice. Instead, all teeth in one arch are isolated, etched, primed, and tentative bracket placement is determined by the orthodontic assistant. The orthodontist is then called to manipulate the bracket into its final position and initiate the light curing process. When this actual bracket placement and bonding process is used with multiple patients being seen at the same time, polymerization delay time may be prolonged (Zachrisson 2012).

With increasing delay time followed by final bracket manipulation, it has been proposed that bracket bond strength may be affected (Brantley 2001; Ponikvar 2014). Excessive manipulation of the bracket after adhesive flash removal and prior to final curing is discouraged, suggesting an increase in bond failure and a decrease in shear bond strength, though research on bracket manipulation is limited (Brantley 2001; Watts 2001; Murfitt et al. 2006; Zachrisson 2012). Moreover, with increasing delay time prior to light activation, the bracket is exposed to a greater amount of ambient energy, and it is speculated that ambient light might initiate more premature adhesive bonds (Brantley 2001; 3M Unitek 2012; Ponikvar 2014). During the delay, it has also been speculated that ambient heat might also be transmitted through the bracket leading to decreased adhesive viscosity and better adaption to the bracket base (Ponikvar 2014). Nevertheless, ambient light or heat transfer would vary depending on whether a stainless steel or ceramic bracket was used.

No published research to date has measured temperature changes of the adhesive beneath different types of brackets with varying delays of time prior to activation of polymerization. Furthermore, no research has investigated bracket shear bond strength and associated adhesive degree of conversion and debond fracture pattern as a function of bracket type in combination with clinically relevant polymerization delay times.

## Problem Statement

The purpose of this study is to examine whether shear bond bracket strength, degree of conversion of the bracket adhesive, and adhesive fracture pattern will be affected by differences in bracket type, consequent to varying polymerization delay time under a controlled lighting environment, as well as to measure any adhesive temperature changes observed during delayed polymerization.

## Hypotheses

1. There will be a difference in the temperature of the adhesive beneath the placed bracket as a function of delayed polymerization time and bracket type.
2. Bracket shear bond strength (SBS) will vary as a function of delayed polymerization time and/or bracket type.
3. Adhesive degree of conversion (DC) will vary as a function of delayed polymerization time and bracket type.
4. The adhesive fracture pattern measured via the Adhesive Remnant Index (ARI) will vary as a function of delayed polymerization time and/or bracket type.
5. There will be correlations between SBS, DC, and ARI within each bracket type.

CHAPTER 2

# MATERIALS AND METHODS

## Tooth Specimen Collection

Investigations involving orthodontic bonding commonly utilize human premolars for *in vitro* studies since these teeth are routinely extracted for orthodontic purposes; however, due to the volume of research conducted at the UMKC School of Dentistry, these teeth are high in demand and difficult to obtain. Third molars are frequently used as a substitute for premolars since they show no difference in bond strengths (Ries 2010) and are frequently extracted. Specimens were collected from private practice offices in the Kansas City and St. Louis regions. Extracted teeth were stored with no patient identifiers in individual containers containing 0.9% phosphate buffered saline[1] (PBS). Once collected, the teeth were cleared of any tissue debris and visually inspected for defects and anomalies. Third molars containing enamel imperfections such as fluorosis, caries, fractures, or abnormal anatomical features were discarded. Ideally, impacted third molars were utilized to limit the effects of the oral cavity. Acceptable teeth were then transferred to a solution of PBS containing 0.02% sodium azide at 4 °C to limit bacterial proliferation.

## Light Cured Resin Adhesive

The adhesive resin cement[2] used in this study is a light cured diacrylic resin commercially available to orthodontists. It is composed of 70-80% silane-treated quartz, 10-20% Bis-GMA, 5-10% Bisphenol A Bis (2-hydroxyethyl ether) dimethacrylate (Bis-EDMA), and 2% silane-treated silica.

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[1] Dulbecco's Phosphate Buffered Saline, Sigma-Aldrich, 3050 Spruce St., St. Louis, MO 63103
[2] Transbond XT™, 3M Unitek, 2724 South Peck Rd., Monrovia, CA 91016

## Orthodontic Bracket Types

Twin wing maxillary universal premolar brackets were used in this study that were designed with a concave bracket base that adapts to the surface of third molars since third molar brackets are not commercially available (Chitnis et al. 2006). Four different bracket types were used as follows: stainless steel brackets with a mesh base (SSm)[3], polycrystalline brackets with a dovetail base (PCd)[4], polycrystalline brackets with a micro-shard base (PCsh)[5], and monocrystalline brackets with a micro-sphere base (MCsp)[6] (Figure 1).

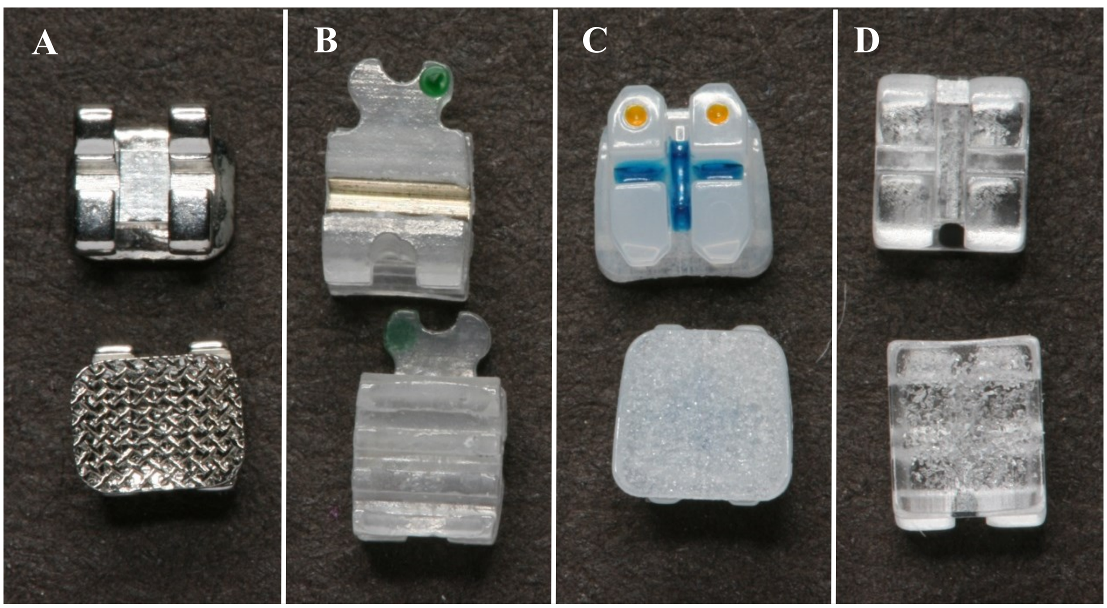


Figure 1. Buccal and base views of first premolar bracket types: A. Stainless steel bracket with mesh base (SSm), B. Polycrystalline bracket with dovetail base (PCd), C. Polycrystalline bracket with micro-shard base (PCsh), and D. Monocrystalline bracket with micro-sphere base (MCsp).

