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## THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: "Effects of Bracket Base Design and Pre-Coated Adhesive Type on Adhesive Thickness"

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## **Title: Effects of bracket base design and pre-coated adhesive type on adhesive thickness**

### **Abstract**

**Objective:** To compare the consistency of the adhesive thickness achieved when using different bracket base designs, and to compare the adhesive thickness measurements when using different pre-coated adhesive types.

**Materials and Methods:** Teeth models were designed and duplicated with a 3D printer. 3Shape Orthodontic Scanner and Ortho Analyzer software were used for the initial measurements without the brackets bonded and final measurements with the brackets bonded. Two different bracket base designs were used: Victory Series Low Profile brackets and Unitek Miniature Twin brackets. Two different pre-coated adhesive types were used: Flash-Free and APC II.

**Results:** 3M Unitek Miniature Twin brackets achieved more consistent adhesive thickness compared to the Victory Series Low Profile brackets for mandibular 1st premolar brackets. Placing brackets with Flash-Free adhesive achieved thicker adhesive thickness compared to APC II adhesive.

**Conclusions:** It is important to annotate the specific bracket types and include the pre-coated adhesive types to prevent mixing different bracket systems within the same arch. The differences in the values from this study were statistically significant, and further studies are needed to determine the clinical significance of the outcome and how it will impact the eventual teeth alignment.

### **Introduction**

Modern-day orthodontic bracket systems contain specific bracket prescriptions intended to deliver optimal clinical results. To fully express the built-in bracket prescription, it is important to place the brackets on the teeth in an accurate position in every dimension.<sup>1,2</sup> Inevitably, bracket positioning errors occur, leading to the need of repositioning the brackets or creating archwire bends during treatment, which may increase patient chair time and overall treatment time.<sup>3</sup> There are adjuncts and techniques to decrease the amount of error created during bracket positioning, such as the use of bracket positioning gauges and indirect bonding techniques.<sup>4-8</sup> While these techniques aid in consistently achieving precise vertical, horizontal, and axial positioning of the brackets, there is no accurate method to evaluate consistent facial-lingual seating of the bracket other than pressing it fully on to the tooth surface and visually inspecting the seating.<sup>3,9</sup>

It is important to note different factors that increase or decrease the adhesive thickness when pressing the bracket on to the tooth. Mackay noted each adhesive has its own minimum thickness and related it to the adhesive viscosity.<sup>10</sup> Goto et al. also linked higher viscosity to a thicker adhesive layer, but noted that lower contact compressive forces increase the thickness.<sup>11</sup> Interestingly, Murguruma et al. suggested a force greater than 200g be applied to the bracket to achieve a thin and sufficient spreading of the adhesive.<sup>12</sup> In addition, Mohammadi et al. mentions application of heavy force leading to higher bond strength, but beyond 400g of force magnitude there was no significant difference.<sup>13</sup> Finally, temperature of the adhesive affects its viscosity and thickness, with lower temperature increasing the adhesive layer thickness.<sup>14</sup>

Another factor that may affect adhesive thickness is the bracket base design and how the base lands on the tooth surface. 3M Victory Series brackets (3M Unitek, Monrovia, CA, USA) have a base design that assures three-point contact on the tooth, and the manufacturer promotes it with increased tooth adaptation. There are no studies relating bracket base design and the effect on consistently achieving the same adhesive thickness.

Furthermore, these 3M Victory Series brackets are available with different types of pre-coated adhesives. One of the pre-coated adhesives is the APC Flash-Free Adhesive (3M Unitek). There is an increasing interest with the APC Flash-Free Adhesive, and studies revealed decreased bracket bonding time with this system by eliminating the need of removing adhesive excess.<sup>15,16</sup> The key feature of the Flash-Free system is the use of a nonwoven mat soaked with a low viscosity adhesive resin.

The amount of adhesive thickness changes the facial-lingual position of the bracket, and this may affect the expression of the bracket prescription. This study was designed to examine: (1) if there is any significant difference in adhesive thickness consistency when using the 3M Victory Series bracket base design; and (2) if there is any significant difference in adhesive thickness when positioning brackets with the APC Flash-Free adhesive.

