Measurement and Comparison of Bracket Transfer Accuracy of 5 Indirect Bonding Techniques

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Measurement and Comparison of Bracket Transfer Accuracy of 5 Indirect Bonding Techniques

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ABSTRACT

Objective: To measure and compare the bracket transfer accuracy of 5 indirect bonding (IDB) techniques.

Materials and Methods: Five IDB techniques were studied: Double Polyvinyl Siloxane (Double-PVS), Polyvinyl Siloxane Vacuum-Form (PVS-VF), Polyvinyl Siloxane Putty (PVS-Putty), Double Vacuum-Form (Double-VF), and Single Vacuum-Form (Single-VF). Brackets were bonded on 25 identical stone models (working models). IDB trays were fabricated over these working models (n=5 for each technique) to transfer brackets to another 25 identical stone models (patient models). The mesio-distal (M-D), occluso-gingival (O-G), and facio-lingual (F-L) position of each bracket on working and patient models was measured using digital photography and calipers. Paired T-tests were performed to compare bracket position between working and patient models. Analysis of Variance (ANOVA) was performed to compare bracket transfer accuracy between the 5 techniques for various groups of teeth, separated into 3 directions.

Results: Double-VF had the most teeth (6), while PVS-VF had the least (1) with significant differences ($P < .05$) in bracket position between working and patient models. With the exception of tooth 21 for Single-VF, all significant differences were ≤ 0.26 mm and 58% of those were < 0.125 mm. When comparing the 5 techniques, the bracket transfer accuracy was comparable for Double-PVS, PVS-Putty, and PVS-VF. However, both Double-VF and Single-VF were significantly less accurate in the O-G direction compared to the other techniques.

Conclusions: The silicone-based techniques were comparable in accuracy and overall accurate at transferring bracket position. Double-VF and Single-VF were significantly less accurate in the O-G direction.

INTRODUCTION

Silverman et al[1] described the first technique for indirect bonding (IDB). Trays were fabricated over brackets on dental casts and used to transfer brackets to a patient's mouth. IDB is still popular today and multiple techniques have since been reported in the literature. Benefits include improved patient comfort and reduced chair-time, increasing the overall cost-effectiveness of treatment[1-5]. In theory, IDB allows for improved visibility and access to teeth to more accurately position brackets; also ultimately reducing treatment time. However, this benefit is misguided if the trays do not accurately transfer the brackets from the cast to the teeth. No published studies have measured the accuracy of bracket transfer for any of the common IDB techniques.

The purpose of this study was to measure and compare bracket transfer accuracy of 5 IDB techniques. The hypothesis was that there is no difference in bracket transfer accuracy between the 5 techniques.

MATERIALS AND METHODS:

Orthodontic brackets were bonded on 25 identical stone models (working models). Twenty-five IDB trays were fabricated over these working models; 5 trays for each of the 5 techniques studied (Table 1). Brackets were transferred from working models to another 25 identical stone models (patient models) using the IDB trays. The position of each bracket on working and patient models was measured using digital photography and calipers.

Fabrication of Stone Models

A maxillary typodont was selected (Viade Products, Inc., Camarillo, CA, Model No. 3134) as the master model on which two reference notches per tooth were drilled using a high-speed hand-piece. The first notch was made on each facial surface using a no. 557 carbide bur. The second, on the approximate center of each lingual surface using a no. 6 carbide bur (Figure 1). Three silicone molds of the master model were fabricated (Excel Orthodontics, Inc., Tigard, OR) and used to duplicate the master model 50 times with orthodontic stone (White ISO Type 3, Whip Mix, Louisville, KY). Each working model was poured consecutively with its corresponding patient model as a pair. Twenty-five models were assigned to the working model group and 25 to the patient model group. Five working and 5 patient models were assigned to each technique.

Indirect Bonding (IDB) Technique

Working models were trimmed, labeled, coated with diluted separating agent, and allowed to dry for 8 hours. Adhesive pre-coated brackets (APC II Victory Series, 3M Unitek, Monrovia, CA) were placed into ideal position[6] on the incisors, canines, premolars, and first molars of working models and light-cured on the facial, for 20 seconds per bracket (Ortholux ™ LED, 3M Unitek, Monrovia, CA). Five trays per technique were fabricated over their corresponding working models (Table 1)[2, 7-10]. Reference notches were blocked out with light-cured resin prior to tray fabrication.

IDB trays were soaked in water for 1 hour to allow the separating agent to dissolve, before separating them from their working models. The trays were cleaned in an ultrasonic machine as described by Sondhi[9]. IDB was conducted on patient models using a chemically-cured bonding adhesive (Sondhi™ Rapid-Set Indirect Bonding Adhesive, 3M Unitek, Monrovia, CA). Care was taken to seat each tray over the patient model uniformly. Once seated, each tray was held in place with firm pressure by placement of the investigator's right hand over the occlusal aspect of the tray. For Double-VF and Single-VF, the anterior part of the trays often did not adapt well to the facial surfaces of the teeth, therefore pressure was applied with the left hand to the anterior surface to ensure bonding. After 2.5 minutes, trays were removed.

Photography of Brackets

Bonded teeth on working and patient models were photographed individually using a digital camera (Nikon® D70 body, 105mm Micro Nikkon lens, and Macro Speedlight SB-29 flash) placed on a custom-made jig designed to hold the camera and a removable model positioner (one for each tooth) in a fixed location. Model positioners were made such that the facial surface of each tooth was parallel to the camera lens. For calibration purposes, a millimeter ruler was fixed to the jig (Figure 2).

Measurement of Mesio-Distal (X) and Occluso-Gingival (Y) Bracket Position

Photographs were saved in JPEG format, imported into Adobe® Photoshop® Elements 10 (Version 10.0), and magnified 8.5 times. A coordinate measuring system for each photograph was created as follows:

1. A grid was placed over each image and calibrated so the distance between the gridlines coincided with the distance of 1 mm on the photographed ruler.
2. Each photograph was rotated so horizontal and vertical lines outlining the corner of the reference notch closest to the bracket were parallel to the horizontal and vertical gridlines, respectively.
3. Two colored guidelines were positioned over the reference notch outline. The origin of the grid was set to coincide with the intersection of these 2 guidelines (Figure 3).

Two points per bracket (A and B) were selected. For non-molar teeth, they were located where the interior of the occlusal wings intersect the occlusal edge of the scribe line base. For molars, they were located at the inner corners of the occlusal wings (Figure 3). X and Y coordinate values were obtained for points A and B by marking each point with a colored dot (3 pixels in size) and recording the coordinate values to the nearest hundredth in millimeters, 3 consecutive times.

Measurement of Facio-Lingual (Z) Position

Two points per bracket (C and D) were selected. For non-molar teeth, they were located at the gingival and occlusal ends of the bracket scribe line respectively. For molars, they were located where the gingival and occlusal scribe lines intersected the bracket base, respectively. The F-L position of each bracket was measured by placing the non-mobile end of a digital caliper (ECCO-100795, US Dental Depot Inc., Ft. Lauderdale, FL) at the depth of the lingual reference notch and the mobile end on each one of the points. Measurements were made 3 consecutive times to the nearest hundredth in millimeters (Figure 4).

Statistical Analysis

Paired T-tests were performed to compare bracket position between working and patient models for each direction and tooth. Analysis of Variance (ANOVA) was performed to compare the bracket transfer accuracy between the IDB techniques for various groups of teeth separated into 3 directions. Tukey-post hoc was applied for pair wise comparison. Statistical significance was set at $P< 0.05$. Five models (one per technique) were randomly selected and re-measured for Method Error calculation of photography measurements. Another five models (one per technique) were randomly selected and re-measured for Method Error calculation of caliper measurements. Method Error calculations were made using Dahlberg's formula[11-14]. Five additional models were randomly selected to calculate measurement repeatability.

RESULTS

Repeatability of the Measurements

The standard deviations for the mean of repeated measurements were ≤ 0.04 mm.

Method Error

The Method Error was 0.068 mm for photography measurements and 0.011 mm for caliper measurements.

Debonds

Four of the 300 brackets debonded during removal of IDB trays from patient models. Two were for Double-VF and 2 for Single-VF. All debonds were discarded.

Comparison of Bracket Position between Working and Patient Models (Intragroup Differences)

Double-VF had the most teeth (6) with significant differences in bracket position; while PVS-VF had the least (1). With the exception of tooth 21 for Single-VF, all significant differences were ≤ 0.26 mm and 58% of those were < 0.125 mm. Out of 17 teeth showing significant differences, 10 (at least 1 per technique) showed significant differences in only 1 of 2 points for a given direction (Table 2).

Comparison of Bracket Transfer Accuracy between the 5 IDB Techniques for Various Groups of Teeth (Intergroup Differences)

When comparing the 5 techniques for all teeth grouped, the bracket transfer accuracy was comparable for Double-PVS, PVS-Putty, and PVS-VF. However, both Double-VF and Single-VF were significantly less accurate than these 3 techniques in the O-G direction.

When comparing the techniques for anterior teeth only, Double-VF and Single-VF were again significantly less accurate than the other 3 techniques in the O-G direction (Figure 5). However, when accuracy was compared for posterior teeth, only Single-VF showed a significantly lower O-G accuracy compared to Double-PVS. In the F-L direction, Double-PVS was significantly less accurate compared to PVS-VF and Double-VF (Figure 6). Comparing right versus left side of the arch, there were more significant differences in accuracy on the right than the left (Figure 7).

DISCUSSION

There are no reports in the literature evaluating bracket transfer accuracy of common IDB techniques. IDB was conducted on maxillary stone models using 5 techniques. An aligned arch was chosen to ensure IDB was uniform, eliminating variables such as teeth rotations, teeth shape, and arch shape.

Bracket positions were measured in 3 directions on patient and working models. Because bracket positions on patient models were compared to the position of the same bracket on the working model, working models served as controls for their corresponding patient models. Reference notches provided a reproducible point to measure bracket positions. Repeatability calculations showed the measurements had high precision. Additionally, the Method Error for both photography and caliper measurements was small.

Armstrong et al[15] reported that a $\geq$ 0.25 mm change for upper centrals and lower incisors and a $\geq$ 0.5 mm change for all other teeth, is clinically significant. For this study, clinical significance was set at 0.125 mm for any direction in a given plane of space. If a bracket was off by 0.125 mm in one direction and an adjacent tooth had a bracket off by 0.125 mm in the opposite direction for the same plane of space, the brackets would be 0.25 mm apart and this would be clinically significant. All IDB techniques studied had at least 1 tooth with significant differences in bracket position but most of the clinically significant differences found were for Single-VF and Double-VF. Single-VF had the highest number of teeth with clinically significant changes. Double-PVS was the only technique with no clinically significant changes between working and patient models.

Two points were measured for each direction to evaluate linear and rotational bracket position changes. Ten teeth (at least 1 per technique) showed significant differences in only 1 of 2 points for a given direction. This indicates that differences in bracket position can occur in multiple directions simultaneously, and therefore result in bracket rotation.

The significant differences in the F-L direction for point C on tooth 21, and point D on tooth 16 for Single-VF may be considered invalid because these teeth also had large significant differences in the O-G direction. This results in a change of angulation for the F-L line of measurement when measuring with the calipers. This is inherent to the methodology chosen for measuring F-L bracket position and may be considered a weakness in the study.

When comparing the 5 techniques for all teeth grouped, the bracket transfer accuracy was comparable for the silicone-based techniques. However, both Double-VF and Single-VF were significantly less accurate than the others in the O-G direction. This was also evidenced when the techniques were compared for anterior teeth but not for posterior teeth. When comparing the techniques for posterior teeth, the O-G accuracy was significantly lower only for Single-VF compared to Double-PVS. The mean O-G change for Single-VF in the posterior teeth was only 0.15 mm and though potentially clinically significant, was considerably smaller than the mean O-G changes for Double-VF and Single-VF for the anterior teeth which were 0.29 mm and 0.33 mm, respectively. Double-PVS in the posterior showed a significantly lower accuracy in the F-L direction when compared to PVS-VF and Double-VF, but the mean F-L change for Double-PVS in this group is also small (0.11 mm) and likely not clinically significant.

The lower O-G accuracy found in the anterior for Double-VF and Single-VF can be attributed to the use of vacuum-formed ethyl vinyl acetate (EVA, Bioplast®) sheets for bracket transfer. Because maxillary anterior teeth are longer, the EVA sheets experienced increased elongation in the O-G direction, resulting in decreased thickness of the trays in the anterior compared to the posterior. Ryokawa et al[16] found a statistically significant decrease in both material thickness and elastic modulus (decreased rigidity) for EVA following vacuum-forming. Because the trays for Double-VF and Single-VF sometimes did not adapt well to the facial surfaces of the anterior teeth during IDB, the investigator's left hand was placed over the anterior part of the tray in addition to the right hand being placed over the occlusal part of the tray. This was done to ensure bonding of the anterior brackets, but may have contributed to the bracket position variability seen for anterior teeth in these 2 techniques.

Although Double-VF has an outer polyethylene terphthalate glycol (PETG, Biocryl) tray, the outer PETG tray is not fused in any way with the inner EVA tray and is trimmed on the facial; occlusal to the gingival bracket wings, away from all heights of contour[9]. Thus, the outer tray does not cover the entire O-G dimension of the brackets.

The 3 techniques in this study that showed an overall significantly higher bracket transfer accuracy all used polyvinyl siloxane (addition silicone) as the material in direct contact with both brackets and tooth surfaces. Addition silicone impression materials have been shown to have excellent dimensional stability, superior recovery from deformation (elastic recovery) and high rigidity[17-19]. Additionally, both of the silicone techniques not requiring a vacuum-formed tray (Double-PVS and PVS-Putty) were much thicker facio-lingually (3- 6 mm) than those techniques that did. This thickness may account for the increased rigidity of the silicone techniques in the anterior part of the arch.

Poor or decreased rigidity of an IDB tray may not only result in inaccurate bracket position transfer, but also in an increase in number of bond failures due to poor adaptation. Bhatnagar et al[20] evaluated bond failures for 4 IDB techniques and found the highest percentage of bond failures (50%) for a single tray vacuum-formed technique using a 2 mm EVA (Bioplast®) sheet. Furthermore, there may be different results when making these IDB trays for various types of malocclusions since the thickness of the tray may change in an arch with crowded or rotated teeth.

Comparing the right side versus the left, there were more significant differences in accuracy on the right but most differences were for Single-VF and Double-VF in the O-G direction. This could be the result of differences in hand pressure on the IDB trays or a result of the lower O-G accuracy found with these 2 techniques.

Based on the results of this study, the choice of Double-PVS, PVS-VF, or PVS-Putty techniques for IDB can be made solely on preference. Other things to consider in technique selection are cost, as well as ease of, and time required for tray fabrication. At the time of this study, PVS-Putty was the least expensive of all the techniques and Double-PVS was the most expensive (approximately 12 times the cost of PVS-Putty). PVS-Putty also took the shortest time (approximately 6 minutes per tray) while Double-PVS took the longest time (approximately 20 minutes per tray) to fabricate. Another thing to consider between these 3 techniques is that a chemically cured adhesive must be used for PVS-VF and PVS-Putty because the trays are opaque, while Double-PVS can be carried out with either chemical or light-cured adhesive because the trays are translucent. The translucency of Double-PVS also allows the operator for visual and not just tactile confirmation of complete tray seating during IDB.

