Evaluation of Damon PSL and Conventional MBT Brackets in Leveling and Alignment Efficiency

Jacob Beckstrand
Marquette University

Follow this and additional works at: https://epublications.marquette.edu/theses_open

Part of the Dentistry Commons

Recommended Citation
https://epublications.marquette.edu/theses_open/719
EVALUATION OF DAMON PSL AND CONVENTIONAL MBT BRACKETS IN LEVELING AND ALIGNMENT EFFICIENCY

By

Jacob D. Beckstrand, DDS

A Thesis submitted to the Faculty of the Graduate School, Marquette University, in Partial Fulfillment of the Requirement for the Degree of Master of Science

Milwaukee, Wisconsin

August 2022
ABSTRACT
EVALUATION OF DAMON PSL AND CONVENTIONAL MBT BRACKETS IN LEVELING AND ALIGNMENT EFFICIENCY

Jacob D. Beckstrand, D.D.S.
Marquette University, 2022

Objective:
Ormco has proposed that the low-friction design of their self-ligation brackets allows for more efficient alignment of crowded teeth with less incisor proclination and faster treatment times compared to conventional MBT bracket systems. The purpose of this study is to examine the hypothesis that there is no difference between Damon PSL and conventional MBT brackets in factors related to leveling and alignment in-vitro.

Methods:
Damon Q2 .022” slot brackets and 3M Unitek .022” slot MBT brackets were bonded to 2 sets of typodont teeth. Typodont teeth were placed into 8 upper and lower Class I crowding wax forms (Kilgore, USA) with 4 sets per group (n=4). Each group reused its respective set of typodont teeth in each test run. .014” CuNiTi wires (Ormco) were inserted and the wax forms were placed in a 48°C water bath for 10 minutes. Digital scans, photos, and lateral cephalograms of the wax models were taken before and after the water bath to evaluate incisor proclination, arch length, interincisal spacing, extraction space closure, intermolar and inter-canine width. After evaluation of leveling and alignment, frictional resistance was tested in the upper right and lower left quadrants in each group with the Autograph AGS-X series Universal Tensile testing machine (Shimadzu). As was done during the evaluation of alignment, each test run was repeated 4 times per group, per arch, with a .014” CuNiTi wire. Statistical analysis was completed with ANOVA, post-hoc, and t-test analysis. P values less than 0.05 were considered statistically significant.

Results:
The MBT bracket group showed a significantly greater increase in arch length, incisor proclination, interincisal spacing, and static friction for both upper and lower arches (p < 0.05). The MBT group also exhibited greater static friction in the upper arch than the lower arch (p < 0.05). The Damon bracket group exhibited a significantly greater decrease in upper arch extraction space and inter-canine width in both arches (p < 0.05). No difference was found in either arch between the groups’ pre and post-treatment intermolar width (p > 0.05).

Conclusion:
Based on the statistical analysis, the null hypothesis is rejected. We accept our working hypothesis that there is a difference between Damon and traditional MBT brackets during in-vitro leveling and alignment, which serves to support Ormco’s claims. Additional studies are required to determine the extent of clinical relevance.
ACKNOWLEDGEMENTS

Jacob D. Beckstrand, D.D.S.

I would like to thank Dr. Dawei Liu, Omidi Meisam, and Dr. Shengtong Han for their help in completing this thesis. This project could not have been completed without their collective knowledge, constructive criticism, and support. I would like to thank all of my co-residents for being as understanding as they were when I occasionally monopolized the available space in the Orthodontic Lab in pursuit of completing this project. I would like to thank all of the staff and faculty in the Orthodontics Department at Marquette University for their willingness to help in matters regarding the acquisition of requisite materials. Finally, I would like to thank my wife for her unwavering support and patience throughout my journey to become an orthodontist.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................... I

TABLE OF CONTENTS ........................................................................................................ II

LIST OF TABLES .................................................................................................................. III

LIST OF FIGURES ............................................................................................................... IV

CHAPTER 1 .......................................................................................................................... 1

CHAPTER 2 .......................................................................................................................... 6

CHAPTER 3 .......................................................................................................................... 15

CHAPTER 4 .......................................................................................................................... 27

CHAPTER 5 .......................................................................................................................... 35

CHAPTER 6 .......................................................................................................................... 40

REFERENCES ....................................................................................................................... 41
LIST OF TABLES

Table 1. Various bracket prescriptions central incisor to second premolar……………….2

Table 2. Various bracket prescriptions for molars…………………………………………2

Table 3. Means, standard deviations, and error of arch length in mm..........................27