[3] Mini Master Series™, American Orthodontics, 3524 Washington Ave., Sheboygan, WI 53081
[4] Virage Ceramic Bracket System, American Orthodontics, 3524 Washington Ave., Sheboygan, WI 53081
[5] Clarity™ Advanced Ceramic Brackets, 3M Unitek, 2724 South Peck Rd., Monrovia, CA 91016
[6] Radiance Plus™, American Orthodontics, 3524 Washington Ave., Sheboygan, WI 53081

## Orthodontic Bracket Bonding Protocol

In preparation for bracket bonding, each third molar specimen was secured in a self-curing acrylic resin[7] positioned with a mounting jig and plastic mounting ring[8]. Each tooth was arranged so that the flattest surface of the mesio-buccal portion of the tooth was perpendicular to the mounting ring and horizontal plane. This orientation was confirmed with a leveling device[9] so that vertical shear force could be applied during shear bond strength testing.

Manufacturer's recommendations were followed for bonding the brackets with resin adhesive prior to testing. Bracket bonding was performed under controlled conditions in an environmental chamber to simulate the oral cavity at 33 °C (+/- 2 °C) and 85% (+/- 5%) humidity (Plasmans et al. 1994). Ambient light conditions were maintained at 1200 lux (+/-100 lux) to simulate the upper limit of what could be expected with orthodontic office lighting without direct exposure from the unit light, as noted in Appendix 1 and a previous thesis project (Ponikvar 2014). Per previously mentioned recommendations, teeth were initially polished with a fluoride-free pumice[10], rinsed, and thoroughly dried. Next, a self-etching primer[11] was activated and rubbed onto the tooth for 5 seconds and thinned with a gentle burst of air for 2 seconds. To simulate bracket adjustment, all brackets were moved by 10° after delay time but prior to adhesive light polymerization. To ensure 10° manipulation of the placed bracket, a fine tip marker was used to draw two small lines on the tooth surface outside the bracket bonding area; the line locations were

[7] Biocryl #040-016, Great Lakes, 200 Cooper Ave., Tonawanda, NY 14150
[8] Item#20-8180, Buehler Ltd., 41 Waukegan Rd., Lake Bluff, IL 60044
[9] Johnson Level & Tool MFg. Co., Inc, 6333 W. Donges Bay Road, Mequon, WI 53092-4456
[10] 1st & Final® pumice , Reliance Orthodontic Products, 1540 West Thorndale Ave, Itasca, IL 60143
[11] Transbond™ Plus Self Etching Primer, 3M Unitek, 2724 South Peck Rd., Monrovia, CA 91016

determined by a protractor and digital calipers. The first line indicated initial bracket placement, and the second line was final bracket placement after 10° of manipulation from the bracket midpoint. The resin adhesive was then applied evenly to the bracket base and a bracket placement instrument was used to align the bracket onto the mesio-buccal surface of the third molar in alignment with the initial mark.  The bracket was then firmly pressed against the surface of the tooth with a hand instrument[12] and excess cement was removed using the same instrument (Figure 2). Further instructions were dependent on the experimental group in which the bracket was assigned.

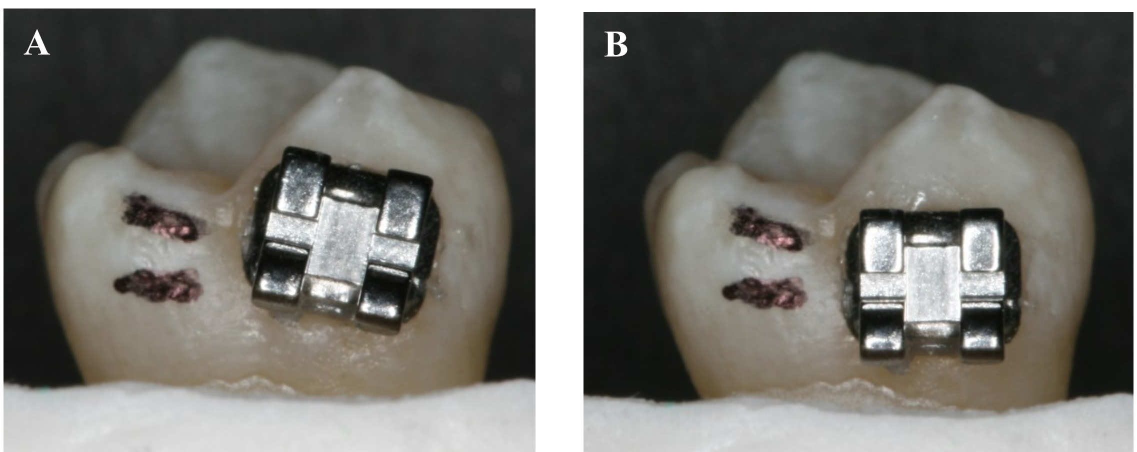


Figure 2. Bracket bonding protocol: A. Maxillary third molar labeled with reference lines, and bracket was placed outside of the reference area with bracket slot oriented 10° to horizontal according to first reference line. B. After manipulation, bracket is in ideal position, positioned according to second reference line.

[12] Hollenbeck Carver, CVHL 1/2, Hu-Friedy, 3232 N. Rockwell, Chicago, IL 60618-5982

## Polymerization Protocol

Brackets were divided into three groups differing in polymerization delay time as follows: 0.5 min, 5 min, and 10 min. These delay times were chosen based on a previous thesis (Ponikvar 2014) and observed clinical delay times (Appendix 2). After the appropriate amount of time had elapsed, the bracket was manipulated 10° to the final mark and light cured according to manufacturer recommendations. For all bracket types, the bracket was cured 6 seconds at the mesial and 6 seconds at the distal (3M Unitek 2009). The curing light[13] was checked daily to ensure an output of at least 1600mW/cm$^2$.

[13] Ortholux™ Luminous Curing Light, 3M Unitek, 2724 South Peck Rd., Monrovia, CA 91016

## Shear Bond Strength Testing

Immediately after each bracket was light cured, shear bond strength testing was completed via a universal testing machine[14]. The universal testing machine secured the mounted tooth specimen on a platform so that the knife-edge rod attachment of the machine crosshead would contact the occlusal edge of the bonded bracket base directing the load vertically in an occlusogingival direction paralleling the mesiobuccal surface of the tooth (Figure 3). The universal testing machine was programmed to a crosshead speed of 1 mm/min to apply a shear force to the bracket-tooth interface thereby debonding the bracket. Maximum load at debonding was recorded in Newtons (N). Shear bond strength was then calculated using the following formula:

$$\text{Shear bond strength (MPa)} = \frac{\text{Maximum load (N)}}{(W*L)(\text{mm}^2)}$$

where W = width of bracket base (mm) and L = height of bracket base (mm) (Rajagopal et al. 2004). The bracket base surface areas were SSm = 10.22 $mm^2$, PCd = 9.05 $mm^2$, PCsh = 11.77 $mm^2$, and MCsp = 12.58 $mm^2$. A representative load/displacement curve is depicted in figure 4.