CONCLUSIONS

- All IDB techniques studied had at least 1 tooth with significant differences in bracket position but most of the clinically significant differences found were for Single-VF and Double-VF.
- Significant changes in bracket position were not strictly linear; some were rotational.
- When comparing the 5 different techniques, bracket transfer accuracy was comparable for the silicone-based techniques.
- Double-VF and Single-VF were significantly less accurate than the other techniques in the O-G direction. This difference may be due to dimensional and mechanical property changes occurring to the thermoplastic tray materials during vacuum-forming.

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FIGURE LEGENDS

Figure 1. Maxillary Typodont with reference notches on facial and lingual surfaces.

Figure 2. Camera and model positioner are place in a repeatable location by fixed positioning blocks.

Figure 3. Points A and B were used for photography measurements. Points C and D were used for caliper measurements.

Figure 4. The F-L position of each bracket was measured by placing the non-mobile end of a digital caliper at the depth of the lingual reference notch and the mobile end on each one of the points.

Figure 5. *= Accuracy of Double-VF and Single-VF significantly lower than Double-PVS, PVS-Putty, and PVS-VF.

Figure 6. *= Accuracy of Single-VF significantly lower than Double-PVS. += Accuracy of Double-PVS significantly lower than PVS-VF and Double-VF.

Figure 7. *: Accuracy of Double-VF significantly lower than Double-PVS, PVS-Putty, PVS-VF, and Single-VF. +: Accuracy of Single-VF significantly lower than Double-PVS. #: Accuracy of Double-PVS significantly lower than Single-VF. ^: Accuracy of Single-VF significantly lower than Double-PVS, PVS-Putty, PVS-VF, and Double-VF.

Figure 1.

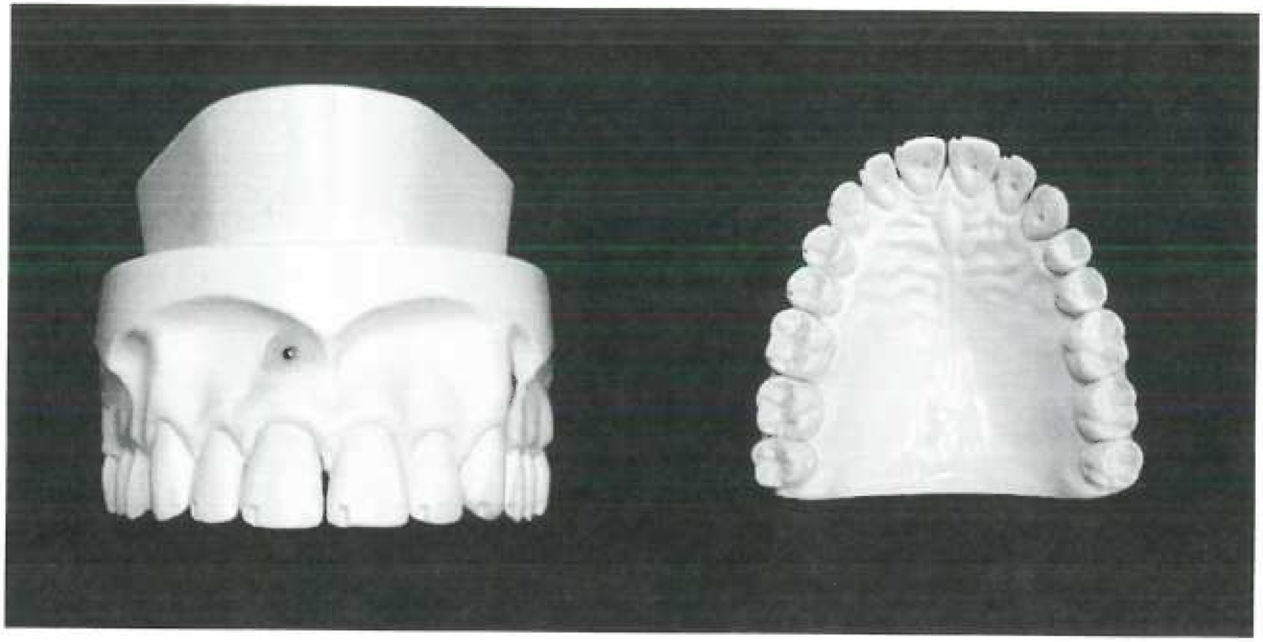


Figure 2.

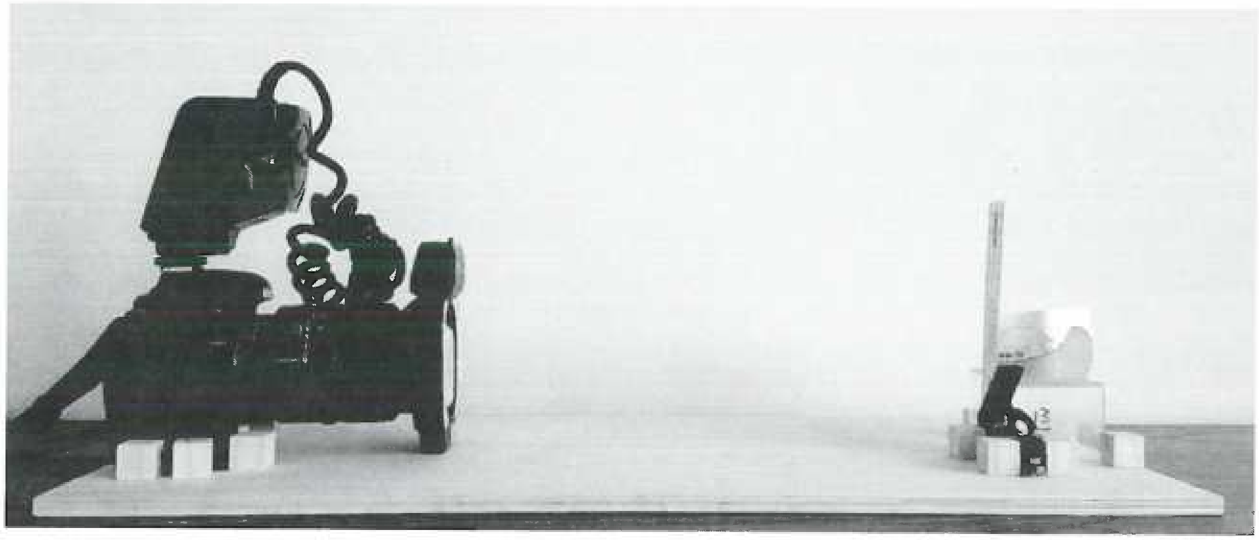


Figure 3.

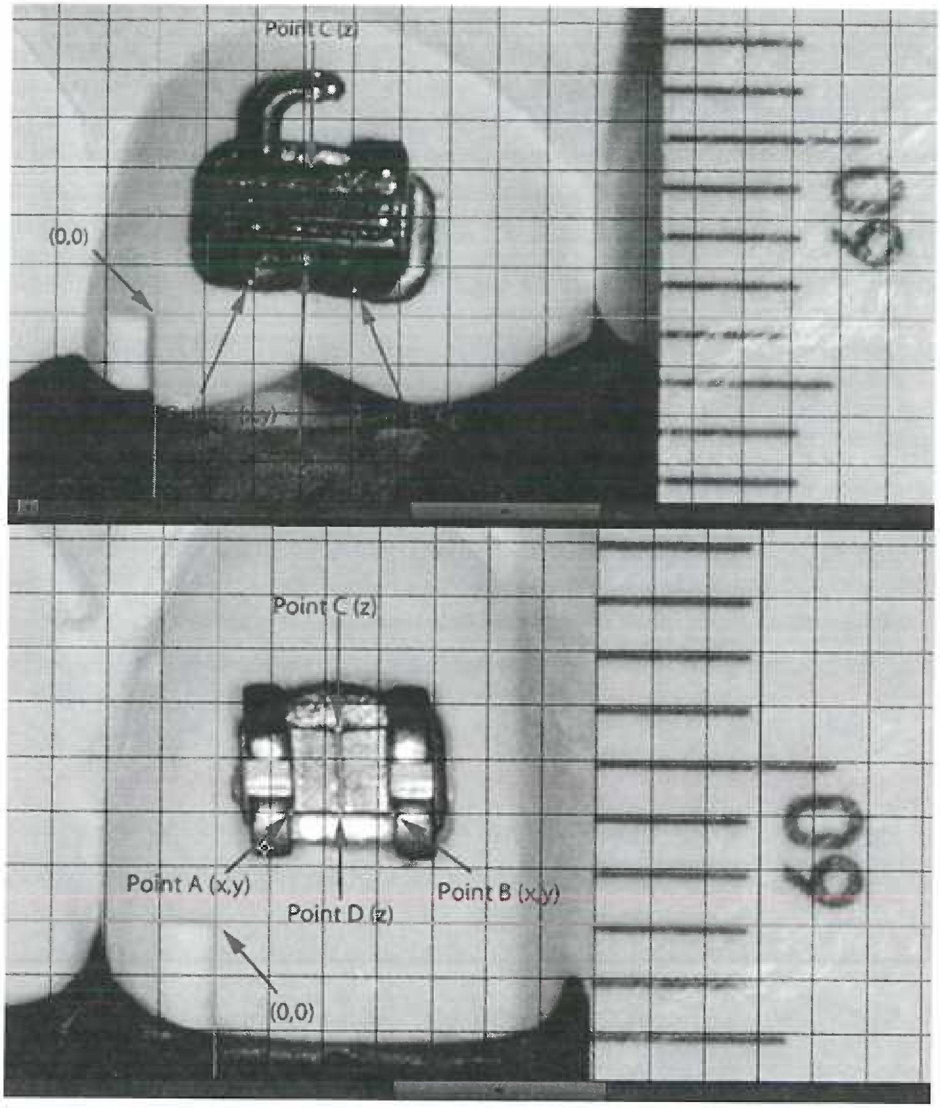


Figure 4.

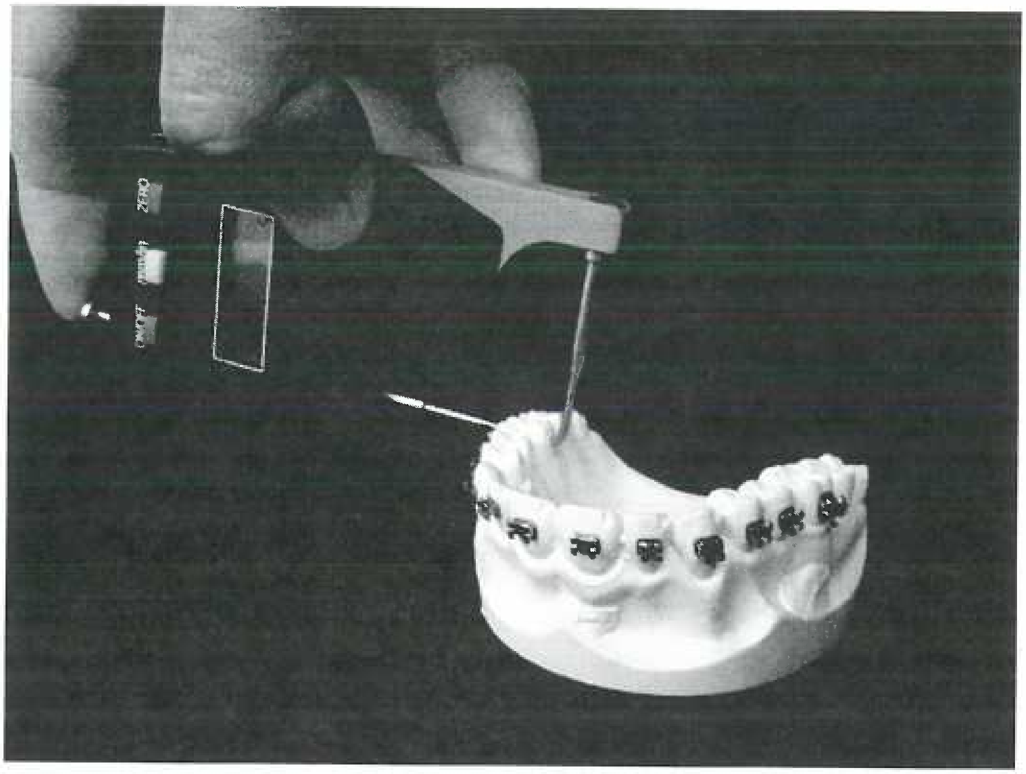


Figure 5.

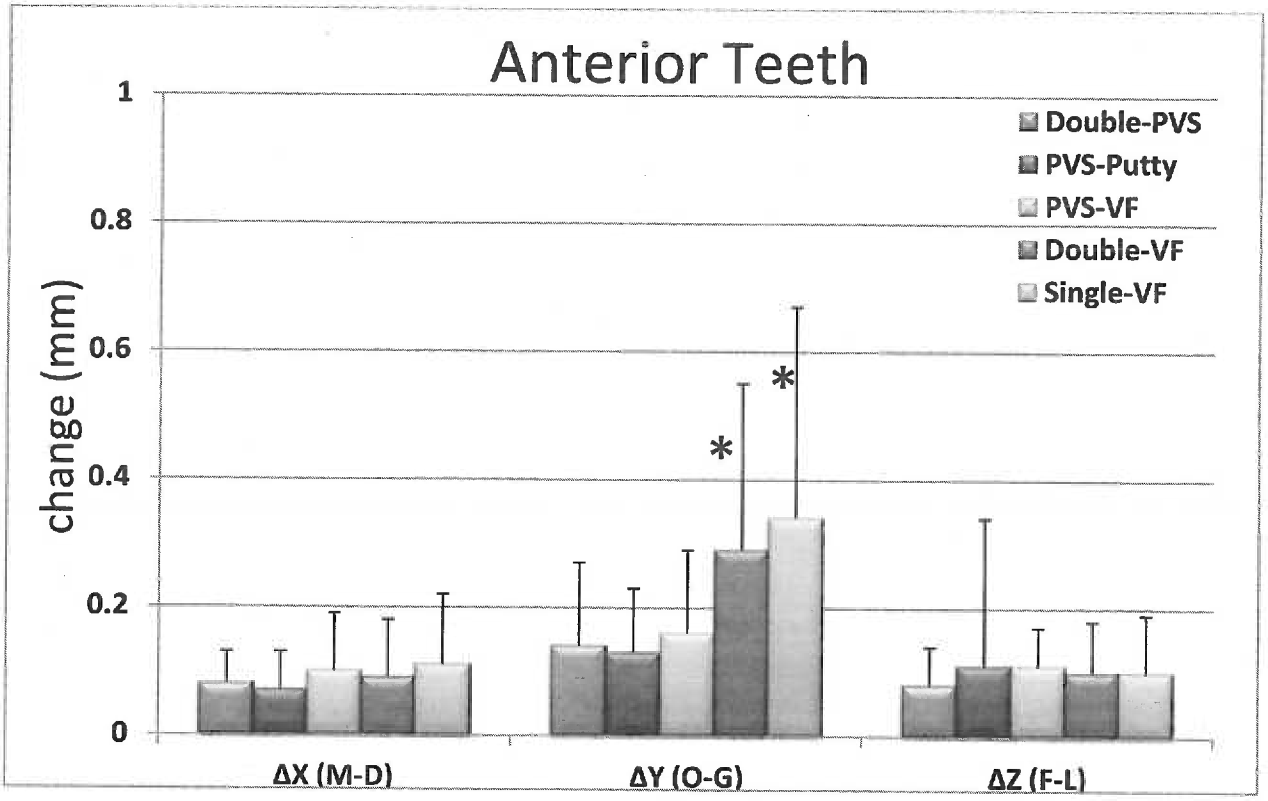

Anterior Teeth
1
0.8
0.6
0.4
0.2
0
change (mm)
Double-PVS
PVS-Putty
PVS-VF
Double-VF
Single-VF
*
*
ΔX (M-D)
ΔY (O-G)
ΔZ (F-L)

Figure 6.