Table 4. Means, standard deviations, and error of intermolar width in mm...............29

Table 5. Means, standard deviations, and error of inter-canine width in mm. ............30

Table 6. Means, standard deviations, and error of extraction space in mm.............31

Table 7. Means, standard deviations, and error of interincisal space in mm.............32

Table 8. Means, standard deviations, and error of incisor proclination in degrees. ....33

Table 9. Means, standard deviations, and error of static friction in Newtons. ..........34
LIST OF FIGURES

Figure 1. Class I crowding orthodontic wax forms by Kilgore ................................................. 15

Figure 2. Bracket placement guide by 3M Unitek................................................................. 17

Figure 3. Wax forms with MBT brackets on typodont teeth in metal articulator .............. 17

Figure 4. Wax form and articulator fixed to the base plate in Shimadzu testing machine. ......................................................................................................................... 18

Figure 5. Pre-tx occlusal view of Damon Q2 brackets on typodont teeth in metal articulator ......................................................................................................................... 19

Figure 6. Pre-tx occlusal view of Damon brackets from intraoral scan.............................. 19

Figure 7. Pre-tx lateral cephalogram of Damon Q2 brackets in wax forms in metal articulator .......................................................................................................................... 20

Figure 8. Wire cleaned and ligated in Damon Q2 brackets ready for water bath............. 21

Figure 9. Models with wire in Damon Q2 brackets in Hamilton Beach water bath ....... 21

Figure 10. Post-tx occlusal view of Damon Q2 brackets on typodont teeth in metal articulator ......................................................................................................................... 22

Figure 11. Post-tx occlusal view of Damon group from intraoral scan ......................... 22

Figure 12. Post-tx lateral cephalogram of Damon brackets in metal articulator ............. 22

Figure 13. Sample of the measurements taken from the MBT intraoral scans ............. 23

Figure 14. Pre and post-tx lateral cephalogram of MBT brackets showing FH and MP.. 24

Figure 15. Benchtop set up for Autograph AGS-X series universal tensile testing machine .......................................................................................................................... 25
Figure 16. Model attached to base plate with wire engaged in universal testing machine .................................................................................................................. 25

Figure 17. Arch length means in mm ................................................................................................................................. 28

Figure 18. Intermolar means in mm ................................................................................................................................. 29

Figure 19. Inter-canine means in mm ............................................................................................................................... 30

Figure 20. Extraction space means in mm .......................................................................................................................... 31

Figure 21. Interincisal space means in mm ........................................................................................................................ 32

Figure 22. Incisor Proclination means measured in degrees ............................................................................................... 33

Figure 23. Static friction means measured in Newtons ........................................................................................................ 34
Leveling and alignment is the first phase of orthodontic treatment and was considered by Begg to be the foundational element that, when properly executed, sets up the patient for an ideal treatment outcome (Begg et al., 1977). Leveling and alignment involves resolving the majority of tooth rotations, horizontal and vertical displacements, and gaining greater wire passivity through obtaining a more idealized arch form (McLaughlin et al., 2001). As it is the unavoidable first stage of orthodontic treatment, it is absolutely essential for the orthodontist to optimize this process to engender and encourage a patient’s trust and confidence (McLaughlin et al., 2001). In pursuit of achieving the most efficient means of leveling and aligning teeth, many iterations of the orthodontic bracket and wire system have been introduced since the specialty’s inception (Proffit et al., 2019).

Edward Angle is credited with the invention of four major appliances: the E-arch, pin and tube, ribbon arch, and finally, in 1928, the edgewise system. Over the years, the edgewise bracket has received several significant modifications, and is now quite different from its historical counterpart. In 1972, Andrews was among the first to attempt to fabricate tooth-specific variations in each bracket to allow for a straight wire appliance (Proffit et al., 2019). In theory, Andrews’ system would produce a nearly perfect finish by simply progressing to a rigid straight wire fully engaged into the bracket slot (McLaughlin et al., 2001). This was accomplished by adjusting the thickness of the base to simulate 1st order bends, varying the horizontal tip of the slot to mimic 2nd order bends, and modifying the facial angulation of the slot to approximate 3rd order bends (Proffit et
al., 2019). Further advancements in technology, manufacturing, and design have facilitated the production of myriad preadjusted bracket systems with unique prescriptions, including Roth and MBT. Examples of these various bracket prescriptions are detailed in the tables below (Table 1, 2, Proffit et al., 2019).