[14] Model 5967, Instron Corporation, 825 University Ave., Norwood, MA 02062-2643

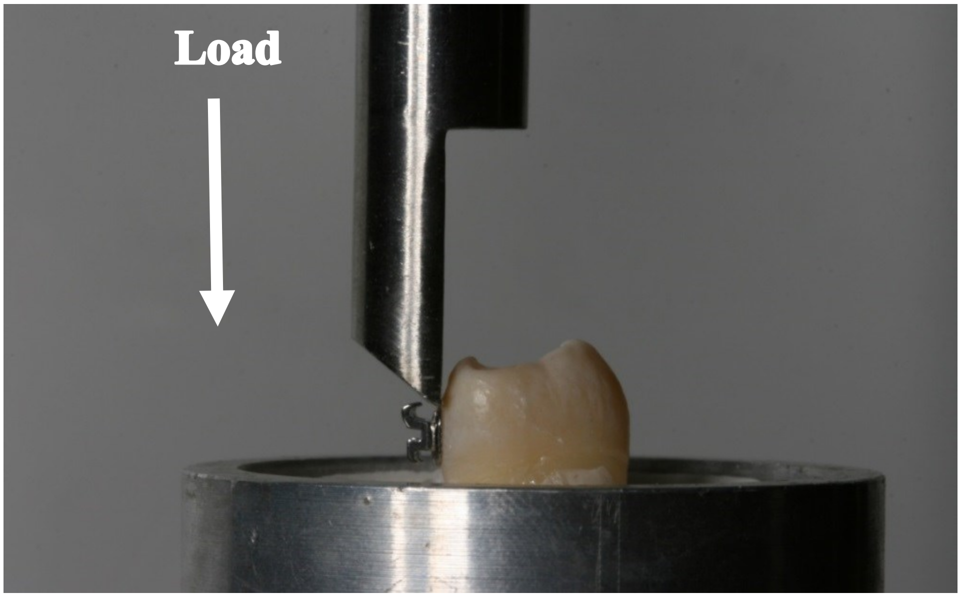


Figure 3. Tooth prepared for shear bond strength testing. Shear load was applied by the stainless steel rod in the universal testing machine.

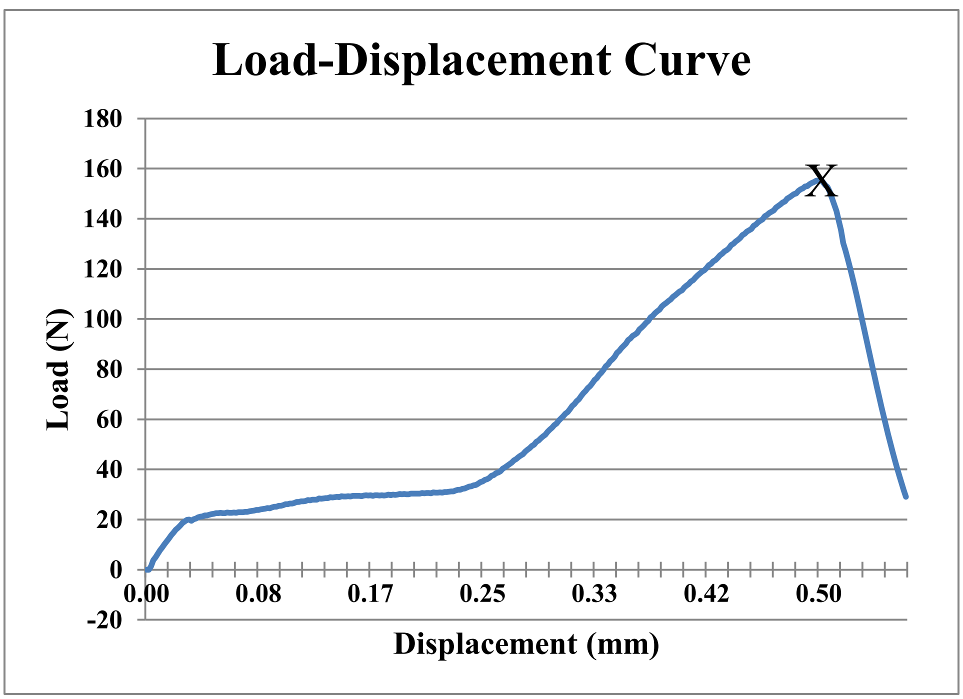


Figure 4. Representative load-displacement curve for shear bond strength testing. Maximum load (X) was used to calculate shear bond strength.

## Degree of Conversion Measurements

Raman spectroscopy data collection was completed within 60 minutes of SBS testing to ensure degree of conversion measurements corresponded to the extent of adhesive polymerization at time of SBS testing and limit any dark cure effects that occur when the adhesive continues to polymerize following light activation. Therefore, immediate testing permitted information to be collected concerning the relationship between adhesive DC and SBS. Point measurements were taken at 3 locations of adhesive remnants collected from the bracket base. The degree of conversion was calculated using the following formula:

$$DC = \left(1 - \frac{R \text{ polymerized}}{R \text{ unpolymerized}}\right) X\ 100$$

where R = band height at 1640 $cm^{-1}$/band height at 1610 $cm^{-1}$ (Pianelli et al. 1999). Figure 5 depicts representative data collected from micro-Raman spectroscopy analysis.

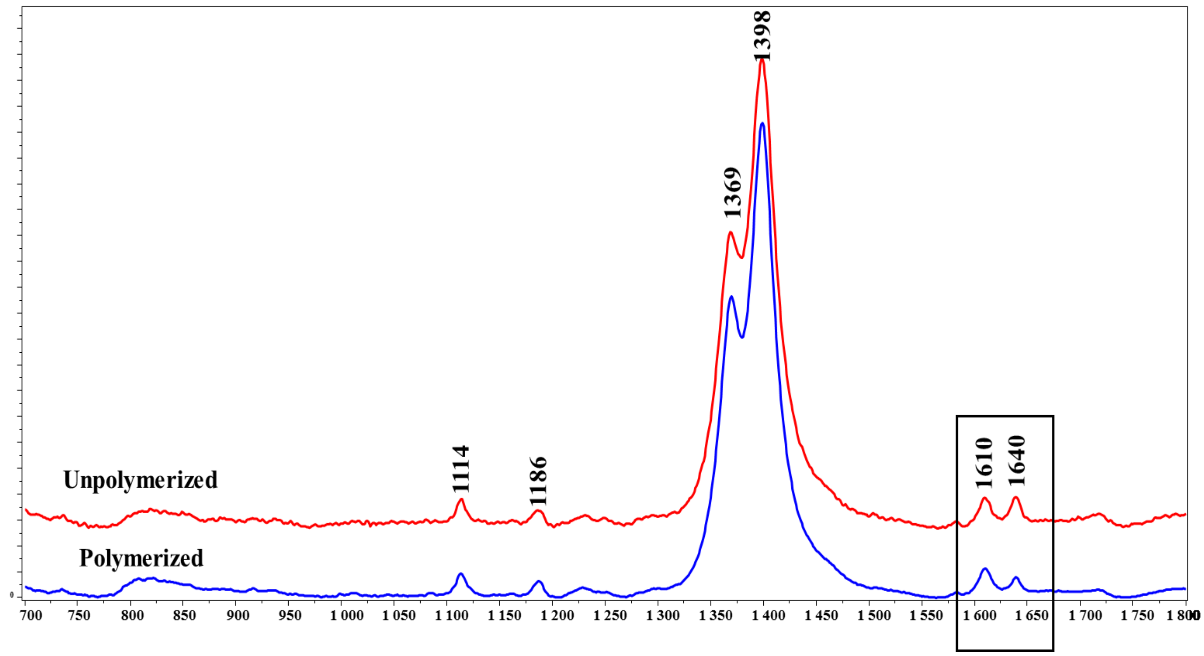


Figure 5. Representative data from micro-Raman spectroscopy analysis for unpolymerized and polymerized resin adhesive. Peaks of interest, 1610 and 1640, are shown above in the black box.