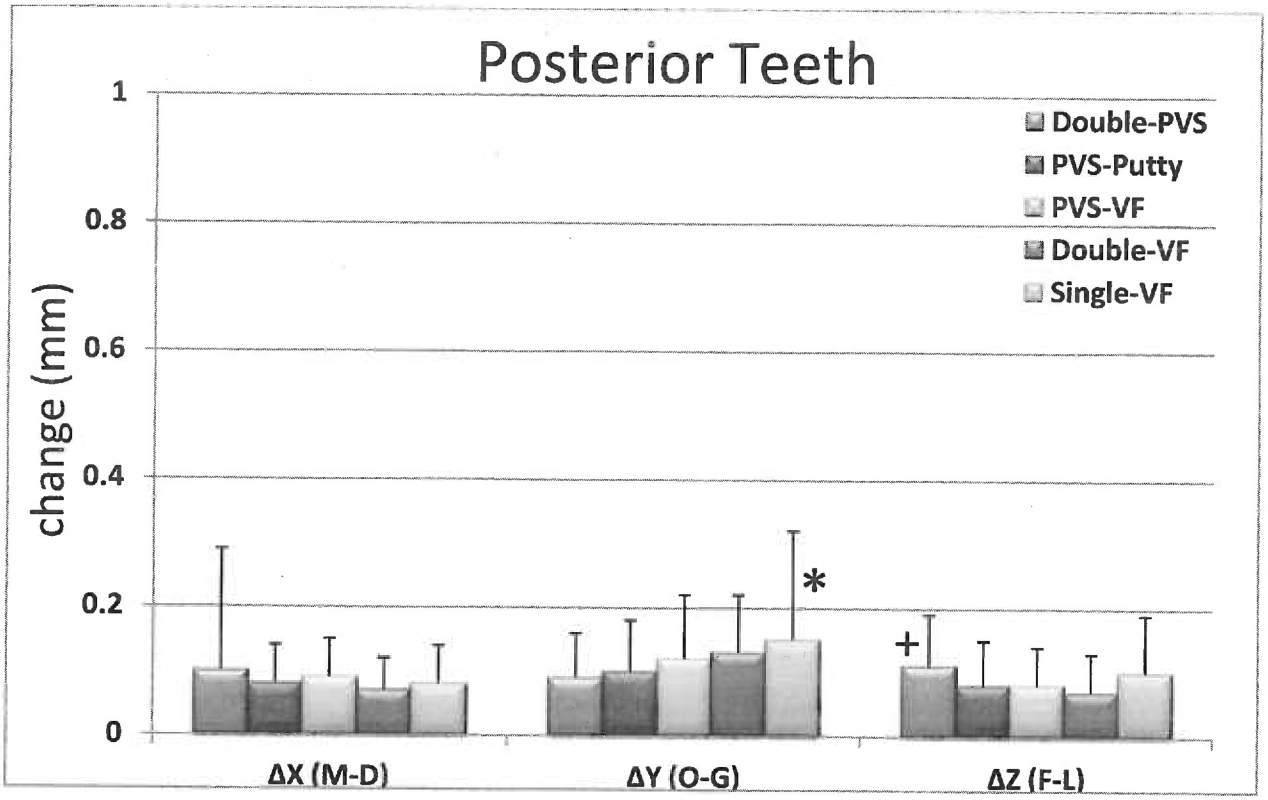
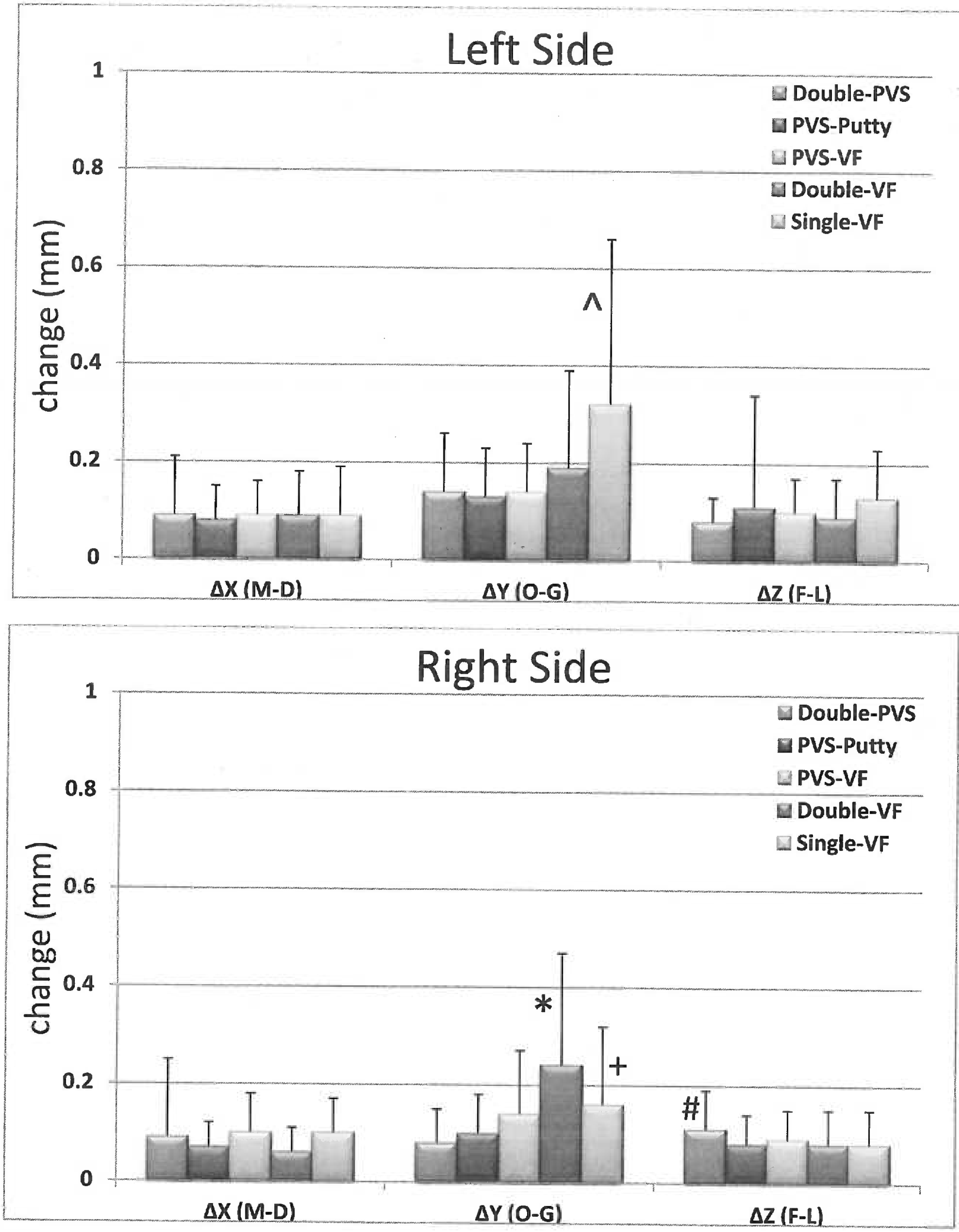

Posterior Teeth
1
0.8
0.6
0.4
0.2
0
change (mm)
Double-PVS
PVS-Putty
PVS-VF
Double-VF
Single-VF
*
+
ΔX (M-D)
ΔY (O-G)
ΔZ (F-L)

Figure 7.



Left Side
change (mm)
1
0.8
0.6
0.4
0.2
0
Double-PVS
PVS-Putty
PVS-VF
Double-VF
Single-VF
^
ΔX (M-D)
ΔY (O-G)
ΔZ (F-L)
Right Side
change (mm)
1
0.8
0.6
0.4
0.2
0
Double-PVS
PVS-Putty
PVS-VF
Double-VF
Single-VF
*
+
#
ΔX (M-D)
ΔY (O-G)
ΔZ (F-L)

Table 1: **Tray Descriptions for Indirect Bonding Techniques Studied**

IDB Technique Name		**Tray Material**	
Code Name	**Proprietary or Published Name**	**Single/Inner**	**Outer**
Double-PVS	Quick IDBS™	Clear soft silicone (Emiluma™, Shofu Co., Tokyo, Japan; or Ortho Kinetics, CA, USA)	Clear Polyvinyl Siloxane (Memosil, Heraeus Kulzer, Hanau, Germany; or Odontsil 50 Dreave Co., Unna, Germany)
Double-VF (Double-Vacuum Form)	Sondhi	Clear vacuum-formed 1.5 mm thick ethyl vinyl acetate (EVA) sheet (Bioplast®, Great Lakes Orthodontics, Tonawanda, NY)	Clear vacuum-formed 0.75mm clear polyethylene terphthalate glycol (PETG) sheet (Biocryl, Great Lakes Orthodontics, Tonawanda, NY)
PVS-VF (PVS-Vacuum Form)	Moskowitz	Light body Polyvinyl Siloxane (Reprosil® LD Caulk Division, Dentsply International, Milford, DE)	Clear vacuum-formed 0.75mm thick co-polyester sheet (Essix A+, Raintree Essix Inc., New Orleans, LA)
PVS-Putty	Kalange	Very High Viscosity Polyvinyl Siloxane putty (Exaflex, GC America, Alsip, IL)	N/A
Single-VF (Single-Vacuum Form)	N/A: modified Thomas technique	Clear vacuum-formed 1.5 mm thick ethyl vinyl acetate (EVA) sheet (Bioplast®, Great Lakes Orthodontics, Tonawanda, NY)	N/A

Table 2. **Differences in Bracket Position between Working and Patient Models Grouped by Technique (Intragroup Differences)***

IDB Technique	Tooth	Measurement Point	Direction⁺	Difference in Mean Bracket Position between Working and Patient Models (mm)⁺	P-value
Double-PVS	24	B	M-D	0.1 (M)	0.041
	14	A	O-G	0.06 (G)	0.002
		B	O-G	0.1 (G)	0.002
	15	A	O-G	0.05 (G)	0.008
		B	O-G	0.06 (G)	0.016
	26	D	F-L	0.08 (F)	0.018
PVS-Putty	21	A	O-G	0.16 (O)	0.048
	16	C	F-L	0.06 (F)	0.039
		D	F-L	0.11 (F)	0.002
PVS-VF	12	A	O-G	0.14 (O)	0.036
Double-VF	23	B	M-D	0.12 (M)	0.035
	24	A	O-G	0.15 (O)	0.013
		B	O-G	0.15 (O)	0.006
	25	A	O-G	0.1 (O)	0.005
		B	O-G	0.08 (O)	0.034
	11	C	F-L	0.13 (L)	0.019
	12	C	F-L	0.08 (L)	0.005
	13	C	F-L	0.08 (L)	0.044
Single-VF	11	B	M-D	0.14 (D)	0.046
	15	A	M-D	0.13 (M)	0.025
		B	M-D	0.12 (M)	0.020
	21	A	O-G	0.45 (O)	0.038
		B	O-G	0.49 (O)	0.037
	16	A	O-G	0.26 (O)	0.045
	21	C	F-L	0.18 (L)	0.009
	16	D	F-L	0.11 (F)	0.028

*: Only Statistically Significant Differences Shown.

+: M= Mesial, D=Distal, O= Occlusal, G= Gingival, F=Facial, L=Lingual.

LITERATURE REVIEW

History of Direct Bonding:

Direct bonding of orthodontic appliances owes its origin in part, to the work of Buonocore who in the mid 1950s was investigating ways to bond restorative materials to enamel surfaces. In 1955, Buonocore[1] demonstrated increased adhesion to enamel of an acrylic filling material by acid pre-treatment (i.e. etching) with 85% phosphoric acid. In 1965, Newman[2] applied these findings when he used 40% phosphoric acid to pre-treat enamel for direct bonding of orthodontic attachments made of plexiglas, polycarbonate, and acrylic using an epoxy adhesive. He conducted both *in vitro* and *in vivo* studies and found the epoxy adhesive joint to be not only of adequate strength, but also safe for use in humans. He did however find the 15 to 30 minute curing time for this epoxy resin to be too long and by 1968, Newman et al[3] reported their investigations of direct bonding of orthodontic attachments using various polymers of methyl methacrylate as adhesive agents. The curing times for these acrylic adhesives were as fast as 5 minutes. Further studies describing the use of acrylic as a satisfactory adhesive soon followed[4, 5].

Newman et al were not the only ones investigating ways to directly bond orthodontic brackets in the late 1960's and early 1970's. Mitchell[6] described a successful, although limited, clinical trial using black copper cement and gold direct attachments. In 1968, Smith[7] introduced a zinc polyacrylate (carboxylate) cement and direct bonding of attachments with this cement was described by Mizrahi et al[8, 9]. In 1970, Retief et al[10] used an epoxy resin system that was able to withstand maximum orthodontic forces (headgear to molar tubes and edgewise torque with rectangular wire). However, like the epoxy resin investigated by Newman, its curing time of 30 minutes, made it too impractical to use.

In 1971, Miura et al[11] described an acrylic resin using tri-n-butyl borane derivative catalyst instead of the more conventional amine-peroxide curing system used by previous investigators. In addition, they used two pre-treatment agents. The first was phosphoric acid which most other investigators were already using. The second was methacryloxyprophyl tri-methoxysilane, an agent meant to react chemically with calcium on the enamel surface. Their system provided not only improved bond strength, but also improved performance in an aqueous environment. A year later, Cohl et al[12] conducted clinical trials and mechanical tests using an ultraviolet light-sensitive acrylic adhesive of the type developed by Buonocore[13] in 1970 for use in pit and fissure sealants.

History of Indirect Bonding (IDB):

Despite the advances in bonding technology and the many advantages of direct bonding over banding, there were many challenges that clinicians experienced with direct bonding. These included:

- Long patient chairtime for bonding of fixed appliances.
- Difficulty in maintaining proper isolation for the entire time required to place full fixed appliances.
- Difficulties with visualization of bracket location, especially in posterior teeth.
- Use of doctor time was still inefficient.

These challenges led to the development of indirect bonding (IDB) of brackets. During IDB, orthodontic brackets were placed on a model of the patient's teeth with full visual access. The brackets were then transferred to the patient's actual teeth all at once with the use of a transfer tray. The benefits of IDB are many and have been listed by several authors[14-18]. They include but are not limited to:

- Improved bracket placement
- Improved patient comfort
- Reduced doctor chairtime
- Reduced patient chairtime and therefore reduced time isolating
- Maximization of staff utilization
- Improved cost effectiveness
- Improved bracket placement accuracy

In 1972, Silverman et al[14] were the first to present a technique of indirect bonding. After attaching brackets to a stone model of a patient's teeth, a plastic transfer tray was hand-formed over this model. When the plastic tray was removed, the brackets separated from the stone cast model and remained inside the tray. The brackets were then bonded to the patient's teeth by positioning these trays over the teeth and seating them by relating them to the occlusal surfaces.