<table>
<thead>
<tr>
<th></th>
<th>CENTRAL</th>
<th></th>
<th>LATERAL</th>
<th></th>
<th>CANINE</th>
<th></th>
<th>FIRST PREMOLAR</th>
<th></th>
<th>SECOND PREMOLAR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Torque</td>
<td>Tip</td>
<td>Torque</td>
<td>Tip</td>
<td>Torque</td>
<td>Tip</td>
<td>Torque</td>
<td>Tip</td>
<td>Torque</td>
<td>Tip</td>
</tr>
<tr>
<td>Maxillary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alexander</td>
<td>15</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>−3</td>
<td>10</td>
<td>−6</td>
<td>0</td>
<td>−8</td>
<td>4</td>
</tr>
<tr>
<td>Andrews</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>9</td>
<td>−7</td>
<td>11</td>
<td>−7</td>
<td>2</td>
<td>−7</td>
<td>2</td>
</tr>
<tr>
<td>Damon (standard torque)</td>
<td>15</td>
<td>5</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>−11</td>
<td>2</td>
<td>−11</td>
<td>2</td>
</tr>
<tr>
<td>MBT</td>
<td>17</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>−7</td>
<td>8</td>
<td>−7</td>
<td>0</td>
<td>−7</td>
<td>0</td>
</tr>
<tr>
<td>Ricketts</td>
<td>22</td>
<td>0</td>
<td>14</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roth</td>
<td>12</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>−2</td>
<td>9</td>
<td>−7</td>
<td>0</td>
<td>−7</td>
<td>0</td>
</tr>
<tr>
<td>Mandibular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alexander</td>
<td>−5</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>−7</td>
<td>6</td>
<td>−7</td>
<td>0</td>
<td>−9</td>
<td>0</td>
</tr>
<tr>
<td>Andrews</td>
<td>−1</td>
<td>2</td>
<td>−1</td>
<td>2</td>
<td>−11</td>
<td>5</td>
<td>−17</td>
<td>2</td>
<td>−22</td>
<td>2</td>
</tr>
<tr>
<td>Damon (standard torque)</td>
<td>−3</td>
<td>2</td>
<td>−3</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>−12</td>
<td>4</td>
<td>−17</td>
<td>4</td>
</tr>
<tr>
<td>MBT</td>
<td>−6</td>
<td>0</td>
<td>−6</td>
<td>0</td>
<td>−6</td>
<td>3</td>
<td>−12</td>
<td>2</td>
<td>−17</td>
<td>2</td>
</tr>
<tr>
<td>Ricketts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roth</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>−11</td>
<td>7</td>
<td>−17</td>
<td>0</td>
<td>−22</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1. Various bracket prescriptions central incisor to second premolar.

<table>
<thead>
<tr>
<th></th>
<th>FIRST MOLAR</th>
<th></th>
<th>SECOND MOLAR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Torque</td>
<td>Tip</td>
<td>Rotation</td>
<td>Torque</td>
</tr>
<tr>
<td>Maxillary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alexander</td>
<td>−10</td>
<td>0</td>
<td>13</td>
<td>−10</td>
</tr>
<tr>
<td>Andrews</td>
<td>−9</td>
<td>5</td>
<td>10</td>
<td>−9</td>
</tr>
<tr>
<td>Damon (standard torque)</td>
<td>−16</td>
<td>0</td>
<td>12</td>
<td>−27</td>
</tr>
<tr>
<td>MBT</td>
<td>−14</td>
<td>0</td>
<td>10</td>
<td>−14</td>
</tr>
<tr>
<td>Ricketts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roth</td>
<td>−14</td>
<td>0</td>
<td>14</td>
<td>−14</td>
</tr>
<tr>
<td>Mandibular</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alexander</td>
<td>−10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Andrews</td>
<td>−25</td>
<td>2</td>
<td>0</td>
<td>−30</td>
</tr>
<tr>
<td>Damon (standard torque)</td>
<td>−28</td>
<td>2</td>
<td>2</td>
<td>−10</td>
</tr>
<tr>
<td>MBT</td>
<td>−20</td>
<td>0</td>
<td>0</td>
<td>−10</td>
</tr>
<tr>
<td>Ricketts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roth</td>
<td>−30</td>
<td>1</td>
<td>4</td>
<td>−30</td>
</tr>
</tbody>
</table>

Table 2. Various bracket prescriptions for molars.
Despite the vast array of preadjusted bracket systems on the market, there is one consistent factor among all edgewise brackets: the need for ligation. Typically, ligation of the wire into the bracket slot is accomplished via a steel ligature or, more commonly, a polyurethane elastomeric tie (McLaughlin et al., 2001). There is, however, another class of bracket requiring no ligation that has made a comeback in terms of popularity within the last two decades: the self-ligating bracket.