### Adhesive Remnant Index

Prior to Raman spectroscopy analysis, unmagnified photos of the debonded bracket bases were taken to subsequently categorize the bracket via the 4-point ARI scale according to location of bracket bond failure. The scale was defined with the following criteria: 0 = all adhesive remained on the bracket base; 1 = >50% of the adhesive remained on the bracket base; 2 = <50% of the adhesive remained on the bracket base; and 3 = no adhesive is present on the bracket base (Artun and Bergland 1984). Photos were magnified to 40 times the bracket size and a grid was placed over the image to accurately determine the amount of adhesive residue that remained on the bracket base following SBS testing. Examiner (WH) calibration was performed prior to ARI evaluations whereby the examiner was blinded to any identifying information and ten photographs of debonded bracket bases were scored according to the ARI scale on two separate instances 4 weeks apart. Intra-rater reliability was calculated from the collected data and there was a 100% agreement between the two scoring sessions.

### Thermal Testing Protocol

Using a separate subset of tooth specimens (different from those used for shear bond testing, degree conversion or ARI), tests were performed to determine whether thermal changes occurred under the bracket base during the orthodontic bracket bonding protocol at different delay times. For each bracket type, the aforementioned protocol was implemented with thermocoupler[15] leads placed underneath the bracket to collect temperature readings (Figure 6). Temperature was recorded at initial bracket placement on the tooth surface, following delay before light polymerization, and the peak temperature during the 6 second light polymerization. No data aside from temperature readings were collected using these specimens.

[15] Omega Engineering INC, One Omega Dr., PO Box 4047, Stamford, CT 06907.

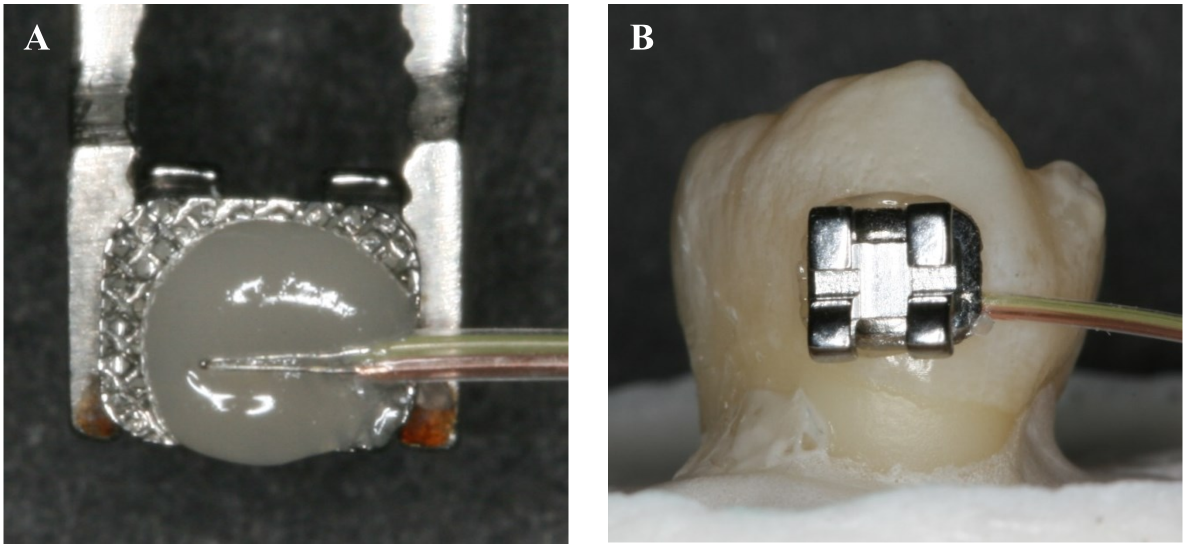


Figure 6. Thermal testing protocol: A. Thermocouple leads placed on bracket base that has been coated with resin cement. B. Bracket placed firmly into tooth, expressing excess resin so that thermocouple lead is in contact with enamel surface and bracket base.

## Experimental Design and Sample Size

This study utilized a 2-factor design with independent variables being bracket type and polymerization time. Bracket type has four levels: MCsp, PCd, PCsh, and SSm. Polymerization time had three levels: 0.5 min, 5 min, and 15 min. The dependent variables measured were adhesive temperature, shear bond strength (MPa), degree of conversion (%), and the Adhesive Remnant Index score (0-3). The experimental design for thermal testing, shear bond strength, degree of conversion, and ARI is presented in Table 1. For thermal testing, a convenience sample of 3 teeth was selected for each bracket type and delay time (N=36). For shear bond strength, degree of conversion, and ARI, a convenience sample of 5 teeth was selected thereby resulting in 5 teeth per experimental group (N=60). Each tooth was assigned at random to an experimental group.

TABLE 1

EXPERIMENTAL DESIGN

| **Bracket Type** | **Delay Time (min)** | **Temperature Change (deg)** N=36 | **Shear Bond Strength (MPa)** N=60 | **Degree of Conversion (%)** N=60 | **Adhesive Remnant Index (0-3)** N=60 |
|---|---|---|---|---|---|
| Monocrystalline with micro-sphere base (MCsp) | 0.5<br>5<br>10 | | | | |
| Polycrystalline with dovetail base (PCd) | 0.5<br>5<br>10 | | | | |
| Polycrystalline with micro-shard base (PCsh) | 0.5<br>5<br>10 | | | | |
| Stainless Steel with mesh base (SSm) | 0.5<br>5<br>10 | | | | |

## Data Analysis

To test whether there was a difference in adhesive resin cement temperature as a function bracket type and delay time, a two-factor ANOVA was used. If differences were found, a Tukey's post hoc test determined where differences exist. A two-factor ANOVA was also used to analyze the dependent variables of temperature, shear bond bracket strength and degree of conversion as a function of bracket type and delay time. If a significant difference was found, a Tukey's post hoc test was used to determine where differences exist. With any significant outcomes, effect size (based on partial eta squared values), which accounts for the percent of dependent variable change associated with the independent variable, were also reported. Effect size can be used as a standardized index that is independent of sample size to quantify the effect of the independent variable on the dependent variables (Cohen 1988; Coe 2002). Effect sizes range from small (0.1-0.3), medium (>0.3-0.5), and large (>0.5) (Cohen 1988).

To determine if the ARI scores vary as a function of bracket type and delay time, a Kruskal-Wallis two-way analysis of variance by ranks was used. A Mann-Whitney paired comparison was included as a post-hoc evaluation approach. To determine if there are any relationships between SBS, DC, and ARI, Spearman correlations was used for each bracket type. All statistical analyses were performed using a statistical analysis software program[16] with significance set at $\alpha = 0.05$ for all testing.