Most current methods of indirect bonding are based on the technique of Thomas[15]; a modification on the technique of Silverman et al[14]. The Thomas technique involved attaching brackets to a stone model using a chemically-cured resin. Once all the brackets were in their proper positions, a transfer tray was fabricated by vacuum-forming a clear plastic tray material over the stone model. Thomas's modification was notable because it was the first to apply the bracket resin cement entirely during the laboratory phase, thereby introducing the first custom resin bracket pad. Prior to that, caramel candy and other types of adhesives where used to attach the brackets to the stone models, then cleaned off after tray fabrication[14, 19]. The adhesive sealant would then be applied chairside, on the brackets in the trays.

In 1993, Cooper et al[20] published an indirect bonding technique that used adhesive pre-coated brackets and a two tray system for transferring the brackets. The trays consisted of a 2mm clear, soft Bioplast®(ethylene vinyl acetate, EVA) sheet vacuum-formed over the stone models with the attached brackets, followed by a 1.5 mm clear hard acrylic sheet vacuum-formed over it. The concept of using two trays had been introduced and recommended by Nakaji and Sheffield at the Table clinic of the 1981 AAO Annual Meeting[21]. The idea behind the two trays was to have an inner tray that was flexible enough to remove after bonding without the risk of debonding the brackets, and an outer tray to provide rigidity for bracket transfer accuracy. After bonding, the outer tray was removed first, leaving the inner tray behind. The softer inner tray could then be carefully peeled off the patient's teeth. In that same year, Hickman[22] published a similar 2 tray technique using the same materials but in different thicknesses: 1 mm Bioplast® for the inner tray and 2 mm Biocryl® for the outer tray.

Thermally cured orthodontic resins soon followed and both Sinha et al[23] and Moskowitz et al[24] published IDB techniques using this type of resin. The resin was used to position the brackets on the stone models and then cured by placing the models with brackets in an oven at 325°F for 15 or 20 minutes. Sinha et al used a silicone impression material in a 1 tray technique, while Moskowitz used a 2 tray system. However, rather than making both the inner and outer tray of thermoplastic materials as heretofore done, Moskowitz described a hybrid technique, using a light-body polyvinyl siloxane (PVS) impression material (Reprosil®) for the inner tray and a vacuum-formed Essix® (co polyester) sheet for the outer tray. The use of opaque impression materials in these 2 techniques required that chemical curing be used chairside.

In 1998, Read et al[25] published a technique that used Memosil®, a clear PVS bite registration material of medium viscosity, to make the IDB tray. This material had the advantages of easy tray fabrication and did not require a vacuum-forming machine. In addition, its transparency allowed the clinician to use either chemical or light-curing adhesives.

While most modern IDB techniques use either silicone impression materials, vacuum-formed thermoplastic materials, or a combination of both, White[26] published his own IDB technique in which the transfer tray was made using a hot glue gun. The glue which formed the tray was composed of ethylene vinyl acetate; essentially the same material used in Bioplast®. Despite the previous introduction of the custom resin bracket base, White used a water-soluble adhesive to place brackets onto the stone models and applied both the resin cement and adhesive sealant, chairside. This was similar to the techniques used prior to that of Thomas.

That same year, Sondhi[27] introduced a 2 tray technique that used two layers of thermoplastic materials vacuum-formed over the stone models with the brackets bonded in place. While this type of tray had been previously described[20, 21], the hallmark of Sondhi's technique was the development of a new bonding adhesive specifically designed for IDB. Previous to that, all the resins had originally been designed for direct bonding and were subsequently just adapted for indirect bonding. Unlike for direct bonding where a generous window of working time is desirable, in IDB there is no use for this because once the tray is placed, the brackets are already in their correct positions. The advantages of this new IDB resin adhesive were increased viscosity to allow small imperfections in the custom base to be taken up by the resin, and a quick set time of 30 seconds, which significantly decreased the time needed to hold the indirect tray in the patient's mouth. This was an improvement from previous techniques employing chemically-cured adhesives which required the tray to stay in place anywhere from 5 to 7 minutes. Sondhi's resin adhesive was completely cured in 2 minutes. Light-curing of course, would also eliminate the need to keep the trays in the patient's mouth for extended periods of time, but this also meant that the trays had to be immediately loaded after placement of the resin adhesive or else risk curing of the adhesive by ambient light.

Soon afterwards, Kalange[28] published his technique for indirect bonding. Like Sondhi, Kalange also used adhesive pre-coated brackets and bonded the brackets chairside using Sondhi's indirect bonding adhesive. However, Kalange favored a single tray technique and used PVS putty (Exaflex®) for fabrication of his IDB trays.

With the increasing popularity of indirect bonding, orthodontic supply companies have also introduced their own versions of indirect bonding techniques. Rocky Mountain Orthodontics' system, RMbond™[29], uses a dual tray system similar to that of Moskowitz, with a PVS impression material as the inner tray, and a clear, vacuum-formed thermoplastic outer tray. Unlike Moskowitz, however, the Rocky Mountain system uses a clear PVS impression material that allows the use of their light-cured bonding adhesive chair-side. The RMbond™ system provides the clear PVS impression material for the inner tray but not the clear thermoplastic material for the outer tray, only recommending a 1 mm thickness for the outer tray of the operator's choice.

In 2007, Koga et al[30] described the Quick Indirect Bonding System (Quick IDBS™). Based on the methods of Sondhi and Kalange, this system used a double-silicone bracket transfer tray. It was, technically speaking, a dual-tray system, however, the inner tray did not cover the entire tooth surfaces as in other dual-tray systems. It instead used a soft silicone material (Emiluma™, Opal Orthodontics) that was expressed only over the brackets, followed by a hard silicone material (Memosil®, Heraeus Kulzer, Hanau, Germany) to form the outer tray. Although the materials used in this technique were translucent and could thus be used with chair-side light-curing, the developers of this technique recommended use of the Sondhi Rapid-set IDB Adhesive (3M Unitek, Monrovia, CA); a chemically-cured adhesive.

Direct Bonding versus Indirect Bonding (IDB):

In order to scientifically quantify the apparent advantages of indirect bonding, most of the studies conducted on indirect bonding have focused on comparing it to the traditional direct bonding techniques. The quality of bonding obtained with direct bonding versus IDB was studied by Zachrisson et al[19] who compared failure rates of direct bonding versus IDB using two different types of resins (small versus coarse filler) and two different types of brackets (mesh-backed vs. perforated brackets). When grouping all of the direct bonded brackets (mesh and perforated together) and comparing them with all the indirect bonded brackets (mesh and perforated together), Zachrisson found the number of failures for IDB to be statistically higher. However, most of the IDB failures came from the perforated brackets, and therefore the bracket design may have been a contributing factor. Furthermore, Read et al[31] also studied bond failure rates using the Thomas IDB technique and found failure rates similar to those previously reported for direct bonding studies. In a practiced-based study, Deahl et al[32] recorded and compared bond failures in 5 orthodontic offices that used direct bonding and 6 that used IDB and found no statistically significant differences between the failure rates of the direct bonding offices and those of the IDB offices. In 1989, Milne et al[33] conducted an *in vitro* study on human teeth and measured both tensile and shear bond strengths of directly bonded and indirectly bonded brackets and found that there were no statistically significant differences between either of the two bracket bonding techniques for both tensile and shear bond strengths. The authors thus concluded that the selection of one bonding technique over another may therefore be determined by the accuracy of bracket positioning and the convenience in handling the materials.

Indeed, one of the purported advantages of IDB is more accurate bracket placement, and a number of studies have compared bracket placement accuracy between direct bonding and IDB. Aguirre et al[34] studied both bracket placement accuracy and bond strength of direct bonded brackets and indirect bonded brackets. The bracket placement was assessed with linear and angular measurements taken on photographs of the brackets *in vivo*. Brackets were photographed using a camera with a jig that engaged on the bracket slot while the bracket was still in the patient's mouth. *In vitro* shear tests of teeth with brackets that were either directly or indirectly bonded were also conducted. Aguirre et al found that both techniques failed to place brackets in ideal positions 100 % of the time. It was found however, that the angulation of both maxillary and mandibular canines was significantly closer to ideal position for the indirect technique. In addition, maxillary canines were also significantly closer to ideal position with respect to height, for indirect bonding. Interestingly, they did find that mandibular second premolars were significantly closer to ideal position with the direct technique. The *in vitro* shear tests showed great variability in bond strength from patient to patient, but after 3 months, the authors found no statistically significant differences in bracket failures recorded between direct bonding and IDB.

In 1999, Koo et al[35] compared bracket placement accuracy between direct bonding and IDB in an *in vitro* study. After either directly bonding or indirectly bonding brackets to stone models, they sectioned the teeth and photographed them using a camera with a jig to compare the bracket positions to those of ideally placed brackets on a stone model that served as the control. The authors found that on average, indirect bonding was more accurate in bracket height, with no significant difference between direct bonding and IDB in terms of angulation and mesio-distal position.

In a clinical study similar to that of Aguirre et al, Hodge et al[36] also compared the accuracy of direct versus indirect bracket bonding. Like previous studies, photography was used to compare bracket placement. However, unlike Aguirre et al who photographed brackets directly in the patients' mouths, Hodge et al made all their measurements on photographs of stone cast models; including the post bond-up brackets. This was done by taking impressions of the patients' teeth after bonding and measuring the post-bonding brackets on the resulting stone models. Their study found no statistically significant difference in overall bracket placement accuracy between direct bonding and IDB. However, the range of error in the three directions assessed (mesio-distal, vertical, and angulation) was greater for the direct technique versus the indirect technique.

Potential disadvantages of IDB include laboratory time for bracket placement and tray fabrication, as well as the cost of the tray materials. In 2001, however, Hodge et al[16] evaluated the cost-effectiveness an IDB technique and found that the savings associated with a reduction in clinical time offset the laboratory costs. They estimated that the use of IDB can cut the clinical time required to carry out a fixed appliance bond-up in half. In addition, they concluded that further savings are possible if molars are routinely bonded, due to a reduction in size of the band inventory.

Bracket Transfer Accuracy with Indirect Bonding (IBD):

There is only 1 study that has measured the bracket transfer accuracy of an IDB technique. This was done by Wendl et al[37] for the Aptus Bonding Device (ABD), a horseshoe-shaped instrument with seven compressed air-driven pistons that use steel wires to transfer brackets from the laboratory working model to the patient's mouth. The bracket transfer accuracy for the ABD system was assessed using both photography and a 3-D laser scanner, and was found to be accurate.

Effect of Different Indirect Bonding Techniques on Bracket Transfer Accuracy:

While it is clear that direct bracket bonding is very operator dependent and that an experienced clinician is capable of accurately bonding brackets directly, it is also clear from the literature that IDB is no less accurate than direct bonding[35, 36]. In fact, it has been shown to be more accurate in bracket height placement and to have a smaller envelope of bracket placement error[35, 36]. There are many IDB techniques being used currently. However, there are no studies that have sought to compare the different IDB techniques with each other. That is, how accurate are different techniques at transferring the bracket positions from the working model to the mouth? In particular, is there a transfer tray material that does this better than others? Several publications have shown that different materials used in common IDB techniques have different mechanical properties even when they are similar[38-41]. Furthermore, it has also been found that different IDB tray materials have sufficiently different properties as to result in significant differences in bond failures and bond strengths[42]. Considering the differences in the properties of various materials used in different IDB techniques, it is possible that there exist differences in bracket transfer accuracy.

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Appendix 1: Descriptive Statistics and Results of Paired T-tests