The first iteration of the self-ligating bracket, brought to market in the mid 1930s, was known as the Russell attachment, and was initially designed to enhance clinical efficiency by replacing traditional ligation with a clip or gate built into the bracket that could engage the wire into the slot, thereby reducing time spent chairside by the clinician (Rinchuse et al., 2007). This clip or gate is often made of stainless steel or nickel-titanium and may be fabricated to be active, engaging the wire, or passive, laying over the wire. Many iterations of the self-ligating bracket have since been produced, including the Ormco Edgelok in 1972, Forestadent Mobil-Lock in 1980, Orec SPEED in 1980, and “A” Company Activa in 1986 (Harradine, 2001). Currently, the most popular self-ligating brackets, including active and passive variations, are Damon, Time, Speed, SmartClip, and In-Ovation R (Rinchuse et al., 2007).

Manufacturers of the self-ligating bracket have made many claims attesting to their inherent superiority in comparison to the conventional preadjusted twin-bracket system. For example, Ormco, the parent company of the Damon bracket, has information available on their website arguing that their passive self-ligating brackets provide increased patient comfort, faster treatment times, shorter chair time, enhanced oral hygiene, reduced need for extractions, greater arch form expansion, and less incisor
proclination in non-extraction treatment (Ormco, 2022). Other companies have asserted that self-ligating brackets deliver more biologically compatible forces that result in greater patient cooperation and case acceptance (Rinchuse et al., 2007).

It is important to note that the claims surrounding self-ligating brackets have found some support within the orthodontic community, and are not made solely by the manufacturers. Dr. Robert Keim, editor of the Journal of Clinical Orthodontics, stated his belief that the future of orthodontics will focus on 3 areas: 3-dimensional (3D) imaging replacing 2-dimensional cephalometry, self-ligating brackets, and micro-implants as endosseous anchorage (Rinchuse et al., 2007). However, even Dr. Keim cautioned that orthodontists must seek out sound scientific evidence before accepting manufacturers’ claims about the superiority of self-ligation brackets as gospel.

The basis for most of these claims rests on the assumption that self-ligating brackets exhibit less frictional resistance to tooth movement than conventional edgewise brackets. This contention is based on the premise that a passive metal gate will generate less pressure on a wire than traditional ligation with an active elastic tie (Burrow et al., 2009). Prior to examining the validity of this assumption, it behooves the practitioner to have a basic understanding of the nature and role of friction in orthodontics.

Friction can be divided into two main types that are significant for orthodontic movement: static and kinetic. Static friction is understood to be the resistance that is first generated when two opposing surfaces encounter one another under pressure; it can be defined as the amount of force required to start movement of the wire against the bracket slot (Burrow et al., 2009). Kinetic friction, also known as dynamic friction, is the resistance to continued movement and can be measured as the force required to keep a
wire moving continuously along the bracket slot (Burrow et al., 2009). Since static
friction related to the elastic binding of the wire against the bracket is always greater than
the kinetic friction, static friction is considered the primary obstacle that must be
overcome to enable tooth movement (Proffit et al., 2019). In addition, tooth movement is
never a continuous process, but is instead more of a “stick-slip” phenomenon that occurs
stepwise. As pressure is exerted on the tooth by the wire acting on the bracket, the
periodontal ligament is compressed, and the process of bone remodeling is triggered.
Once a sufficient amount of bone is remodeled, the tooth will jump to its new location
within the remodeled alveolus, enabling the wire to slip from its previous site of binding
to a new site of bracket-wire engagement (Proffit et al., 2019).

With all of the brackets and treatment modalities available to orthodontists today
and the incessant, competing voices in the market touting their product’s superiority, it
can be incredibly disorienting to the common doctor simply seeking to treat his patients
as well as he is able. While it may be correctly stated that the variety of bracket systems
available to orthodontists today has expanded compared to the limited selection on offer
at the time of Edward Angle, it behooves the profession to determine whether these so-
called advancements result in more competent patient care, or whether they are little
more than a hollow, albeit attractive, marketing ploy.
Self-ligating VS Conventional Twin Brackets: Leveling and Alignment

With all of the aforementioned claims regarding the superiority of passive self-ligating brackets over conventional twin brackets, the burden of proof must necessarily fall on the manufacturers and clinicians supporting these assertions. To that effect, one must carefully analyze and thoroughly vet each claim independently in an effort to arrive at any sort of an unbiased appreciation of the current understanding of the scientific literature.