[16] SPSS version 21, 233 S. Wacker Dr., Chicago IL 60606

CHAPTER 3

RESULTS

**Temperature Measurements**

Means and standard deviations of mean temperature change for the four bracket types at three delay times are presented in figure 7. Based on the 2-Factor ANOVA, bracket type was not a significant factor ($p>0.05$) for the change in temperature of the resin cement. This did not support the hypothesis that there would be a difference in the temperature of the adhesive beneath the placed bracket as a function of bracket type. Delay time was found to be a significant factor ($p<0.05$) for mean temperature change which supported the hypothesis that the adhesive beneath the placed bracket would vary as a function of delayed polymerization time. The partial eta squared value was 0.744, which means that 74.4% of the variability of mean temperature change can be explained as a function of delay time. As described previously, this is a large effect size. Minimal changes in resin temperature were seen at 0.5 min and higher temperature changes were seen at 5 min that were about equal to the changes seen at the 10 min delay. Overall, standard deviation was high for mean temperature change at all time delays and for all bracket types.

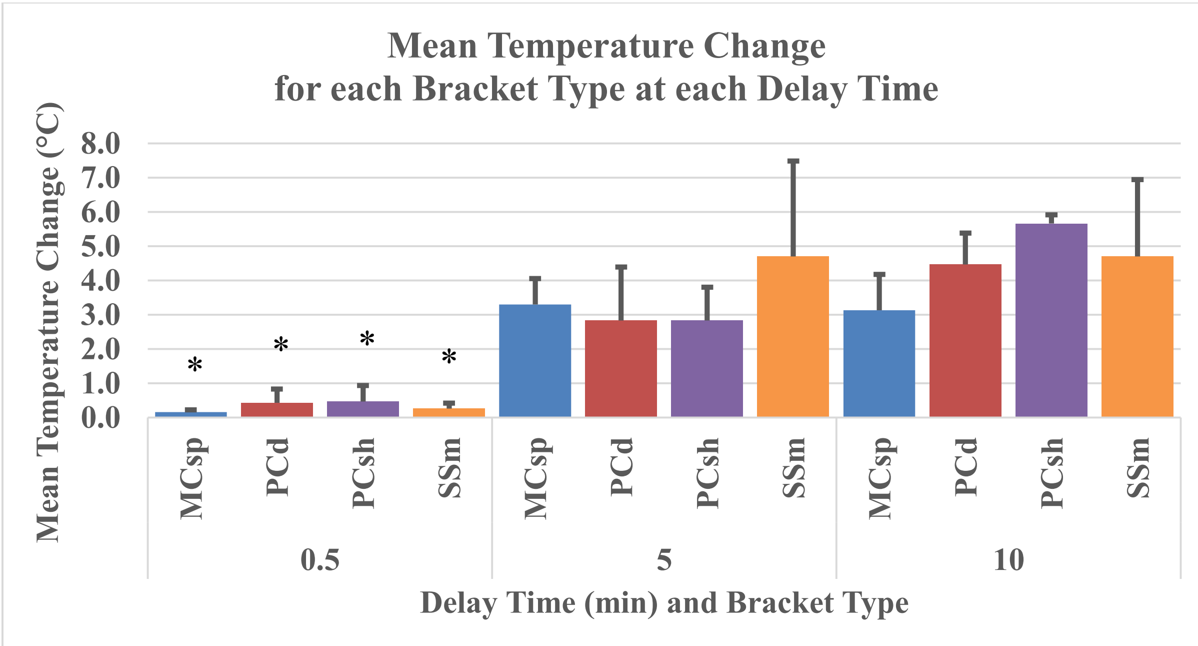


Figure 7. Means and standard deviations of mean temperature change for each delay time and bracket type. Bracket type was not found to be a significant factor; however, delay time was found to be a significant factor. *The 0.5 min delay time had significantly lower changes in mean temperature than the other delay times. (Monocrystalline micro-sphere base (MCsp), polycrystalline dovetail base (PCd), polycrystalline micro-shard base (PCsh), stainless steel mesh base (SSm))

## Shear Bond Strength Measurements

Means and standard deviations of shear bond strengths for each bracket type and delay times are presented in figure 8. Individual specimen shear bond strength measurements ranged from 4.43-20.35 MPa. Based on the 2-Factor ANOVA, as a function of time, there was no significant difference in shear bond strength across bracket types. This did not support the hypothesis that SBS would vary as a function of delayed polymerization time. Differences in SBS were seen as a function of bracket type across all time delays, which supports the hypothesis that SBS would vary as a function of bracket type. The PCsh bracket type had significantly higher shear bond strengths than all other bracket types at each time delay. The partial eta squared value was 0.531, which means that 53.1% of the variability of SBS can be explained as a function of bracket type. As described previously, this is a large effect size. When the PCsh shear bond strengths were compared, there was no difference between delay times for this bracket type.

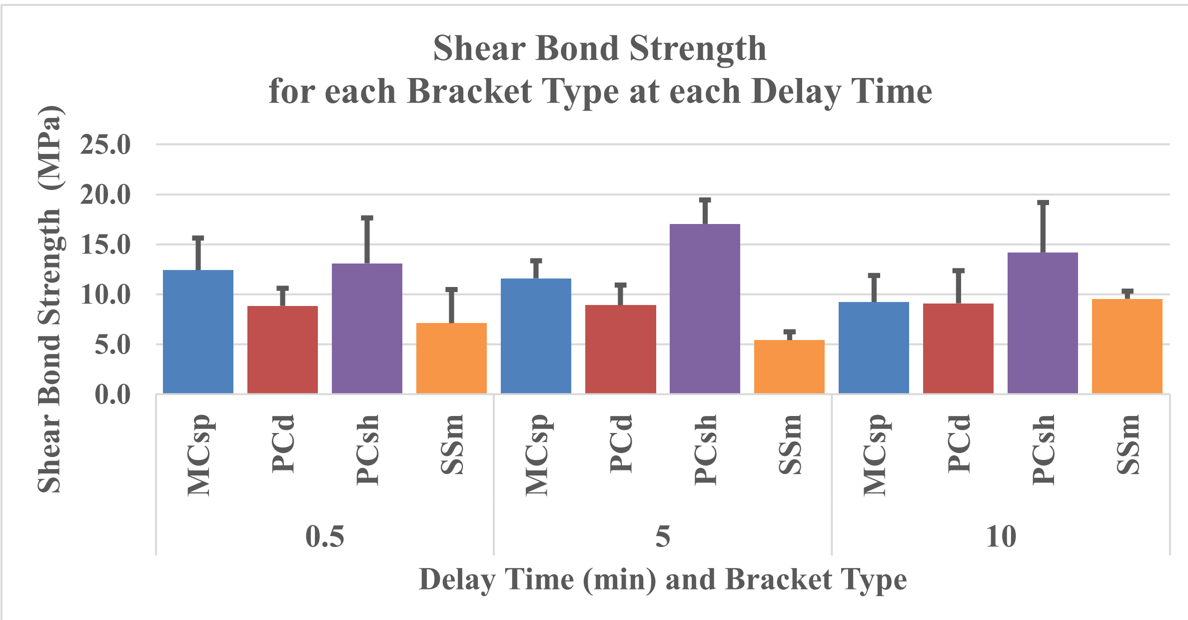


Figure 8. Means and standard deviations of SBS for each delay time and bracket type. Delay time was not a significant factor; however, bracket type was significant. *The PCsh bracket type had significantly higher SBS than all other bracket types but were not different from each other when delay times were compared. (Monocrystalline micro-sphere base (MCsp), polycrystalline dovetail base (PCd), polycrystalline micro-shard base (PCsh), stainless steel mesh base (SSm))

**Degree of Conversion Measurements**

Means and standard deviations for degree of conversion of the bracket adhesive are presented in figure 9. Based on a 2-Factor ANOVA, neither bracket type nor delay time were shown to be a significant factor in DC measurements ($p>0.05$). This does not support the hypothesis that the adhesive degree of conversion will vary as a function of delayed polymerization time and bracket type.