## **Materials and Methods**

### **Teeth models and initial measurements**

Teeth models were designed and duplicated using Form 3B (Formlabs, Somerville, MA, USA) 3D printer with Model Resin V3 (Formlabs). Each model included a mandibular central incisor, canine, and 1st premolar with no significant surface defects or prominent facial ridges (Fig. 1). The outline of the bracket position was engraved onto the facial aspect of each tooth to maintain consistent bracket positioning between different samples. Additional lines were engraved to mark the center of the bracket location. The backings of the models were sanded flat using different grit of sandpaper up to 7000 grit to create a smooth and even surface. 90 teeth models were duplicated, which included a total of 270 teeth. All teeth models were initially scanned with a 3Shape R2000 Orthodontic Scanner (3Shape, Copenhagen, Denmark). With the 3Shape Ortho Analyzer (3Shape, Copenhagen, Denmark), the initial measurements (T1) of the scanned models were measured perpendicular from the backing of the models to the center of the bracket outlines (Fig. 2). Each measurement was made three times on separate days and the average value was calculated.

### **Brackets and pre-coated adhesives**

Victory Series Low Profile brackets (3M Unitek) were selected to test the effect of the three-point bracket base design on adhesive thickness. Miniature Twin brackets (3M Unitek), which feature a four-point landing design, were used for the control group. Both bracket systems were used with the APC II adhesive pre-coating (3M Unitek). To test the effect of Flash-Free Adhesive on adhesive thickness, Victory Series Low Profile brackets with Flash-Free Adhesive pre-coated brackets (3M Unitek) were used. The control group was the same Victory Series Low Profile brackets with APC II adhesive pre-coating.

The test and control groups were further divided into subgroups according to the type of tooth. The 9 groups were designated as follows:

- Group 1: Victory bracket with APC II adhesive pre-coating on a mandibular central incisor
- Group 2: Victory bracket with APC II adhesive pre-coating on a mandibular canine
- Group 3: Victory bracket with APC II adhesive pre-coating on a mandibular 1st premolar
- Group 4: Twin bracket with APC II adhesive pre-coating on a mandibular central incisor
- Group 5: Twin bracket with APC II adhesive pre-coating on a mandibular canine
- Group 6: Twin bracket with APC II adhesive pre-coating on a mandibular 1st premolar
- Group 7: Victory bracket with Flash-Free adhesive pre-coating on a mandibular central incisor
- Group 8: Victory bracket with Flash-Free adhesive pre-coating on a mandibular canine
- Group 9: Victory bracket with Flash-Free adhesive pre-coating on a mandibular 1st premolar

### **Bracket preparation, placement, and final measurements**

The brackets and the teeth models were pre-heated to 37°C in a digital benchtop incubator (Boekel Scientific, Feasterville, PA, USA) for 10 minutes prior to placing them on the teeth models (Fig. 3). A Dontrix force gauge (Orthodontic Supply & Equipment, Gaithersburg, MD, USA) was used to apply an initial 400g of contact compressive force when placing the bracket. With a dental explorer instrument, excess adhesive was carefully removed around the brackets pre-coated with the APC II adhesive; no adhesive was removed for the Flash-Free system. The brackets were carefully aligned according to the engraved bracket outline on the facial aspect of

each tooth, and an additional 400g of compressive force was applied in the final position. The adhesive was light cured with an LED curing light (VALO Ortho Cordless, Ultradent, South Jordan, Utah) at standard setting for total 20 seconds, which was divided into 10 seconds from the mesial and 10 seconds from the distal aspect.

The facial aspects of teeth models with the brackets in place were sprayed with one coat of the the AESUB scanning spray (AESUB, Recklinghausen, Germany), and the models were scanned with the same 3Shape Orthodontic Scanner. The final measurements (T2) of the scanned models were measured perpendicular from the backing of the models to the center of the brackets (Fig. 4). Each measurement was made three times on separate days and the average value was calculated.

Subtracting the initial measurement (T1) from the final measurement (T2) gave the adhesive thickness along with the slot-to-base distance of the bracket (Fig. 5).

### **Statistical analysis**

Statistical analysis was performed using IBM SPSS Statistics Software version 24 (SPSS Inc., Chicago, IL, USA). The means, standard deviations, and ranges of the values were calculated for each group (Table 1). Standard deviations were evaluated to see the overall difference in variance between all the groups. The Levene's test, which is a 2-way ANOVA for the absolute value of the difference between the sample value and the mean of the group to which the sample belongs, was used to verify statistical significance of the homogeneity of variances of the adhesive thickness between the different bracket base designs. Furthermore, Student t-tests were used to determine differences between the adhesive thickness values of the pre-coated adhesive types. A P value less than 0.05 was considered to indicate statistical significance.