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Double-PVS	UL1	X	A	W mean	5	1.34	0.25	0.11	1.04	1.62	0.39
				P mean	5	1.29	0.3	0.14	0.96	1.6	
			B	W mean	5	3.22	0.24	0.11	2.94	3.47	0.31
				P mean	5	3.16	0.3	0.13	2.83	3.46	
		Y	A	W mean	5	2.11	0.09	0.04	2.01	2.22	0.1246
				P mean	5	1.92	0.27	0.12	1.55	2.22	
			B	W mean	5	2.17	0.09	0.04	2.09	2.29	0.23
				P mean	5	1.99	0.31	0.14	1.58	2.37	
		Z	C	W mean	5	3.68	0.05	0.02	3.63	3.74	0.0768
				P mean	5	3.64	0.05	0.02	3.59	3.71	
			D	W mean	5	3.38	0.08	0.03	3.28	3.46	0.52
				P mean	5	3.41	0.15	0.07	3.25	3.57	
	UL2	X	A	W mean	5	0.9	0.14	0.06	0.68	1.05	0.14
				P mean	5	0.86	0.18	0.08	0.58	1	
			B	W mean	5	1.94	0.16	0.07	1.67	2.05	0.0724
				P mean	5	1.88	0.21	0.09	1.52	2.06	
		Y	A	W mean	5	1.89	0.11	0.05	1.77	2.02	0.14
				P mean	5	1.74	0.24	0.11	1.49	2.1	
			B	W mean	5	2.03	0.09	0.04	1.91	2.12	0.14
				P mean	5	1.89	0.22	0.1	1.67	2.22	
		Z	C	W mean	5	2.89	0.06	0.03	2.8	2.94	0.38
				P mean	5	2.86	0.07	0.03	2.79	2.98	
			D	W mean	5	3.27	0.09	0.04	3.15	3.38	0.72
				P mean	5	3.26	0.12	0.06	3.08	3.41	
	UL3	X	A	W mean	5	1.17	0.24	0.11	0.91	1.46	0.83
				P mean	5	1.18	0.27	0.12	0.94	1.59	
			B	W mean	5	2.37	0.2	0.09	2.13	2.59	1
				P mean	5	2.37	0.24	0.11	2.14	2.71	
		Y	A	W mean	5	2.32	0.11	0.05	2.14	2.43	0.18
				P mean	5	2.21	0.23	0.1	1.86	2.46	
			B	W mean	5	2.5	0.11	0.05	2.32	2.6	0.17
				P mean	5	2.38	0.24	0.11	2.01	2.65	
		Z	C	W mean	5	5.59	0.08	0.04	5.53	5.73	0.2
				P mean	5	5.53	0.08	0.04	5.43	5.63	
			D	W mean	5	5.11	0.06	0.03	5.05	5.19	0.91
				P mean	5	5.11	0.08	0.04	4.96	5.17	
	UL4	X	A	W mean	5	0.98	0.23	0.1	0.72	1.24	0.66
				P mean	5	1.08	0.33	0.15	0.79	1.64	
			B	W mean	5	2.34	0.24	0.11	2.04	2.6	0.0409
				P mean	5	2.24	0.2	0.09	1.95	2.42	
		Y	A	W mean	5	1.82	0.1	0.05	1.74	1.94	0.45
				P mean	5	1.78	0.2	0.09	1.53	1.99	
			B	W mean	5	1.79	0.09	0.04	1.64	1.86	0.89
				P mean	5	1.77	0.18	0.08	1.55	1.99	
		Z	C	W mean	5	6.83	0.09	0.04	6.71	6.97	0.49
				P mean	5	6.78	0.11	0.05	6.66	6.95	
			D	W mean	5	6.72	0.06	0.03	6.61	6.76	0.96
				P mean	5	6.72	0.08	0.03	6.64	6.83	
	UL5	X	A	W mean	5	0.76	0.21	0.1	0.51	1.01	0.5
				P mean	5	0.74	0.26	0.11	0.38	1.01	
			B	W mean	5	2.16	0.22	0.1	1.91	2.4	0.34
				P mean	5	2.12	0.26	0.11	1.77	2.4	
		Y	A	W mean	5	1.73	0.05	0.02	1.69	1.81	0.37
				P mean	5	1.69	0.09	0.04	1.55	1.78	
			B	W mean	5	1.73	0.17	0.08	1.43	1.84	0.71
				P mean	5	1.76	0.09	0.04	1.66	1.88	
		Z	C	W mean	5	7.61	0.11	0.05	7.5	7.8	0.61
				P mean	5	7.57	0.11	0.05	7.45	7.74	
			D	W mean	5	7.55	0.06	0.03	7.46	7.62	0.96
				P mean	5	7.55	0.09	0.04	7.44	7.66	
	UL6	X	A	W mean	5	1.87	0.09	0.04	1.77	2.02	0.1059
				P mean	5	1.8	0.15	0.07	1.64	2.04	
			B	W mean	5	4.02	0.11	0.05	3.87	4.17	0.0899
				P mean	5	3.95	0.16	0.07	3.77	4.17	
		Y	A	W mean	5	0.66	0.26	0.12	0.29	1	0.97
				P mean	5	0.67	0.31	0.14	0.23	1.09	
			B	W mean	5	0.71	0.33	0.15	0.27	1.21	0.88
				P mean	5	0.7	0.42	0.19	0.25	1.38	
		Z	C	W mean	5	9.4	0.08	0.04	9.33	9.49	0.56
				P mean	5	9.43	0.08	0.04	9.32	9.54	
			D	W mean	5	8.88	0.12	0.05	8.71	9.02	0.018
				P mean	5	8.96	0.1	0.04	8.8	9.06	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Double-PVS	UR1	X	A	W mean	5	1.19	0.12	0.05	1.02	1.3	0.32
				P mean	5	1.14	0.11	0.05	1.03	1.26	
			B	W mean	5	3.03	0.14	0.06	2.9	3.18	0.19
				P mean	5	2.96	0.11	0.05	2.83	3.12	
		Y	A	W mean	5	1.97	0.17	0.08	1.69	2.09	0.12
				P mean	5	1.86	0.25	0.11	1.49	2.12	
			B	W mean	5	1.91	0.17	0.08	1.63	2.04	0.19
				P mean	5	1.79	0.25	0.11	1.45	2.08	
		Z	C	W mean	5	3.27	0.06	0.03	3.19	3.35	0.2
				P mean	5	3.23	0.04	0.02	3.2	3.31	
			D	W mean	5	2.86	0.07	0.03	2.77	2.95	0.66
				P mean	5	2.89	0.16	0.07	2.69	3.05	
	UR2	X	A	W mean	5	0.79	0.15	0.07	0.64	0.96	0.13
				P mean	5	0.75	0.12	0.06	0.59	0.92	
			B	W mean	5	1.85	0.17	0.07	1.59	2	0.56
				P mean	5	1.81	0.1	0.04	1.67	1.91	
		Y	A	W mean	5	1.5	0.15	0.07	1.33	1.69	0.74
				P mean	5	1.48	0.22	0.1	1.28	1.8	
			B	W mean	5	1.39	0.18	0.08	1.18	1.64	0.68
				P mean	5	1.37	0.26	0.11	1.08	1.76	
		Z	C	W mean	5	2.9	0.07	0.03	2.81	3	0.8
				P mean	5	2.89	0.05	0.02	2.81	2.93	
			D	W mean	5	2.69	0.07	0.03	2.62	2.77	0.85
				P mean	5	2.68	0.13	0.06	2.48	2.79	
	UR3	X	A	W mean	5	1.39	0.24	0.11	1.18	1.79	0.94
				P mean	5	1.39	0.22	0.1	1.13	1.69	
			B	W mean	5	2.74	0.2	0.09	2.54	3.06	0.76
				P mean	5	2.72	0.19	0.08	2.47	2.94	
		Y	A	W mean	5	2.09	0.11	0.05	1.96	2.27	0.47
				P mean	5	2.12	0.11	0.05	1.99	2.27	
			B	W mean	5	1.95	0.12	0.06	1.75	2.09	0.96
				P mean	5	1.95	0.06	0.03	1.87	2.01	
		Z	C	W mean	5	5.39	0.15	0.07	5.24	5.61	0.94
				P mean	5	5.38	0.13	0.06	5.17	5.49	
			D	W mean	5	4.89	0.1	0.04	4.78	5.01	0.62
				P mean	5	4.85	0.1	0.05	4.68	4.95	
	UR4	X	A	W mean	5	0.86	0.13	0.06	0.67	1.03	0.45
				P mean	5	1.08	0.66	0.3	0.72	2.26	
			B	W mean	5	2.24	0.14	0.06	2.03	2.4	0.32
				P mean	5	2.19	0.12	0.05	2.06	2.35	
		Y	A	W mean	5	1.92	0.1	0.04	1.77	2.04	0.0015
				P mean	5	1.98	0.1	0.04	1.84	2.09	
			B	W mean	5	1.97	0.09	0.04	1.83	2.07	0.0018
				P mean	5	2.07	0.09	0.04	1.94	2.17	
		Z	C	W mean	5	7.48	0.11	0.05	7.33	7.59	1
				P mean	5	7.48	0.08	0.04	7.35	7.55	
			D	W mean	5	7.55	0.11	0.05	7.42	7.66	0.85
				P mean	5	7.53	0.11	0.05	7.35	7.62	
	UR5	X	A	W mean	5	0.6	0.16	0.07	0.37	0.77	0.57
				P mean	5	0.58	0.18	0.08	0.37	0.72	
			B	W mean	5	1.97	0.18	0.08	1.69	2.13	0.56
				P mean	5	1.94	0.19	0.08	1.73	2.14	
		Y	A	W mean	5	1.82	0.13	0.06	1.64	1.96	0.0075
				P mean	5	1.87	0.14	0.06	1.69	2.02	
			B	W mean	5	1.88	0.16	0.07	1.64	2.06	0.0155
				P mean	5	1.94	0.17	0.08	1.67	2.09	
		Z	C	W mean	5	7.72	0.09	0.04	7.58	7.8	0.52
				P mean	5	7.78	0.1	0.04	7.61	7.86	
			D	W mean	5	7.58	0.06	0.03	7.51	7.66	0.73
				P mean	5	7.61	0.14	0.06	7.41	7.8	
	UR6	X	A	W mean	5	1.83	0.19	0.08	1.67	2.08	0.88
				P mean	5	1.83	0.15	0.07	1.66	2.02	
			B	W mean	5	4.03	0.16	0.07	3.87	4.27	0.61
				P mean	5	4.05	0.13	0.06	3.93	4.27	
		Y	A	W mean	5	0.61	0.12	0.05	0.46	0.74	0.18
				P mean	5	0.69	0.15	0.07	0.46	0.87	
			B	W mean	5	0.54	0.14	0.06	0.36	0.69	0.32
				P mean	5	0.61	0.17	0.08	0.33	0.77	
		Z	C	W mean	5	9.72	0.07	0.03	9.65	9.82	0.38
				P mean	5	9.78	0.07	0.03	9.69	9.84	
			D	W mean	5	9.08	0.13	0.06	8.85	9.17	0.31
				P mean	5	9.17	0.19	0.09	9.03	9.51	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
PVS-Putty	UL1	X	A	W_mean	5	1.32	0.17	0.08	1.05	1.46	0.5
				P_mean	5	1.36	0.1	0.04	1.23	1.5	
			B	W_mean	5	3.22	0.17	0.08	2.96	3.37	0.77
				P_mean	5	3.24	0.08	0.04	3.12	3.31	
		Y	A	W_mean	5	2.14	0.16	0.07	2.01	2.35	0.0477
				P_mean	5	1.98	0.17	0.07	1.73	2.18	
			B	W_mean	5	2.19	0.12	0.06	2.08	2.37	0.0799
				P_mean	5	2.01	0.2	0.09	1.67	2.17	
		Z	C	W_mean	5	3.76	0.14	0.06	3.65	3.95	0.49
				P_mean	5	3.72	0.06	0.03	3.64	3.8	
			D	W_mean	5	3.42	0.06	0.03	3.35	3.51	0.5
				P_mean	5	3.47	0.12	0.06	3.33	3.66	
	UL2	X	A	W_mean	5	0.96	0.2	0.09	0.64	1.18	0.055
				P_mean	5	0.89	0.19	0.08	0.62	1.1	
			B	W_mean	5	2.02	0.26	0.12	1.59	2.28	0.1132
				P_mean	5	1.96	0.23	0.1	1.59	2.24	
		Y	A	W_mean	5	1.8	0.15	0.07	1.64	1.95	0.067
				P_mean	5	1.65	0.19	0.09	1.33	1.86	
			B	W_mean	5	1.9	0.14	0.06	1.76	2.07	0.19
				P_mean	5	1.78	0.19	0.09	1.46	1.96	
		Z	C	W_mean	5	2.91	0.09	0.04	2.82	3.05	0.81
				P_mean	5	2.9	0.05	0.02	2.81	2.96	
			D	W_mean	5	3.27	0.13	0.06	3.2	3.49	0.81
				P_mean	5	3.28	0.1	0.04	3.12	3.36	
	UL3	X	A	W_mean	5	0.98	0.21	0.09	0.79	1.33	0.59
				P_mean	5	1	0.2	0.09	0.82	1.33	
			B	W_mean	5	2.23	0.15	0.07	2.06	2.45	0.89
				P_mean	5	2.24	0.14	0.06	2.09	2.45	
		Y	A	W_mean	5	2.35	0.1	0.04	2.25	2.52	0.11
				P_mean	5	2.24	0.1	0.05	2.13	2.4	
			B	W_mean	5	2.51	0.12	0.05	2.42	2.71	0.29
				P_mean	5	2.41	0.1	0.05	2.32	2.58	
		Z	C	W_mean	5	5.22	0.82	0.37	3.76	5.64	0.43
				P_mean	5	5.54	0.07	0.03	5.43	5.62	
			D	W_mean	5	5.11	0.07	0.03	5.03	5.22	0.54
				P_mean	5	5.08	0.08	0.04	4.95	5.18	
	UL4	X	A	W_mean	5	0.92	0.1	0.04	0.79	1.02	0.38
				P_mean	5	0.86	0.05	0.02	0.79	0.93	
			B	W_mean	5	2.31	0.1	0.04	2.19	2.4	0.27
				P_mean	5	2.22	0.07	0.03	2.13	2.32	
		Y	A	W_mean	5	1.81	0.14	0.06	1.59	1.96	0.3
				P_mean	5	1.74	0.2	0.09	1.56	2.04	
			B	W_mean	5	1.82	0.12	0.06	1.63	1.95	0.78
				P_mean	5	1.8	0.19	0.08	1.64	2.09	
		Z	C	W_mean	5	6.83	0.17	0.08	6.68	7.12	0.52
				P_mean	5	6.77	0.04	0.02	6.72	6.81	
			D	W_mean	5	6.71	0.12	0.06	6.56	6.9	0.34
				P_mean	5	6.78	0.12	0.05	6.66	6.98	
	UL5	X	A	W_mean	5	0.82	0.11	0.05	0.69	0.97	0.16
				P_mean	5	0.76	0.13	0.06	0.59	0.9	
			B	W_mean	5	2.21	0.08	0.03	2.11	2.28	0.1001
				P_mean	5	2.16	0.11	0.05	2.01	2.27	
		Y	A	W_mean	5	1.57	0.14	0.06	1.39	1.69	0.32
				P_mean	5	1.6	0.15	0.07	1.43	1.79	
			B	W_mean	5	1.63	0.14	0.06	1.44	1.76	0.0884
				P_mean	5	1.7	0.18	0.08	1.45	1.91	
		Z	C	W_mean	5	7.58	0.11	0.05	7.46	7.74	0.83
				P_mean	5	7.59	0.05	0.02	7.51	7.62	
			D	W_mean	5	7.53	0.12	0.05	7.38	7.71	0.43
				P_mean	5	7.56	0.05	0.02	7.51	7.64	
	UL6	X	A	W_mean	5	1.88	0.13	0.06	1.67	2.01	0.49
				P_mean	5	1.85	0.1	0.04	1.74	1.95	
			B	W_mean	5	4.01	0.12	0.05	3.82	4.13	0.83
				P_mean	5	4	0.12	0.05	3.85	4.12	
		Y	A	W_mean	5	0.52	0.21	0.09	0.25	0.78	0.22
				P_mean	5	0.6	0.23	0.1	0.31	0.89	
			B	W_mean	5	0.52	0.23	0.1	0.3	0.82	0.11
				P_mean	5	0.67	0.21	0.09	0.44	0.96	
		Z	C	W_mean	5	9.38	0.07	0.03	9.27	9.44	0.28
				P_mean	5	9.43	0.09	0.04	9.32	9.52	
			D	W_mean	5	8.84	0.09	0.04	8.73	8.99	0.12
				P_mean	5	8.9	0.09	0.04	8.8	9.01	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
PVS-Putty	UR1	X	A	W mean	5	1.14	0.2	0.09	0.87	1.41	0.85
				P mean	5	1.15	0.14	0.06	0.95	1.33	
			B	W mean	5	3.03	0.19	0.08	2.8	3.32	0.93
				P mean	5	3.04	0.17	0.07	2.8	3.27	
		Y	A	W mean	5	2.07	0.24	0.11	1.77	2.33	0.4
				P mean	5	2.01	0.24	0.11	1.76	2.37	
			B	W mean	5	1.98	0.28	0.13	1.64	2.27	0.34
				P mean	5	1.9	0.24	0.11	1.64	2.27	
		Z	C	W mean	5	3.38	0.14	0.06	3.24	3.58	0.77
				P mean	5	3.37	0.12	0.05	3.28	3.57	
			D	W mean	5	2.93	0.06	0.03	2.88	3.04	0.27
				P mean	5	3	0.09	0.04	2.94	3.15	
	UR2	X	A	W mean	5	0.63	0.19	0.09	0.44	0.9	0.96
				P mean	5	0.63	0.2	0.09	0.38	0.86	
			B	W mean	5	1.72	0.19	0.09	1.54	2.01	0.82
				P mean	5	1.73	0.19	0.09	1.49	1.91	
		Y	A	W mean	5	1.43	0.22	0.1	1.17	1.69	0.45
				P mean	5	1.38	0.24	0.11	1.13	1.76	
			B	W mean	5	1.35	0.23	0.1	1.1	1.63	0.46
				P mean	5	1.31	0.26	0.12	1.05	1.69	
		Z	C	W mean	5	2.97	0.07	0.03	2.87	3.04	0.6
				P mean	5	2.95	0.04	0.02	2.92	3.02	
			D	W mean	5	2.81	0.1	0.04	2.76	2.98	0.91
				P mean	5	2.81	0.13	0.06	2.63	2.98	
	UR3	X	A	W mean	5	1.27	0.37	0.16	0.85	1.6	0.0916
				P mean	5	1.19	0.31	0.14	0.84	1.49	
			B	W mean	5	2.65	0.38	0.17	2.22	2.99	0.11
				P mean	5	2.55	0.3	0.13	2.19	2.88	
		Y	A	W mean	5	2.02	0.13	0.06	1.88	2.18	0.48
				P mean	5	2.06	0.09	0.04	1.95	2.17	
			B	W mean	5	1.86	0.12	0.05	1.69	2.01	0.19
				P mean	5	1.94	0.09	0.04	1.83	2.05	
		Z	C	W mean	5	5.44	0.08	0.04	5.34	5.55	0.6
				P mean	5	5.46	0.12	0.05	5.27	5.57	
			D	W mean	5	4.91	0.06	0.03	4.83	4.97	0.3
				P mean	5	4.95	0.1	0.04	4.78	5.02	
	UR4	X	A	W mean	5	0.86	0.16	0.07	0.67	1.1	0.24
				P mean	5	0.82	0.15	0.07	0.67	1.05	
			B	W mean	5	2.22	0.12	0.05	2.06	2.39	0.18
				P mean	5	2.17	0.12	0.06	2.04	2.32	
		Y	A	W mean	5	1.94	0.19	0.09	1.73	2.21	0.78
				P mean	5	1.96	0.13	0.06	1.75	2.09	
			B	W mean	5	1.97	0.19	0.09	1.78	2.26	0.39
				P mean	5	2.03	0.14	0.06	1.81	2.19	
		Z	C	W mean	5	7.55	0.08	0.04	7.45	7.62	0.76
				P mean	5	7.56	0.08	0.03	7.46	7.66	
			D	W mean	5	7.58	0.12	0.05	7.41	7.72	0.19
				P mean	5	7.66	0.08	0.04	7.57	7.78	
	UR5	X	A	W mean	5	0.79	0.27	0.12	0.59	1.2	0.88
				P mean	5	0.78	0.29	0.13	0.54	1.28	
			B	W mean	5	2.19	0.26	0.12	2	2.58	0.62
				P mean	5	2.16	0.23	0.1	1.93	2.54	
		Y	A	W mean	5	1.7	0.11	0.05	1.62	1.85	0.0604
				P mean	5	1.78	0.11	0.05	1.65	1.94	
			B	W mean	5	1.74	0.11	0.05	1.59	1.88	0.13
				P mean	5	1.87	0.14	0.06	1.67	2.01	
		Z	C	W mean	5	7.8	0.05	0.02	7.73	7.87	0.4
				P mean	5	7.85	0.12	0.05	7.71	8.01	
			D	W mean	5	7.61	0.08	0.03	7.52	7.69	0.31
				P mean	5	7.66	0.09	0.04	7.54	7.74	
	UR6	X	A	W mean	5	1.93	0.14	0.06	1.81	2.1	0.3
				P mean	5	1.9	0.11	0.05	1.76	2.06	
			B	W mean	5	4.11	0.15	0.07	3.96	4.3	0.54
				P mean	5	4.09	0.1	0.04	3.98	4.24	
		Y	A	W mean	5	0.48	0.14	0.06	0.32	0.68	0.47
				P mean	5	0.51	0.14	0.06	0.3	0.63	
			B	W mean	5	0.48	0.23	0.1	0.26	0.83	0.77
				P mean	5	0.5	0.19	0.09	0.22	0.73	
		Z	C	W mean	5	9.76	0.04	0.02	9.71	9.81	0.0388
				P mean	5	9.82	0.03	0.01	9.8	9.88	
			D	W mean	5	9.07	0.21	0.09	8.84	9.39	0.0022
				P mean	5	9.18	0.23	0.1	8.93	9.54	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
PVS-VF	UL1	X	A	W mean	5	1.37	0.18	0.08	1.06	1.5	0.0667
				P mean	5	1.27	0.19	0.09	1	1.44	
			B	W mean	5	3.24	0.18	0.08	2.93	3.37	0.0582
				P mean	5	3.13	0.19	0.08	2.86	3.29	
		Y	A	W mean	5	2.28	0.1	0.05	2.14	2.4	0.11
				P mean	5	2.17	0.17	0.08	1.92	2.39	
			B	W mean	5	2.29	0.11	0.05	2.13	2.42	0.32
				P mean	5	2.21	0.18	0.08	1.94	2.45	
		Z	C	W mean	5	3.73	0.14	0.06	3.53	3.86	0.7
				P mean	5	3.71	0.05	0.02	3.63	3.76	
			D	W mean	5	3.37	0.1	0.05	3.25	3.48	0.71
				P mean	5	3.41	0.11	0.05	3.27	3.51	
	UL2	X	A	W mean	5	0.91	0.13	0.06	0.79	1.09	0.29
				P mean	5	0.97	0.13	0.06	0.79	1.11	
			B	W mean	5	1.97	0.15	0.07	1.82	2.17	0.23
				P mean	5	2.03	0.15	0.07	1.83	2.19	
		Y	A	W mean	5	1.83	0.05	0.02	1.77	1.88	0.15
				P mean	5	1.71	0.16	0.07	1.56	1.96	
			B	W mean	5	1.95	0.06	0.03	1.86	1.99	0.11
				P mean	5	1.79	0.16	0.07	1.64	2.04	
		Z	C	W mean	5	2.84	0.12	0.06	2.7	2.99	0.95
				P mean	5	2.85	0.08	0.04	2.73	2.96	
			D	W mean	5	3.24	0.13	0.06	3.1	3.39	1
				P mean	5	3.24	0.09	0.04	3.13	3.37	
	UL3	X	A	W mean	5	1.05	0.2	0.09	0.83	1.28	0.66
				P mean	5	1.01	0.14	0.06	0.82	1.21	
			B	W mean	5	2.28	0.15	0.07	2.11	2.46	0.38
				P mean	5	2.23	0.12	0.05	2.06	2.37	
		Y	A	W mean	5	2.32	0.17	0.08	2.02	2.43	0.61
				P mean	5	2.29	0.17	0.08	2.06	2.55	
			B	W mean	5	2.46	0.18	0.08	2.14	2.59	0.76
				P mean	5	2.48	0.18	0.08	2.27	2.77	
		Z	C	W mean	5	5.57	0.09	0.04	5.46	5.64	0.0922
				P mean	5	5.48	0.04	0.02	5.44	5.52	
			D	W mean	5	5.11	0.09	0.04	5	5.21	0.21