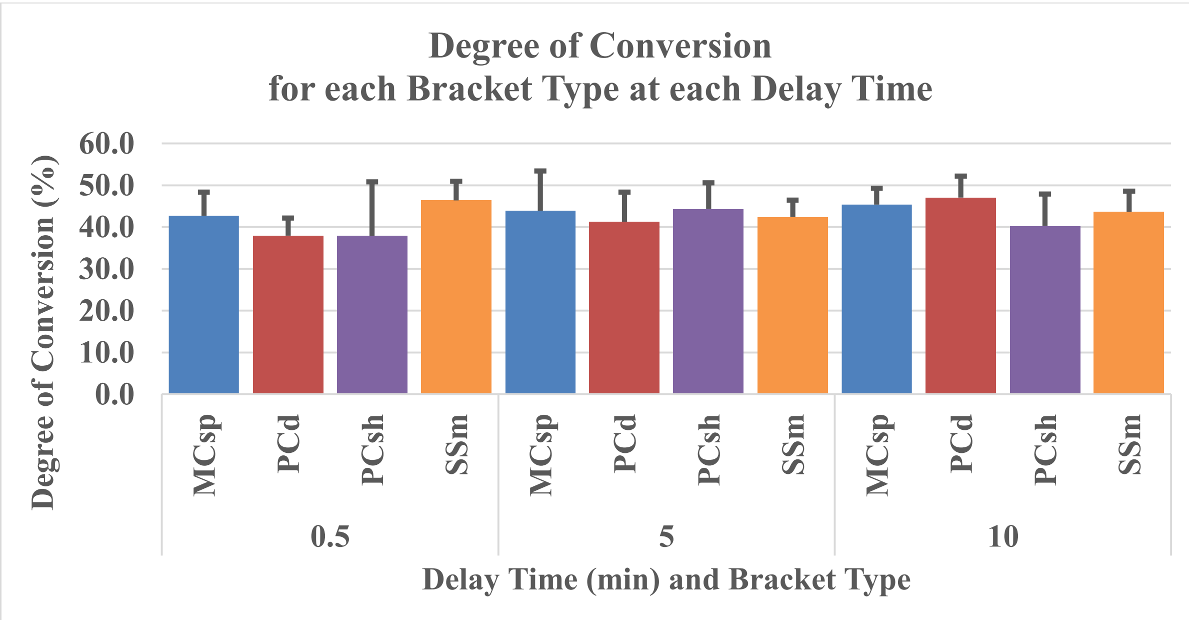


Figure 9. Means and standard deviations for DC of the bracket adhesive for each delay time and bracket type. No significant differences were found. (Monocrystalline micro-sphere base (MCsp), polycrystalline dovetail base (PCd), polycrystalline micro-shard base (PCsh), stainless steel mesh base (SSm))

## Adhesive Remnant Index Measurements

ARI frequency distributions for all bracket types and delay times are presented in Table 2. Representative images of each ARI score are included in figure 10. Based on the Kruskal-Wallis one-way ANOVA, there was no significant difference in ARI as a function of time or bracket type. As noted in the table, a majority of the specimens scored an ARI 1 across all bracket types and delay times. This does not support the hypothesis that the adhesive fracture pattern will vary as a function of delayed polymerization time and/or bracket type.

TABLE 2

ARI FREQUENCY DISTRIBUTIONS

| Bracket Type | Delay Time (min) | Number of Specimens (%) with each ARI Score | | | |
|---|---|---|---|---|---|
| | | 0 | 1* | 2 | 3 |
| MCsp | 0.5 | 0 (0%) | 2 (40%) | 2 (40%) | 1 (20%) |
| | 5 | 0 (0%) | 3 (60%) | 0 (0%) | 2 (40%) |
| | 10 | 0 (0%) | 3 (60%) | 2 (40%) | 0 (0%) |
| PCd | 0.5 | 0 (0%) | 4 (80%) | 1 (20%) | 0 (0%) |
| | 5 | 1 (20%) | 4 (80%) | 0 (0%) | 0 (0%) |
| | 10 | 0 (0%) | 5 (100%) | 0 (0%) | 0 (0%) |
| PCsh | 0.5 | 1 (20%) | 3 (60%) | 0 (0%) | 1 (20%) |
| | 5 | 1 (20%) | 3 (60%) | 0 (0%) | 1 (20%) |
| | 10 | 0 (0%) | 3 (60%) | 1 (20%) | 1 (20%) |
| SSm | 0.5 | 1 (20%) | 4 (80%) | 0 (0%) | 0 (0%) |
| | 5 | 1 (20%) | 4 (80%) | 0 (0%) | 0 (0%) |
| | 10 | 0 (0%) | 3 (60%) | 1 (20%) | 1 (20%) |

*Most specimen fell within the ARI 1 group across all bracket types and delay times.

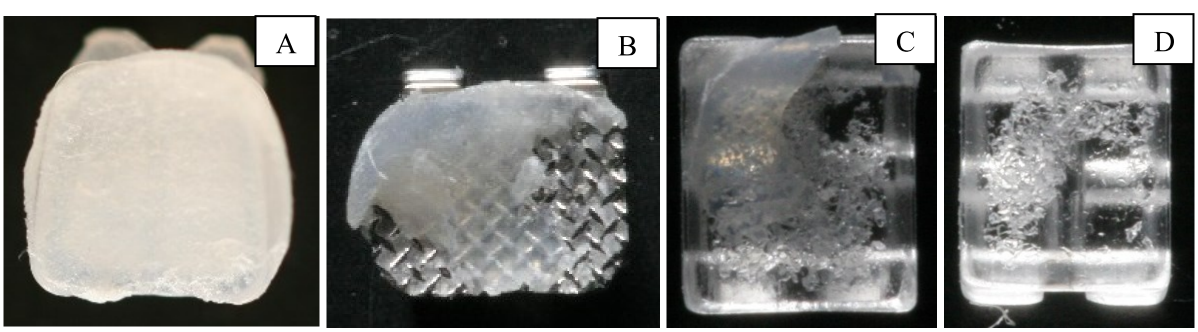


Figure 10. Representative images of debonded bracket bases. ARI score 0 (A), ARI Score 1 (B), ARI Score 2 (C), and ARI Score 3 (D).

## Correlations between Shear Bond Strength, Degree of Conversion, and Adhesive Remnant Index

Based on Spearman correlations, there was a 33% correlation between SBS and ARI across all time delays and bracket types. Looking more closely, across bracket types there was a 57% correlation at the 0.5 min time delay between SBS and ARI. This supports the hypothesis that correlations would exist between SBS and ARI. However, there was no correlation between ARI and SBS as a function of bracket type across time delays. There were no correlations between DC and SBS and DC and ARI and therefore did not support the hypothesis that correlations would be seen between these groups.