### **Results**

The standard deviations of each group are listed in Table 1. When comparing the same type of teeth and same pre-coated adhesives (APC II), the standard deviations of the Victory series brackets were larger than those of the Twin brackets, indicating a larger dispersion of data and larger variance for the Victory brackets. When comparing the same bracket types and same pre-coated adhesive, the incisor brackets had the largest standard deviations, and the canine brackets had the smallest standard deviations. Furthermore, when comparing the same bracket types and same teeth, APC II pre-coated brackets had larger standard deviations than the Flash-Free brackets.

The Levene's test, revealed a statistically significant difference in variance between the adhesive thickness achieved when placing the brackets with different landing designs (Table 2). Data was further analyzed with the Student t-tests, and it was noted that the significant difference was between the Victory brackets and Twin brackets for the premolars. The variance for the Victory bracket was greater at 0.043mm than the Twin bracket at 0.024mm.

The adhesive thickness comparison between APC II and Flash-Free is shown in Table 3. For all three types of teeth, Flash-Free adhesive was significantly thicker than APC II adhesive. The average difference in thickness between the two pre-coated adhesive types was 0.084mm.

### **Discussion**

Multiple studies examined and attempted to define an ideal adhesive thickness that provides the maximum bond strength.<sup>10, 11, 17-19</sup> However, Reynolds noted a clinically acceptable bond strength to be between 5.9MPa to 7.8MPa<sup>20</sup>, and the adhesive thickness produced in the referred studies all resulted in either a clinically acceptable or greater than clinically acceptable bond strength. The focus pertaining to adhesive thickness should be redirected to the variability or unevenness of adhesive thickness that can result from various factors and eventually cause an undesired movement of the tooth.

This study verified a statistically significant difference in the variance between the premolar Victory series brackets and the premolar Twin brackets. However, the actual difference in the variance is 0.02mm. Furthermore, the statistically significant difference in adhesive thickness between the Flash-Free adhesive and the APC II adhesive is 0.08mm. The greatest difficulty of this study is the lack of previous studies correlating actual adhesive thickness measurements with the clinical impact on teeth alignment. In other words, without having data on the clinical significance these thickness values have, it will be difficult to influence orthodontic providers to use one bracket system or pre-coated adhesive over the other ones based solely on the results from this study.

When comparing the difference in variance of adhesive thickness between the Victory and Twin brackets, it is worth noting that while the premolar brackets showed a significant difference in variance, the incisor and canine brackets did not have a significant difference in variance between the two landing designs. One speculation can be related to the premolar having a more convex surface than the incisor and canine brackets and the possibility that this can affect the performance of a 3-point landing design for the Victory brackets compared to the Twin bracket.

As mentioned previously, a key feature of the Flash-Free adhesive is the use of a nonwoven mat soaked with a low viscosity adhesive resin. The use of the non-woven mat seems to be contributing to the additional 0.08mm adhesive thickness for the Flash-Free brackets. Even with the unknown factor of how much of a clinical impact this additional thickness may lead to, it is important to annotate the use of the Flash-Free adhesive system in the treatment notes, especially if the orthodontic provider has other available options of pre-coated adhesives in the same clinic. Furthermore, this also suggests that the type of pre-coated adhesive should be annotated when transferring a patient to another orthodontic clinic that may not use the same bracket system.

It is important to acknowledge that the measurement calculations were done with the assumption that the slot-to-base distance of the same bracket type will be the same or consistent enough to not affect the outcome when evaluating the adhesive thickness (Fig. 5). There were no studies found specifically examining the manufacturing inaccuracies of the slot-to-base distance. However, Cash et al. noted inaccurate machining of the bracket slot dimensions across difference bracket types<sup>21</sup>, and this may suggest that the slot-to-base distance between brackets of the same type may not be consistent as well.

Lastly, it was difficult to measure the adhesive thickness at the mesial and distal aspects of the bracket due to the inaccuracy of the digital scan in those regions. This is most likely due to the inability of the scanning spray to reach the mesial and distal parts of the bracket slot and the metal reflective properties during the digital scan creating distortion in those areas (Fig 6). Uneven adhesive thickness across the bracket mesiodistally can lead to undesired rotation of the tooth<sup>3</sup>. Follow up studies can be conducted with different methods of measurements to determine the extent of the difference in adhesive thicknesses at different locations of the same bracket.