				P mean	5	5.04	0.08	0.04	4.91	5.11	
	UL4	X	A	W mean	5	0.82	0.23	0.1	0.54	1.14	0.6
				P mean	5	0.84	0.22	0.1	0.62	1.18	
			B	W mean	5	2.15	0.27	0.12	1.83	2.53	0.48
				P mean	5	2.18	0.25	0.11	1.91	2.53	
		Y	A	W mean	5	1.95	0.12	0.05	1.78	2.06	0.5
				P mean	5	1.89	0.13	0.06	1.67	2.02	
			B	W mean	5	1.98	0.11	0.05	1.78	2.06	0.44
				P mean	5	1.89	0.15	0.07	1.64	2.04	
		Z	C	W mean	5	6.85	0.09	0.04	6.75	6.99	0.1001
				P mean	5	6.77	0.08	0.03	6.68	6.87	
			D	W mean	5	6.73	0.09	0.04	6.58	6.83	0.22
				P mean	5	6.66	0.1	0.04	6.54	6.77	
	UL5	X	A	W mean	5	0.57	0.13	0.06	0.41	0.73	0.94
				P mean	5	0.57	0.1	0.05	0.46	0.71	
			B	W mean	5	1.96	0.14	0.06	1.79	2.14	0.8
				P mean	5	1.95	0.1	0.04	1.86	2.09	
		Y	A	W mean	5	1.66	0.15	0.07	1.41	1.81	0.33
				P mean	5	1.59	0.12	0.05	1.44	1.76	
			B	W mean	5	1.72	0.16	0.07	1.45	1.86	0.49
				P mean	5	1.67	0.13	0.06	1.51	1.83	
		Z	C	W mean	5	7.61	0.08	0.04	7.48	7.69	0.14
				P mean	5	7.51	0.14	0.06	7.34	7.65	
			D	W mean	5	7.54	0.09	0.04	7.46	7.69	0.35
				P mean	5	7.5	0.13	0.06	7.37	7.66	
	UL6	X	A	W mean	5	2.09	0.19	0.08	1.78	2.26	0.25
				P mean	5	2.03	0.23	0.1	1.69	2.25	
			B	W mean	5	4.24	0.19	0.09	3.93	4.43	0.43
				P mean	5	4.2	0.23	0.1	3.87	4.42	
		Y	A	W mean	5	0.68	0.13	0.06	0.51	0.87	0.73
				P mean	5	0.65	0.09	0.04	0.5	0.73	
			B	W mean	5	0.55	0.19	0.09	0.31	0.79	0.83
				P mean	5	0.53	0.15	0.07	0.33	0.67	
		Z	C	W mean	5	9.39	0.1	0.04	9.25	9.52	0.2
				P mean	5	9.32	0.09	0.04	9.21	9.44	
			D	W mean	5	8.85	0.13	0.06	8.75	9.07	0.96
				P mean	5	8.85	0.14	0.06	8.68	9.02	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
PVS-VF	UR1	X	A	W mean	5	1.24	0.1	0.05	1.07	1.32	0.15
				P mean	5	1.17	0.13	0.06	0.99	1.31	
			B	W mean	5	3.07	0.11	0.05	2.92	3.22	0.24
				P mean	5	3.02	0.13	0.06	2.86	3.2	
		Y	A	W mean	5	2.21	0.18	0.08	2	2.41	0.79
				P mean	5	2.19	0.29	0.13	1.91	2.63	
			B	W mean	5	2.15	0.17	0.07	1.99	2.4	0.87
				P mean	5	2.14	0.29	0.13	1.88	2.58	
		Z	C	W mean	5	3.39	0.16	0.07	3.23	3.61	0.86
				P mean	5	3.38	0.12	0.05	3.26	3.52	
			D	W mean	5	2.91	0.1	0.04	2.79	2.98	0.9
				P mean	5	2.92	0.08	0.04	2.83	3.01	
	UR2	X	A	W mean	5	0.8	0.15	0.07	0.59	0.95	0.7
				P mean	5	0.83	0.16	0.07	0.62	1.05	
			B	W mean	5	1.87	0.13	0.06	1.67	1.99	0.78
				P mean	5	1.89	0.1	0.05	1.76	2.01	
		Y	A	W mean	5	1.64	0.08	0.03	1.59	1.77	0.0362
				P mean	5	1.5	0.08	0.04	1.44	1.64	
			B	W mean	5	1.53	0.09	0.04	1.44	1.68	0.052
				P mean	5	1.38	0.1	0.04	1.27	1.54	
		Z	C	W mean	5	2.99	0.12	0.05	2.85	3.12	0.55
				P mean	5	2.95	0.04	0.02	2.9	3.01	
			D	W mean	5	2.72	0.05	0.02	2.65	2.79	0.89
				P mean	5	2.73	0.08	0.04	2.62	2.81	
	UR3	X	A	W mean	5	1.42	0.14	0.06	1.26	1.64	0.23
				P mean	5	1.51	0.13	0.06	1.32	1.64	
			B	W mean	5	2.78	0.13	0.06	2.63	2.99	0.19
				P mean	5	2.87	0.11	0.05	2.71	2.99	
		Y	A	W mean	5	2.01	0.13	0.06	1.79	2.11	0.33
				P mean	5	1.89	0.21	0.09	1.59	2.19	
			B	W mean	5	1.87	0.17	0.08	1.58	2.02	0.39
				P mean	5	1.72	0.26	0.12	1.37	2.11	
		Z	C	W mean	5	5.39	0.05	0.02	5.33	5.46	0.69
				P mean	5	5.36	0.11	0.05	5.26	5.54	
			D	W mean	5	4.92	0.05	0.02	4.85	4.97	0.47
				P mean	5	4.89	0.09	0.04	4.78	5.01	
	UR4	X	A	W mean	5	0.87	0.11	0.05	0.72	1	0.67
				P mean	5	0.87	0.12	0.05	0.72	1.04	
			B	W mean	5	2.21	0.07	0.03	2.09	2.28	0.37
				P mean	5	2.24	0.1	0.04	2.11	2.36	
		Y	A	W mean	5	1.97	0.14	0.06	1.82	2.17	0.59
				P mean	5	1.95	0.15	0.07	1.76	2.17	
			B	W mean	5	2.02	0.17	0.07	1.83	2.26	0.9
				P mean	5	2.02	0.17	0.08	1.77	2.22	
		Z	C	W mean	5	7.55	0.06	0.03	7.47	7.61	0.73
				P mean	5	7.53	0.09	0.04	7.45	7.65	
			D	W mean	5	7.58	0.05	0.02	7.5	7.62	0.52
				P mean	5	7.6	0.1	0.05	7.5	7.73	
	UR5	X	A	W mean	5	0.82	0.11	0.05	0.72	0.97	0.78
				P mean	5	0.8	0.16	0.07	0.55	0.96	
			B	W mean	5	2.19	0.08	0.04	2.09	2.27	0.79
				P mean	5	2.18	0.13	0.06	1.97	2.32	
		Y	A	W mean	5	1.86	0.08	0.04	1.78	1.99	0.39
				P mean	5	1.9	0.08	0.04	1.78	2	
			B	W mean	5	1.95	0.13	0.06	1.87	2.17	0.36
				P mean	5	2.01	0.15	0.07	1.8	2.18	
		Z	C	W mean	5	7.8	0.1	0.04	7.72	7.97	0.92
				P mean	5	7.8	0.04	0.02	7.77	7.88	
			D	W mean	5	7.59	0.05	0.02	7.53	7.66	0.27
				P mean	5	7.63	0.07	0.03	7.56	7.72	
	UR6	X	A	W mean	5	1.83	0.26	0.12	1.41	2.09	0.52
				P mean	5	1.78	0.37	0.16	1.22	2.24	
			B	W mean	5	4.03	0.27	0.12	3.66	4.35	0.56
				P mean	5	3.99	0.32	0.14	3.53	4.42	
		Y	A	W mean	5	0.56	0.19	0.08	0.24	0.73	0.55
				P mean	5	0.6	0.09	0.04	0.5	0.72	
			B	W mean	5	0.54	0.23	0.1	0.15	0.69	0.42
				P mean	5	0.62	0.08	0.04	0.55	0.73	
		Z	C	W mean	5	9.75	0.07	0.03	9.66	9.83	0.39
				P mean	5	9.8	0.1	0.05	9.7	9.96	
			D	W mean	5	9.11	0.13	0.06	8.94	9.29	0.13
				P mean	5	9.16	0.14	0.06	8.94	9.31	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Double-VF	UL1	X	A	W mean	5	1.48	0.19	0.09	1.31	1.78	0.19
				P mean	5	1.34	0.16	0.07	1.12	1.51	
			B	W mean	5	3.31	0.14	0.06	3.17	3.5	0.2
				P mean	5	3.18	0.16	0.07	2.99	3.39	
		Y	A	W mean	5	2.27	0.15	0.07	2.05	2.41	0.31
				P mean	5	2.06	0.52	0.23	1.15	2.43	
			B	W mean	5	2.26	0.18	0.08	1.99	2.42	0.45
				P mean	5	2.1	0.6	0.27	1.1	2.63	
		Z	C	W mean	5	3.69	0.17	0.07	3.57	3.97	0.22
				P mean	5	3.63	0.09	0.04	3.5	3.76	
			D	W mean	5	3.36	0.08	0.04	3.29	3.5	0.49
				P mean	5	3.41	0.13	0.06	3.32	3.64	
	UL2	X	A	W mean	5	1.09	0.08	0.03	1.01	1.21	0.58
				P mean	5	1.1	0.07	0.03	1	1.18	
			B	W mean	5	2.17	0.08	0.04	2.06	2.28	0.56
				P mean	5	2.15	0.07	0.03	2.05	2.24	
		Y	A	W mean	5	2.03	0.13	0.06	1.94	2.27	0.12
				P mean	5	1.75	0.37	0.17	1.18	2.09	
			B	W mean	5	2.14	0.17	0.08	1.96	2.42	0.12
				P mean	5	1.87	0.35	0.16	1.38	2.23	
		Z	C	W mean	5	2.83	0.15	0.07	2.66	3.06	0.3
				P mean	5	2.89	0.11	0.05	2.78	3.03	
			D	W mean	5	3.13	0.02	0.01	3.09	3.15	0.15
				P mean	5	3.29	0.19	0.09	3.05	3.56	
	UL3	X	A	W mean	5	1.19	0.21	0.1	0.9	1.41	0.0604
				P mean	5	1.08	0.29	0.13	0.67	1.35	
			B	W mean	5	2.4	0.18	0.08	2.17	2.6	0.0352
				P mean	5	2.28	0.25	0.11	1.92	2.5	
		Y	A	W mean	5	2.34	0.13	0.06	2.25	2.55	0.23
				P mean	5	2.19	0.26	0.12	1.81	2.45	
			B	W mean	5	2.47	0.12	0.06	2.36	2.67	0.44
				P mean	5	2.38	0.26	0.12	1.99	2.59	
		Z	C	W mean	5	5.53	0.11	0.05	5.41	5.71	0.67
				P mean	5	5.51	0.08	0.03	5.41	5.58	
			D	W mean	5	5.08	0.1	0.05	4.97	5.24	0.43
				P mean	5	5.11	0.07	0.03	5.01	5.18	
	UL4	X	A	W mean	5	0.69	0.17	0.07	0.56	0.95	0.96
				P mean	5	0.69	0.16	0.07	0.5	0.92	
			B	W mean	5	1.98	0.21	0.1	1.83	2.31	0.96
				P mean	5	1.98	0.2	0.09	1.74	2.26	
		Y	A	W mean	5	1.95	0.1	0.05	1.8	2.04	0.0129
				P mean	5	1.8	0.15	0.07	1.64	2	
			B	W mean	5	1.94	0.07	0.03	1.86	1.99	0.0057
				P mean	5	1.79	0.09	0.04	1.66	1.88	
		Z	C	W mean	5	6.75	0.09	0.04	6.65	6.85	0.47
				P mean	5	6.79	0.07	0.03	6.69	6.88	
			D	W mean	5	6.66	0.07	0.03	6.59	6.74	0.29
				P mean	5	6.7	0.08	0.04	6.6	6.79	
	UL5	X	A	W mean	5	0.72	0.14	0.06	0.51	0.86	0.21
				P mean	5	0.66	0.18	0.08	0.38	0.85	
			B	W mean	5	2.1	0.12	0.05	1.93	2.23	0.16
				P mean	5	2.02	0.17	0.07	1.76	2.19	
		Y	A	W mean	5	1.81	0.11	0.05	1.68	1.91	0.0047
				P mean	5	1.71	0.14	0.06	1.57	1.88	
			B	W mean	5	1.87	0.11	0.05	1.73	1.96	0.0342
				P mean	5	1.79	0.14	0.06	1.64	1.94	
		Z	C	W mean	5	7.57	0.07	0.03	7.49	7.66	0.3
				P mean	5	7.62	0.09	0.04	7.53	7.76	
			D	W mean	5	7.5	0.04	0.02	7.47	7.57	0.0666
				P mean	5	7.57	0.07	0.03	7.51	7.67	
	UL6	X	A	W mean	5	1.84	0.06	0.03	1.78	1.94	0.0522
				P mean	5	1.78	0.09	0.04	1.67	1.92	
			B	W mean	5	4.01	0.08	0.04	3.94	4.14	0.22
				P mean	5	3.97	0.11	0.05	3.86	4.14	
		Y	A	W mean	5	0.68	0.16	0.07	0.51	0.91	0.2
				P mean	5	0.6	0.14	0.06	0.46	0.83	
			B	W mean	5	0.62	0.15	0.07	0.4	0.8	0.28
				P mean	5	0.54	0.13	0.06	0.41	0.74	
		Z	C	W mean	5	9.41	0.07	0.03	9.34	9.52	0.48
				P mean	5	9.45	0.08	0.03	9.34	9.52	
			D	W mean	5	8.85	0.05	0.02	8.8	8.92	0.0506
				P mean	5	8.93	0.11	0.05	8.81	9.05	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Double-VF	UR1	X	A	W mean	5	1.28	0.17	0.08	1.08	1.46	0.8
				P mean	5	1.3	0.16	0.07	1.05	1.46	
			B	W mean	5	3.12	0.21	0.1	2.87	3.32	0.93
				P mean	5	3.13	0.19	0.09	2.83	3.29	
		Y	A	W mean	5	2.18	0.07	0.03	2.09	2.27	0.0567
				P mean	5	1.87	0.32	0.14	1.33	2.17	
			B	W mean	5	2.09	0.1	0.05	1.96	2.24	0.0633
				P mean	5	1.78	0.33	0.15	1.21	2.05	
		Z	C	W mean	5	3.36	0.12	0.05	3.25	3.56	0.0188
				P mean	5	3.23	0.1	0.04	3.08	3.35	
			D	W mean	5	2.9	0.09	0.04	2.8	3.03	0.58
				P mean	5	2.87	0.1	0.04	2.75	3.02	
	UR2	X	A	W mean	5	0.82	0.13	0.06	0.68	0.97	0.96
				P mean	5	0.83	0.15	0.07	0.6	0.95	
			B	W mean	5	1.87	0.18	0.08	1.59	2.06	0.21
				P mean	5	1.85	0.22	0.1	1.5	2.06	
		Y	A	W mean	5	1.24	0.58	0.26	0.2	1.59	0.95
				P mean	5	1.23	0.33	0.15	0.85	1.59	
			B	W mean	5	1.37	0.06	0.03	1.28	1.46	0.14
				P mean	5	1.13	0.31	0.14	0.72	1.46	
		Z	C	W mean	5	2.92	0.09	0.04	2.8	3.03	0.005
				P mean	5	2.84	0.08	0.04	2.75	2.95	
			D	W mean	5	2.74	0.05	0.02	2.67	2.79	0.58
				P mean	5	2.77	0.1	0.05	2.62	2.88	
	UR3	X	A	W mean	5	1.42	0.15	0.07	1.31	1.64	0.51
				P mean	5	1.44	0.14	0.06	1.33	1.67	
			B	W mean	5	2.75	0.12	0.05	2.64	2.91	0.35
				P mean	5	2.79	0.13	0.06	2.71	3.03	
		Y	A	W mean	5	2.04	0.08	0.03	1.94	2.14	0.0843
				P mean	5	1.69	0.34	0.15	1.23	2.04	
			B	W mean	5	1.87	0.08	0.03	1.76	1.97	0.11
				P mean	5	1.51	0.4	0.18	1.04	1.95	
		Z	C	W mean	5	5.39	0.08	0.03	5.29	5.48	0.0437
				P mean	5	5.31	0.09	0.04	5.19	5.41	
			D	W mean	5	4.91	0.05	0.02	4.83	4.95	0.58
				P mean	5	4.88	0.08	0.04	4.74	4.94	
	UR4	X	A	W mean	5	1.02	0.16	0.07	0.82	1.19	0.56
				P mean	4	1.03	0.14	0.07	0.86	1.17	
			B	W mean	5	2.34	0.11	0.05	2.18	2.47	0.32
				P mean	4	2.32	0.11	0.05	2.2	2.42	
		Y	A	W mean	5	1.91	0.07	0.03	1.81	2.01	0.56
				P mean	4	1.87	0.19	0.1	1.59	2.03	
			B	W mean	5	1.96	0.13	0.06	1.73	2.06	0.68
				P mean	4	1.97	0.23	0.12	1.64	2.19	
		Z	C	W mean	5	7.53	0.05	0.02	7.48	7.59	0.42
				P mean	4	7.5	0.11	0.06	7.33	7.58	
			D	W mean	5	7.58	0.03	0.01	7.53	7.62	0.62
				P mean	4	7.55	0.13	0.06	7.36	7.62	
	UR5	X	A	W mean	5	0.79	0.13	0.06	0.56	0.9	0.22
				P mean	4	0.83	0.15	0.07	0.63	0.97	
			B	W mean	5	2.16	0.13	0.06	1.94	2.27	0.63
				P mean	4	2.18	0.12	0.06	2.03	2.33	
		Y	A	W mean	5	1.84	0.06	0.03	1.78	1.94	0.14
				P mean	4	1.72	0.07	0.04	1.62	1.78	
			B	W mean	5	1.93	0.07	0.03	1.81	2.01	0.11
				P mean	4	1.82	0.09	0.05	1.69	1.91	
		Z	C	W mean	5	7.77	0.03	0.01	7.73	7.8	0.29
				P mean	4	7.72	0.06	0.03	7.65	7.77	
			D	W mean	5	7.64	0.05	0.02	7.58	7.72	0.27
				P mean	4	7.56	0.06	0.03	7.48	7.63	
	UR6	X	A	W mean	5	1.79	0.08	0.04	1.69	1.91	0.32
				P mean	5	1.83	0.06	0.03	1.76	1.9	
			B	W mean	5	4.02	0.08	0.04	3.94	4.13	0.51
				P mean	5	4.06	0.06	0.03	3.96	4.13	
		Y	A	W mean	5	0.46	0.11	0.05	0.3	0.6	0.41
				P mean	5	0.39	0.17	0.08	0.2	0.62	
			B	W mean	5	0.43	0.12	0.05	0.3	0.6	0.39
				P mean	5	0.36	0.17	0.08	0.21	0.62	
		Z	C	W mean	5	9.73	0.07	0.03	9.65	9.79	0.41
				P mean	5	9.69	0.05	0.02	9.61	9.74	
			D	W mean	5	9.11	0.08	0.03	9.01	9.18	0.49
				P mean	5	9.07	0.1	0.04	8.99	9.23	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Single-VF	UL1	X	A	W mean	5	1.56	0.1	0.05	1.41	1.67	0.37
				P mean	5	1.47	0.17	0.07	1.21	1.64	
			B	W mean	5	3.44	0.11	0.05	3.3	3.55	0.36
				P mean	5	3.34	0.16	0.07	3.09	3.5	
		Y	A	W mean	5	2.31	0.14	0.06	2.17	2.46	0.0374
				P mean	5	1.86	0.33	0.15	1.36	2.17	
			B	W mean	5	2.34	0.15	0.07	2.19	2.55	0.0369
				P mean	5	1.85	0.29	0.13	1.46	2.19	
		Z	C	W mean	5	3.77	0.07	0.03	3.66	3.83	0.0091
				P mean	5	3.59	0.09	0.04	3.44	3.69	
			D	W mean	5	3.41	0.07	0.03	3.32	3.5	0.72
				P mean	5	3.44	0.12	0.05	3.31	3.61	
	UL2	X	A	W mean	5	0.98	0.19	0.09	0.81	1.28	0.39
				P mean	5	1.04	0.2	0.09	0.81	1.33	
			B	W mean	5	2.04	0.16	0.07	1.87	2.27	0.46
				P mean	5	2.09	0.17	0.08	1.88	2.32	
		Y	A	W mean	5	1.97	0.08	0.04	1.89	2.08	0.0835
				P mean	5	1.53	0.47	0.21	0.9	2.14	
			B	W mean	5	2.09	0.07	0.03	2.01	2.18	0.0775
				P mean	5	1.63	0.48	0.22	0.94	2.21	
		Z	C	W mean	5	2.91	0.03	0.01	2.87	2.94	0.97
				P mean	5	2.91	0.1	0.04	2.78	3.02	
			D	W mean	5	3.19	0.03	0.01	3.14	3.23	0.42
				P mean	5	3.26	0.18	0.08	3.07	3.53	
	UL3	X	A	W mean	5	1.06	0.17	0.08	0.82	1.24	0.69
				P mean	5	1.1	0.17	0.08	0.92	1.33	
			B	W mean	5	2.3	0.16	0.07	2.09	2.47	0.94
				P mean	5	2.31	0.15	0.07	2.14	2.5	
		Y	A	W mean	5	2.26	0.06	0.02	2.22	2.35	0.13
				P mean	5	1.77	0.56	0.25	1.1	2.45	
			B	W mean	5	2.42	0.06	0.03	2.36	2.5	0.15
				P mean	5	1.96	0.59	0.26	1.21	2.65	
		Z	C	W mean	5	5.53	0.05	0.02	5.45	5.58	0.3
				P mean	5	5.48	0.1	0.04	5.36	5.63	
			D	W mean	5	5.06	0.04	0.02	5.02	5.1	0.66
				P mean	5	5.09	0.14	0.06	4.95	5.32	
	UL4	X	A	W mean	5	0.84	0.19	0.09	0.67	1.14	1
				P mean	5	0.84	0.17	0.07	0.67	1.1	
			B	W mean	5	2.18	0.22	0.1	1.93	2.51	0.68
				P mean	5	2.19	0.2	0.09	1.96	2.48	
		Y	A	W mean	5	1.92	0.09	0.04	1.76	1.99	0.18
				P mean	5	1.7	0.25	0.11	1.31	1.91	
			B	W mean	5	1.9	0.08	0.04	1.76	1.97	0.25
				P mean	5	1.74	0.24	0.11	1.37	1.93	
		Z	C	W mean	5	6.77	0.07	0.03	6.66	6.85	0.87
				P mean	5	6.76	0.13	0.06	6.59	6.93	
			D	W mean	5	6.65	0.08	0.03	6.56	6.75	0.81
				P mean	5	6.68	0.17	0.08	6.45	6.92	
	UL5	X	A	W mean	5	0.73	0.18	0.08	0.44	0.92	0.62
				P mean	5	0.76	0.17	0.08	0.51	0.96	
			B	W mean	5	2.13	0.19	0.09	1.82	2.35	0.41
				P mean	5	2.16	0.17	0.08	1.91	2.37	
		Y	A	W mean	5	1.71	0.16	0.07	1.46	1.85	0.28
				P mean	5	1.6	0.27	0.12	1.22	1.82	
			B	W mean	5	1.73	0.17	0.08	1.46	1.88	0.21
				P mean	5	1.62	0.25	0.11	1.28	1.81	
		Z	C	W mean	5	7.55	0.08	0.03	7.46	7.64	0.98
				P mean	5	7.55	0.2	0.09	7.32	7.86	
			D	W mean	5	7.49	0.09	0.04	7.38	7.6	0.97
				P mean	5	7.5	0.24	0.11	7.21	7.87	
	UL6	X	A	W mean	5	2.02	0.11	0.05	1.9	2.19	0.92
				P mean	5	2.02	0.11	0.05	1.91	2.16	
			B	W mean	5	4.18	0.11	0.05	4.04	4.34	0.61
				P mean	5	4.21	0.12	0.05	4.06	4.36	
		Y	A	W mean	5	0.57	0.1	0.05	0.46	0.72	0.56
				P mean	5	0.59	0.08	0.04	0.49	0.67	
			B	W mean	5	0.5	0.12	0.05	0.38	0.64	0.73
				P mean	5	0.53	0.14	0.06	0.35	0.69	
		Z	C	W mean	5	9.39	0.05	0.02	9.34	9.47	0.41
				P mean	5	9.32	0.14	0.06	9.14	9.54	
			D	W mean	5	8.78	0.1	0.04	8.62	8.86	0.88
				P mean	5	8.8	0.16	0.07	8.59	9.04	