# CHAPTER 4

# DISCUSSION

A variety of bracket types, including stainless steel and ceramic options, are now available for use with orthodontic treatment. It is important to understand how differences in bracket properties can be affected by ambient light and heat energy over time which may prematurely initiate the light cure resin composite resin cement under the bracket base (Brantley 2001; Ponikvar 2014). Several studies have investigated the effects of ambient light and bracket manipulation on shear bond strength and degree of conversion of the composite resin (Brantley 2001; Watts 2001; Murfitt et al. 2006; Zachrisson 2012; Ponikvar 2014); however, this is the first study to measure the change in temperature of the resin adhesive beneath the bracket base with delayed polymerization time. In addition, this study investigated shear bond strength, degree of conversion, and debond fracture pattern as a function of bracket type in combination with clinically relevant polymerization delay times.

## Temperature

The data did not support the hypothesis that there would be a difference in the temperature of the adhesive beneath the placed bracket as a function of bracket type. Previous research speculated that due to the differences in intrinsic properties of bracket materials, ambient heat may be transmitted through the bracket types differently. It was hypothesized that an increase in heat transfer, such as with stainless steel brackets, would lead to a decrease in adhesive viscosity and therefore better adaptation to the bracket base (Ponikvar 2014). Our results however did not support this theory. While there was a change in the temperature of the resin adhesive, it was similar across bracket types suggesting that any temperature change is more likely related to heat transfer from the tooth to the resin adhesive. To further explain, during the bonding process, resin adhesive is applied to the bracket base at room temperature outside of the oral cavity (approximately 21 °C). The bracket-adhesive combination is then placed on the tooth surface within the oral cavity (33 °C). According to the second law of thermodynamics, heat flows from a higher temperature to a lower temperature (e.g. from the tooth surface to the resin adhesive) thereby eliminating the effect of the bracket type on resin temperature increase (Atkins 2010b).

This study showed significantly lower mean temperature change for the 0.5 min delay time which supports the hypothesis that the adhesive beneath the placed bracket would vary as a function of delay time. Again, a previous unpublished thesis speculated that there would be a direct relation between polymerization delay time and resin temperature under the bracket base (Ponikvar 2014); however, although a significant change in mean temperature was seen initially, this trend did not continue over time. One possibility is that the temperature of the resin may reach equilibrium with the ambient temperature early during the polymerization delay time. This theory obeys the zeroth law of thermodynamics that defines thermal equilibrium (Atkins 2010a).

### Shear Bond Strength

In terms of delayed polymerization time, the results presented in this study showed that there was no significant difference in shear bond strength across bracket types, which did not support the hypothesis that SBS would vary as a function of delayed polymerization time. This finding goes against the common belief that as the placed bracket undergoes longer polymerization delays while exposed to ambient light conditions, the bond strength decreases due to partial curing of the resin adhesive beneath the bracket base (Brantley 2001; 3M Unitek 2012; Ponikvar 2014). Although it has been speculated that ambient light may decrease bond strength, the consistent SBS values seen over time may suggest that the thickness of the bracket may block or reflect light thereby preventing it from prematurely curing the resin adhesive during the delayed polymerization time. It has also been speculated that manipulation of the bracket after formation of these initial bonds would disrupt their formation thereby further decreasing bond strength (Brantley 2001; 3M Unitek 2012). The current study does not support this theory.

Another factor that was considered was bracket type, and it was demonstrated that the polycrystalline bracket with a micro-shard base (PCsh) had significantly higher shear bond strengths than all other bracket types at each time delay. These results supported the hypothesis that SBS would vary as a function of bracket type. Despite the fact that the bracket with the highest SBS is a ceramic bracket, the other ceramic brackets (another polycrystalline and a monocrystalline), did not demonstrate similar high SBS values. These differences between ceramic brackets is likely related to bracket base design differences. The PCsh bracket is designed with irregular undercuts on the base of the bracket. This patented base design may allow the resin adhesive to adapt more efficiently to the bracket base and thereby produce higher bond strengths. Previous studies have shown that the design of the bracket base can have a significant effect on shear bond strength (Knox et al. 2000; Sharma-Sayal et al. 2003).

While this was a laboratory investigation, the reported shear bond strengths from this study were 4.43-20.35 MPa which is within the clinically relevant range of 3.5-27.8 MPa previously reported in a systematic review by Finnema and colleagues (Finnema et al. 2010). However while the current results suggest clinical relevance, it is always challenging to directly compare laboratory studies to the in vivo situation.

## Degree of Conversion

This study did not support the hypothesis that adhesive degree of conversion would vary as a function of bracket type or delay time. It has been suggested that areas within the resin that were unable to fully polymerize due to an impediment to light would result in lower DC measurements (Finnema et al. 2010; Verma et al. 2013). Therefore, one would expect lower degrees of conversion with the opaque stainless steel bracket type as compared to the ceramic brackets. Furthermore, since the grains within the polycrystalline brackets deflect light at the grain boundary unlike the monocrystalline brackets, one would expect a lower DC value with the polycrystalline material as well. This theory was not supported by the current study, where all bracket types had similar degree of conversion values.

One explanation for the DC results of this study is that the thickness of the ceramic bracket prevented the light from reaching the adhesive beneath the bracket base. Studies have shown that ceramic thickness can have a negative effect on curing depth (Jung et al. 2006). This could result in lower degrees of conversion for the ceramic bracket types thereby giving conversion rates similar to the opaque stainless steel brackets that prevent the passage of light. In addition, all brackets were cured from the mesial and distal of the bracket for consistency within the method and for comparison to previous studies; however, the manufacturer now recommends curing through the ceramic bracket facially to ensure the most effective polymerization to take place (3M Unitek 2009). The angle of the curing light can alter the output and therefore efficiency of polymerization of the resin adhesive. Since the curing light was held at an angle to the surface of the resin instead of perpendicular, this would reduce the amount of light energy delivered to the composite resin during the polymerization process (Konerding et al. 2016).

Resin conversion has been linked to shear bond strength in previous studies (Finnema et al. 2010; Verma et al. 2013). In the current study, differences were seen in shear bond strengths yet no differences were seen in degree of conversion. This could be explained by the fact that degree of conversion does not take into account the crosslinking that occurs with polymerization of the resin adhesive (Watts 2001). Therefore, differences in SBS could be related to the amount of crosslinking present during the polymerization process.

**Adhesive Remnant Index**

The majority of the specimens in this study were in the ARI 1 category which indicates that most of the adhesive remained on the bracket base after debonding. This suggests that there were higher bond strengths at the bracket-adhesive interface than between the adhesive-tooth surface interface for all bracket types and time delays. This is beneficial to the orthodontist because less adhesive on the tooth surface results in both a reduction of appointment time and risk of enamel damage during removal of the remaining adhesive with a handpiece.

Previous studies have reported high MARI scores of 4 or 5 using the modified classification method, indicating that the majority of the adhesive remains on the bracket base (Finnema et al. 2010; Verma et al. 2013). The current study agrees with these findings, which equates to low ARI scores. One explanation for the low ARI scores seen with the current study is that bracket manipulation may have severed initial bonds that formed within the composite resin, thereby increasing the potential for adhesive fracture within the resin adhesive during debond.