## **Conclusion**

- 1) 3M Unitek Miniature Twin brackets achieved more consistent adhesive thickness compared to the Victory Series Low Profile brackets for mandibular 1st premolar brackets.
- 2) Placing brackets with Flash-Free adhesive achieved thicker adhesive thickness compared to APC II adhesive.
- 3) It is important to annotate the specific bracket types and include the pre-coated adhesive types to prevent mixing different bracket systems within the same arch.
- 4) The differences in the values from this study were statistically significant, and further studies are needed to determine the clinical significance of the outcome and how it will impact the eventual teeth alignment.

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## **Figure Legends**

Fig. 1. Front and back of the teeth models

Fig. 2. Initial measurements

Fig. 3. Pre-heating of models and brackets

Fig. 4. Final measurements with brackets in place

Fig. 5. Final measurement (T2) - Initial measurement (T1) = Adhesive thickness + Slot-to-base distance

Fig. 6. Distorted scanning at the distal bracket slot of the canine bracket

**Table Files**

	Victory Incisor APC II	Victory Canine APC II	Victory Premolar APC II	Victory Incisor Flash-free	Victory Canine Flash-free	Victory Premolar Flash-free	Twin Incisor APC II	Twin Canine APC II	Twin Premolar APC II
Range (mm)	0.29	0.25	0.28	0.22	0.15	0.22	0.13	0.11	0.12
Mean (mm)	0.85	0.79	0.98	0.94	0.87	1.06	0.89	0.66	0.72
Median (mm)	0.84	0.78	0.98	0.94	0.87	1.07	0.90	0.66	0.72
Standard Deviation (mm)	0.058	0.046	0.055	0.050	0.038	0.044	0.033	0.023	0.029

Table 1. Range, mean, median, standard deviation of the values (adhesive thickness + bracket slot-to-base distance)

Variance (mm)			
	Incisor	Canine	Premolar
Victory	0.041 (0.040) Aa	0.030 (0.035) Aa	0.043 (0.034) Aa
Twin	0.026 (0.021) Aa	0.017 (0.015) Aa	0.024 (0.017) Ab

Table 2. Variance, measured as |sample value - mean|, for each tooth type and bracket base design

Groups with the same upper-case letter per row or lower-case letter per column are not significantly different (P>0.05)

n=30; parentheses indicate standard deviation

	Adhesive Thickness (mm)
Incisor / Victory APC II	0.847 (0.058) <b>a</b>
Incisor / Victory Flash-Free	0.936 (0.050) <b>b</b>

	Adhesive Thickness (mm)
Canine / Victory APC II	0.793 (0.046) <b>a</b>
Canine / Victory Flash-Free	0.874 (0.038) <b>b</b>

	Adhesive Thickness (mm)
Premolar / Victory APC II	0.977 (0.055) <b>a</b>
Premolar / Victory Flash-Free	1.060 (0.044) <b>b</b>

Table 3. Adhesive thickness (adhesive thickness + bracket slot-to-base distance) between different pre-coated adhesive types; separate comparison for each tooth type

Groups with different letters per column are significantly different (p<0.05)