Method	Tooth	Direction	Location	Variable	N	Mean	Std Dev	Std Error	Minimum	Maximum	Paired T test p value
Single-VF	UR1	X	A	W_mean	5	1.13	0.12	0.06	0.99	1.31	0.0751
				P_mean	5	1.02	0.17	0.08	0.74	1.18	
			B	W_mean	5	3	0.13	0.06	2.88	3.21	0.0455
				P_mean	5	2.86	0.17	0.08	2.58	3.02	
		Y	A	W_mean	5	2.19	0.11	0.05	2.09	2.35	0.4
				P_mean	5	2.06	0.34	0.15	1.55	2.44	
			B	W_mean	5	2.11	0.15	0.07	1.91	2.31	0.32
				P_mean	5	1.94	0.37	0.17	1.37	2.3	
		Z	C	W_mean	5	3.39	0.08	0.03	3.29	3.48	0.45
				P_mean	4	3.3	0.23	0.11	3.02	3.53	
			D	W_mean	5	2.96	0.09	0.04	2.83	3.06	0.73
				P_mean	4	2.89	0.21	0.11	2.57	3.01	
	UR2	X	A	W_mean	5	0.82	0.14	0.06	0.6	0.95	0.45
				P_mean	5	0.77	0.19	0.08	0.48	0.93	
			B	W_mean	5	1.91	0.15	0.07	1.68	2.05	0.31
				P_mean	5	1.84	0.18	0.08	1.56	2	
		Y	A	W_mean	5	1.58	0.08	0.04	1.46	1.67	0.9
				P_mean	5	1.59	0.21	0.09	1.36	1.91	
			B	W_mean	5	1.47	0.08	0.04	1.37	1.56	0.74
				P_mean	5	1.52	0.29	0.13	1.17	1.96	
		Z	C	W_mean	5	2.96	0.06	0.03	2.88	3.05	0.78
				P_mean	4	2.96	0.07	0.03	2.88	3.03	
			D	W_mean	5	2.76	0.06	0.03	2.71	2.85	0.53
				P_mean	4	2.71	0.13	0.07	2.51	2.79	
	UR3	X	A	W_mean	5	1.32	0.15	0.07	1.2	1.59	0.79
				P_mean	5	1.34	0.23	0.1	1.13	1.73	
			B	W_mean	5	2.69	0.17	0.08	2.55	2.98	0.74
				P_mean	5	2.67	0.2	0.09	2.5	3	
		Y	A	W_mean	5	1.95	0.07	0.03	1.86	2.04	0.75
				P_mean	5	1.97	0.09	0.04	1.87	2.1	
			B	W_mean	5	1.8	0.11	0.05	1.67	1.96	0.98
				P_mean	5	1.81	0.11	0.05	1.67	1.94	
		Z	C	W_mean	5	5.38	0.06	0.03	5.35	5.48	0.8
				P_mean	5	5.38	0.05	0.02	5.31	5.43	
			D	W_mean	5	4.88	0.05	0.02	4.85	4.97	0.44
				P_mean	5	4.86	0.06	0.03	4.78	4.92	
	UR4	X	A	W_mean	5	0.94	0.05	0.02	0.85	0.98	0.45
				P_mean	5	0.92	0.09	0.04	0.81	1	
			B	W_mean	5	2.29	0.06	0.03	2.19	2.35	1
				P_mean	5	2.29	0.09	0.04	2.17	2.38	
		Y	A	W_mean	5	1.91	0.09	0.04	1.78	2.01	0.21
				P_mean	5	1.98	0.13	0.06	1.81	2.14	
			B	W_mean	5	1.96	0.11	0.05	1.83	2.09	0.16
				P_mean	5	2.03	0.15	0.07	1.86	2.18	
		Z	C	W_mean	5	7.48	0.06	0.02	7.42	7.53	0.33
				P_mean	5	7.51	0.04	0.02	7.45	7.55	
			D	W_mean	5	7.55	0.03	0.01	7.51	7.58	0.65
				P_mean	5	7.57	0.08	0.03	7.43	7.61	
	UR5	X	A	W_mean	5	0.76	0.14	0.06	0.54	0.9	0.0253
				P_mean	5	0.89	0.21	0.09	0.63	1.15	
			B	W_mean	5	2.09	0.12	0.05	1.94	2.22	0.02
				P_mean	5	2.21	0.19	0.08	2.01	2.41	
		Y	A	W_mean	5	1.91	0.06	0.03	1.86	2	0.26
				P_mean	5	1.81	0.2	0.09	1.49	2.04	
			B	W_mean	5	2	0.09	0.04	1.88	2.09	0.15
				P_mean	5	1.9	0.17	0.08	1.67	2.12	
		Z	C	W_mean	5	7.76	0.05	0.02	7.72	7.84	0.48
				P_mean	5	7.74	0.1	0.05	7.65	7.9	
			D	W_mean	5	7.58	0.05	0.02	7.52	7.65	0.35
				P_mean	5	7.61	0.1	0.05	7.45	7.71	
	UR6	X	A	W_mean	5	1.87	0.15	0.07	1.65	2.03	0.41
				P_mean	5	1.92	0.16	0.07	1.79	2.14	
			B	W_mean	5	4.14	0.16	0.07	3.87	4.27	1
				P_mean	5	4.14	0.14	0.06	4.01	4.34	
		Y	A	W_mean	5	0.51	0.12	0.05	0.37	0.69	0.0453
				P_mean	5	0.25	0.11	0.05	0.14	0.41	
			B	W_mean	5	0.49	0.13	0.06	0.33	0.68	0.0634
				P_mean	5	0.25	0.15	0.07	0	0.39	
		Z	C	W_mean	5	9.7	0.06	0.03	9.62	9.77	0.17
				P_mean	5	9.66	0.05	0.02	9.58	9.72	
			D	W_mean	5	8.99	0.07	0.03	8.91	9.09	0.0276
				P_mean	5	9.1	0.08	0.03	8.99	9.2	