## Correlations Between Shear Bond Strength, Degree of Conversion, and Adhesive Remnant Index

There was a moderate to strong positive correlation (57%) between SBS and ARI at the 0.5 min delay time for all bracket types; however, meaningful correlations were not seen for the other delay times. This suggests that the adhesive fracture pattern only relates to the shear bond strength at a minimal delay time when ambient effects are limited. Considering the overall outcomes with minimal effects from bracket type and delay time, it is not surprising that no correlations were seen between DC and SBS and DC and ARI.

## Study Limitations

While this study attempted to simulate oral conditions and control for as many variables as possible, as with any *in vitro* study, there are limitations. For example, although previous studies have suggested that third molars, which were used in this study, can be substituted for premolars in benchtop studies (Ries 2010), the curvature of the bracket base may not adapt as ideally to the surface anatomy of the third molars thereby affecting shear bond strength and ARI scores. In addition, the teeth used in this study had undergone extraction and may have incurred damage in the process. Although all teeth were inspected for anatomic irregularities and decalcification, slight imperfections may have affected the bonding process as well.

Tooth specimens were stored in a PBS solution containing 0.02% sodium azide at 4 °C to prevent microbial proliferation prior to bonding. This solution has different properties from saliva and previous studies have shown that storage solutions can affect shear bond strength (Finnema et al. 2010). In addition, since the teeth were collected over a period of three months, differences in length of storage in the PBS solution may also have affected bond strengths.

All brackets in this study were debonded with a crosshead speed of 1 mm/min in order to compare to previous studies. Although this is the current recommendation for debonding brackets *in vitro*, the forces used in benchtop studies are very different than those used intraorally when debonding a patient.

## Clinical Implications

The current study demonstrated that SBS values were not significantly altered when a delay occurs between bracket placement and final manipulation and curing of the resin cement. This is relevant to many clinicians whose bracket placement is delegated to an orthodontic assistant before final manipulation and polymerization by the orthodontist. Since no differences were seen, the orthodontist need not rush to manipulate the brackets as long as it is completed within ten minutes. It was also shown that the polycrystalline bracket with the micro-shard base had significantly higher bond strengths than the other bracket types; therefore, a clinician may opt to use this bracket over its competitors.

With ARI analyses, for all bracket types, the majority of the brackets fell into the ARI 1 category, meaning less than 50% of the composite remained on the tooth surface, which is preferable. Thus, this study suggests that a clinician need not choose a bracket solely upon the belief that it will require less removal of cement following debond.

## Future Investigations

Based on the current study results, it appears that bracket base design may be the most important factor for differences in SBS. Future studies could compare bracket base design with the same ceramic bracket material to more precisely determine if differences are seen.

Although no enamel damage was seen in the current study, it is still very difficult to remove ceramic brackets at the end of treatment as compared to stainless steel bracket types. With stainless steel brackets, a clinician applies a force to the bracket which causes it to flex and debond from the surface of the tooth. With ceramic brackets, no flexure is possible and much care is required to prevent the bracket from shattering during the debond process. A common procedure is to use a finishing bur to remove all flash around the bracket base and create a purchase point under the bracket. This enables the orthodontist to place a debonding instrument under the edge of the bracket and apply a shear force on the cement beneath the base. This requires much time and lessens efficiency in a busy orthodontic practice. In light of this, companies are now altering the base of the brackets as well as the bracket designs to help ease debond post-treatment. Future studies could investigate whether these new bracket designs have a detrimental effect on shear bond strength and adhesive fracture pattern.

Recently, much attention has been focused on the reduction of white spot lesions in orthodontic patients. Several products have been marketed to prevent enamel decalcification including enamel sealants consisting of unfilled resins as well as resin-modified glass ionomer (RMGI) cements. Although studies have looked at SBS of RMGI adhesives with stainless steel brackets (Gilbert 2015), future studies are needed that focus on the use of these products with ceramic brackets.

# CHAPTER 5

# CONCLUSIONS

1. There was no significant difference in the temperature of the adhesive beneath the placed bracket as a function of bracket type. The 0.5 min polymerization delay time displayed a significantly lower mean temperature change across all bracket types when compared to the 5 min and 10 min delays.
2. There was no significant difference in bracket shear bond strength as a function of delayed polymerization time; however, bracket type did have an effect with the PCsh bracket type demonstrating significantly higher shear bond strengths than all other bracket types at each time delay.
3. There was no significant difference in adhesive degree of conversion as a function of delayed polymerization time or bracket type.
4. There was no significant difference in adhesive remnant index as a function of delayed polymerization time or bracket type with the majority of debonded brackets in ARI 1 category.
5. There was a 57% positive correlation between SBS and ARI at the 0.5 min time delay across bracket types, while there were no correlations between DC and SBS and DC and ARI within each bracket type.

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## APPENDIX 1

## LIGHTING CONDITIONS DATA COLLECTION

## APPENDIX 1

## LIGHTING CONDITIONS DATA COLLECTION

| Lighting Condition | Luxometer Reading (lux) |
|---|---|
| Ambient Light in Orthodontic Office | 451 |
| | 348 |
| | 812 |
| | 554 |
| | 1009 |
| | 462 |
| | 522 |
| | 625 |
| | 692 |
| Direct Light from Chair Unit | 3310 |
| | 5740 |
| | 10180 |
| | 8450 |
| | 12300 |
| | 4220 |
| | 18080 |
| | 3280 |
| | 12050 |

# APPENDIX 2

# DELAY TIME DATA COLLECTION

# APPENDIX 2

## DELAY TIME DATA COLLECTION

| Office Number | Delay Time |
|---|---|
| Office 1 | 8 min 22 sec<br>9 min 4 sec |
| Office 2 | 6 min 37 sec<br>4 min 55 sec |
| Office 3 | 10 min 2 sec<br>7 min 14 sec<br>8 min 43 sec |

# VITA

NAME:

Whitney Nicole DeForest Hewitt

DATE AND PLACE OF BIRTH:

October 13, 1987; St. Charles, Missouri

MARITAL STATUS:

Married

EDUCATION:

| | | |
|---|---|---|
| 2006 | Diploma | St. Charles West High School<br>St. Charles, Missouri |
| 2009 | BS/Biochemistry | University of Missouri<br>Columbia, Missouri |
| 2014 | DDS | University of Missouri-Kansas City School of Dentistry<br>Kansas City, Missouri |

PROFESSIONAL ORGANIZATIONS:

| | |
|---|---|
| 2014-present | American Association of Orthodontists, Member |
| 2014-present | American Dental Association, Member |
| 2014-present | Omicron Kappa Upsilon National Dental Honor Society, Member |
| 2010-2015 | Psi Omega Professional Dental Fraternity, Member |
| 2012-2015 | American Association of Women Dentists, UMKC Chapter President |
| 2012-2013 | AADR-Student Research Group, Co-President |

SELECTED HONORS:

| | |
|---|---|
| 2014 | Dean's Academic Distinction Award, UMKC School of Dentistry |
| 2014 | National Council Scholastic Achievement Award, Psi Omega Fraternity |
| 2014 | American Association of Orthodontists Award, UMKC School of Dentistry |
| 2014 | Quintessence Award for Research Achievement |
| 2014 | Poster Award, Federation of American Societies for Experimental Biology |
| 2013 | Dr. William S. Kramer Award of Excellence, Omicron Kappa Upsilon |
| 2013 | Colgate Research Award, American Association of Women Dentists |
| 2012-2014 | Top Scholar Award, UMKC School of Dentistry |