n=30; parentheses indicate standard deviation



Figure 3



Figure 4

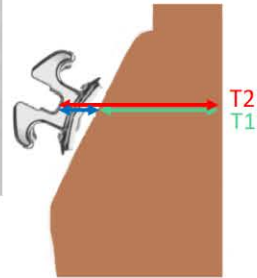


Figure 5

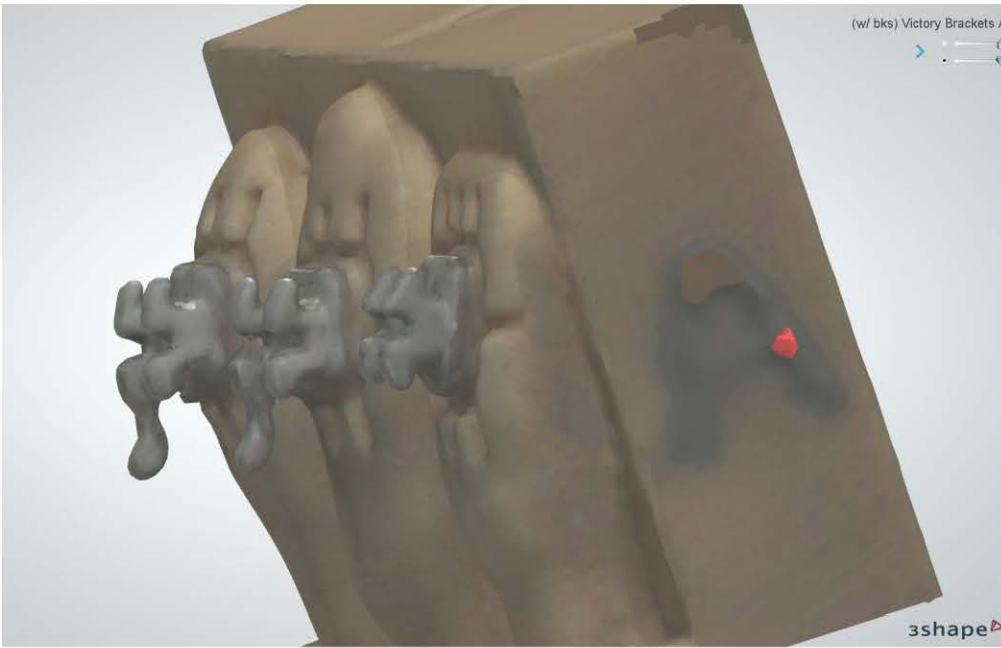


Figure 6



Figure 1

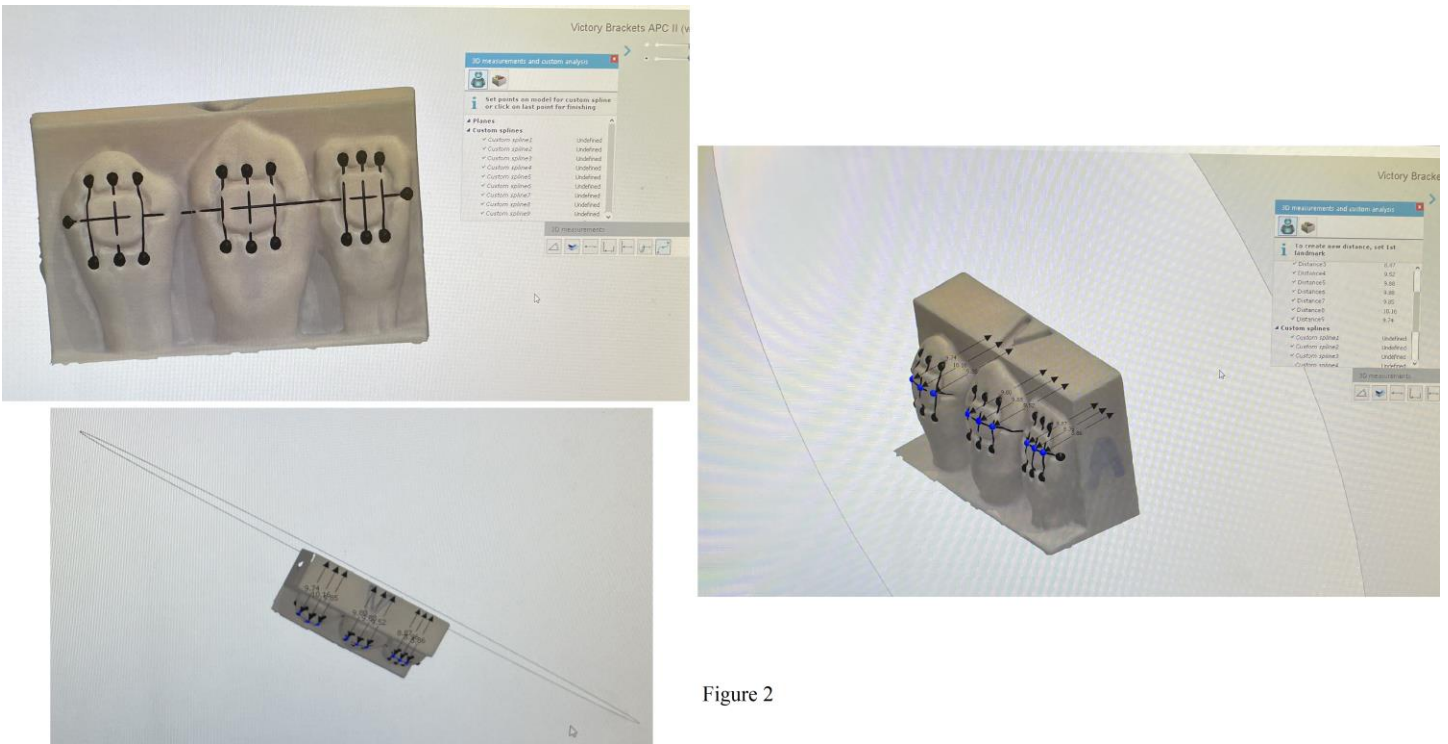


Figure 2