Appendix 2: ANOVA for Comparison of Techniques for all Teeth

Table 1					
Method	**Direction**	**N Obs**	**N**	**Mean**	**Std Dev**
Double-PVS	**ΔX**	**120**	120	0.09	0.14
	ΔY	**120**	120	0.11	0.1
	ΔZ	**120**	120	0.1	0.07
PVS-Putty	**ΔX**	**120**	120	0.08	0.06
	ΔY	**120**	120	0.12	0.09
	ΔZ	**120**	120	0.1	0.17
PVS-VF	**ΔX**	**120**	120	0.09	0.08
	ΔY	**120**	120	0.14	0.11
	ΔZ	**120**	120	0.09	0.06
Double-VF	**ΔX**	**120**	116	0.08	0.07
	ΔY	**120**	116	0.21	0.22
	ΔZ	**120**	116	0.09	0.07
Single-VF	**ΔX**	**120**	120	0.09	0.09
	ΔY	**120**	120	0.24	0.28
	ΔZ	**120**	116	0.1	0.09

Table 2: ΔX				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	591	0.91	0.4584

Table 3: ΔY						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**Double-VF**	-0.1009	-4.39	<.0001	0.0001
Method	**Double-PVS**	**Single-VF**	-0.1305	-5.73	<.0001	<.0001
Method	**PVS-Putty**	**Double-VF**	-0.09505	-4.14	<.0001	0.0004
Method	**PVS-Putty**	**Single-VF**	-0.1247	-5.47	<.0001	<.0001
Method	**PVS-VF**	**Double-VF**	-0.0773	-3.36	0.0008	0.0073
Method	**PVS-VF**	**Single-VF**	-0.1069	-4.69	<.0001	<.0001

Table 4: ΔZ				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	587	0.35	0.8441

Appendix 3: ANOVA for Comparison of Techniques for Anterior Teeth

Table 1					
Method	**Direction**	**N Obs**	**N**	**Mean**	**Std Dev**
Double-PVS	**ΔX**	**60**	60	0.08	0.05
	ΔY	**60**	60	0.14	0.13
	ΔZ	**60**	60	0.08	0.06
PVS-Putty	**ΔX**	**60**	60	0.07	0.06
	ΔY	**60**	60	0.13	0.1
	ΔZ	**60**	60	0.11	0.23
PVS-VF	**ΔX**	**60**	60	0.1	0.09
	ΔY	**60**	60	0.16	0.13
	ΔZ	**60**	60	0.11	0.06
Double-VF	**ΔX**	**60**	60	0.09	0.09
	ΔY	**60**	60	0.29	0.26
	ΔZ	**60**	60	0.1	0.08
Single-VF	**ΔX**	**60**	60	0.11	0.11
	ΔY	**60**	60	0.34	0.33
	ΔZ	**60**	56	0.1	0.09

Table 2: ΔX				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	295	2.32	0.0573

Table 3: ΔY						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**Double-VF**	-0.1557	-4.06	<.0001	0.0006
Method	**Double-PVS**	**Single-VF**	-0.2052	-5.35	<.0001	<.0001
Method	**PVS-Putty**	**Double-VF**	-0.158	-4.12	<.0001	0.0005
Method	**PVS-Putty**	**Single-VF**	-0.2075	-5.41	<.0001	<.0001
Method	**PVS-VF**	**Double-VF**	-0.1343	-3.5	0.0005	0.0048
Method	**PVS-VF**	**Single-VF**	-0.1838	-4.79	<.0001	<.0001

Table 4: ΔZ				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	291	0.81	0.5195

Appendix 4: ANOVA for Comparison of Techniques for Posterior Teeth

Table 1					
Method	**Direction**	**N Obs**	**N**	**Mean**	**Std Dev**
Double-PVS	**ΔX**	**60**	60	0.1	0.19
	ΔY	**60**	60	0.09	0.07
	ΔZ	**60**	60	0.11	0.08
PVS-Putty	**ΔX**	**60**	60	0.08	0.06
	ΔY	**60**	60	0.1	0.08
	ΔZ	**60**	60	0.08	0.07
PVS-VF	**ΔX**	**60**	60	0.09	0.06
	ΔY	**60**	60	0.12	0.1
	ΔZ	**60**	60	0.08	0.06
Double-VF	**ΔX**	**60**	56	0.07	0.05
	ΔY	**60**	56	0.13	0.09
	ΔZ	**60**	56	0.07	0.06
Single-VF	**ΔX**	**60**	60	0.08	0.06
	ΔY	**60**	60	0.15	0.17
	ΔZ	**60**	60	0.1	0.09

Table 2: ΔX				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	291	0.89	0.4702

Table 3: ΔY						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**Single-VF**	-0.05583	-2.85	0.0047	0.0377

Table 4: ΔZ						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**PVS-VF**	0.03817	2.78	0.0057	0.0451
Method	**Double-PVS**	**Double-VF**	0.0438	3.14	0.0019	0.016

Appendix 5: ANOVA for Comparison of Techniques for Left and Right Sides of the Arch

Left Side:

Table 1					
Method	direction	N Obs	N	Mean	Std Dev
Double-PVS	ΔX	60	60	0.09	0.12
	ΔY	60	60	0.14	0.12
	ΔZ	60	60	0.08	0.05
PVS-Putty	ΔX	60	60	0.08	0.07
	ΔY	60	60	0.13	0.1
	ΔZ	60	60	0.11	0.23
PVS-VF	ΔX	60	60	0.09	0.07
	ΔY	60	60	0.14	0.1
	ΔZ	60	60	0.1	0.07
Double-VF	ΔX	60	56	0.09	0.09
	ΔY	60	56	0.19	0.2
	ΔZ	60	56	0.09	0.08
Single-VF	ΔX	60	60	0.09	0.1
	ΔY	60	60	0.32	0.34
	ΔZ	60	56	0.13	0.1

Table 2: ΔX				
Effect	Num DF	Den DF	F Value	Pr > F
Method	4	295	0.07	0.991

Table 3: ΔY						
Effect	Method	Method	Estimate	t Value	Pr > |t|	Adj P
Method	Double-PVS	Single-VF	-0.178	-4.95	<.0001	<.0001
Method	PVS-Putty	Single-VF	-0.1892	-5.26	<.0001	<.0001
Method	PVS-VF	Single-VF	-0.1843	-5.13	<.0001	<.0001
Method	Double-PVS	Single-VF	-0.1358	-3.78	0.0002	0.0018

Table 4: ΔZ				
Effect	Num DF	Den DF	F Value	Pr > F
Method	4	295	1.37	0.2426

Right Side:

Table 1					
Method	**Direction**	**N Obs**	**N**	**Mean**	**Std Dev**
Double-PVS	**ΔX**	**60**	60	0.09	0.16
	ΔY	**60**	60	0.08	0.07
	ΔZ	**60**	60	0.11	0.08
PVS-Putty	**ΔX**	**60**	60	0.07	0.05
	ΔY	**60**	60	0.1	0.08
	ΔZ	**60**	60	0.08	0.06
PVS-VF	**ΔX**	**60**	60	0.1	0.08
	ΔY	**60**	60	0.14	0.13
	ΔZ	**60**	60	0.09	0.06
Double-VF	**ΔX**	**60**	56	0.06	0.05
	ΔY	**60**	56	0.24	0.23
	ΔZ	**60**	56	0.08	0.07
Single-VF	**ΔX**	**60**	60	0.1	0.07
	ΔY	**60**	60	0.16	0.16
	ΔZ	**60**	56	0.08	0.07

Table 2: ΔX				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Method	4	291	1.73	0.1438

Table 3: ΔY						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**Double-VF**	-0.1615	-6.06	<.0001	<.0001
Method	**Double-PVS**	**Single-VF**	-0.083	-3.17	0.0017	0.0145
Method	**PVS-Putty**	**Double-VF**	-0.1387	-5.2	<.0001	<.0001
Method	**PVS-VF**	**Double-VF**	-0.108	-4.05	<.0001	<.0001
Method	**Double-VF**	**Single-VF**	0.07855	2.95	0.0035	0.0284

Table 4: ΔZ						
Effect	**Method**	**Method**	**Estimate**	**t Value**	**Pr > |t|**	**Adj P**
Method	**Double-PVS**	**PVS-Putty**	0.03217	2.58	0.0104	0.0772
Method	**Double-PVS**	**Double-VF**	0.03329	2.62	0.0092	0.0692
Method	**Double-PVS**	**Single-VF**	0.03739	2.94	0.0035	0.0286