The first of these claims is that passive self-ligating brackets result in more efficient leveling and alignment. An analysis of this premise ought to include not only the speed of alignment, but also the ultimate degree of incisor irregularity, incisor proclination, arch form expansion, and even patient comfort (Harradine et al., 2008). One such study was designed to compare the effectiveness and comfort of Damon 2 brackets and conventional twin brackets during initial alignment (Miles et al., 2006). The researchers measured the irregularity index, lip comfort, preferred look, and bracket failure rates at the 10th and 20th week of treatment. They found that the twin bracket was more painful with the initial archwire (P = 0.04), but the Damon bracket was more painful when placing the second archwire and had a higher bracket failure rate, likely due to greater difficulty in closing the gate. They also found no significant difference in incisor irregularity between the two groups (Miles et al., 2006).
Another study looked at the efficiency of passive self-ligating vs conventional brackets during initial alignment with upper and/or lower 1st bicuspids extracted (Ong et al., 2010). The authors measured incisor irregularity scores, extraction space closure, and inter-canine widths after 20 weeks of treatment. They found that self-ligating brackets were no more efficient than conventional ligation brackets at initial alignment or extraction space closure during the first 20 weeks. They proposed that slight changes in arch dimensions might be due to a number of factors other than ligation, including variations in the arch-form of the wire (Ong et al., 2010). Other researchers focused on examining the efficiency of self-ligating and conventional brackets in the initial alignment of the mandibular incisors in 1st bicuspid extraction patients based on the irregularity index and the incisor proclination as measured by lateral cephalograms. They also found no significant difference between the two groups in final incisor alignment or proclination but admitted that the study may have suffered from insufficient power due to a small sample size of 10 patients per group (Prasad et al., 2011).

Conversely, there was one study conducted more recently that was able to identify a difference in the speed of alignment and patients’ pain perception when using Damon 3 and conventional MBT brackets (Jahanbin et al., 2019). During the four-month alignment stage, the researchers found significantly more improvement in the upper dental irregularity index with self-ligating compared to conventional brackets. The lower arch had no detectable difference in alignment between the groups. They also observed that bracket type had no effect on pain experience during the alignment stage (Jahanbin et al., 2019).
There have been other high-quality studies that serve to support the premise that self-ligating brackets may lead to faster treatment time. One clinical study took a sample of 60 patients and divided them into two groups of 30 with similar malocclusion, peer assessment ratings (PAR), and extraction patterns. At the conclusion of treatment, the author concluded that those treated with the passive self-ligating brackets required an average of four fewer months and four fewer visits to be treated to an equivalent level of occlusal regularity as measured by the PAR scores (Harradine, 2001).

Another relatively large sample study of 54 patients was conducted to investigate the speed of mandibular-crowding alleviation with passive self-ligating brackets compared to conventional appliances. Overall, the researchers found no difference in the time required to correct mandibular crowding with Damon 2 and conventional brackets. However, for moderate crowding (irregularity index <5) the self-ligating group had a statistically significant 2.7 times faster correction, and severely crowded cases were only marginally insignificant. Damon 2 subjects also displayed a greater change in intermolar width, although there was no difference between the groups in lower incisor proclination (Pandis et al., 2007). A similar study of 66 patients also found a greater increase in mandibular intermolar width within the self-ligating group, although this difference was relatively small at only 0.91 mm (Fleming et al., 2009).

As with the other parameters assessed during leveling and alignment, there seems to be no universal agreement on whether or not certain types of self-ligating brackets result in increased arch widths or faster treatment times. For example, a separate group of investigators found that the smart clip appliance (active self-ligation) did not perform faster alignment compared to conventional MBT appliances for mandibular crowding.
They also found that both groups increased intermolar and inter-canine widths by a statistically similar amount (Hada et al., 2009). Another study that examined maxillary arch width changes during orthodontic treatment with passive self-ligating and traditional straight-wire appliances similarly found no difference between groups (Tecco et al., 2009). On the other hand, several investigators in a Chinese study of 40 patients concluded that those treated with passive self-ligating brackets did indeed demonstrate a significantly greater post-treatment inter-premolar width of 4.45 mm when compared to the conventional twin bracket’s 2.41 mm width (Chen et al., 2012). The contrasting results of these studies underscores the inconclusive nature of the expected treatment benefits from either active or passive self-ligating brackets.

Perhaps the largest independent clinical study investigating this topic was conducted in 2012. Researchers took a pool of 100 patients with similar ICON (index of complexity, outcome, and need) scores and randomly divided them into two groups based on bracket type. The treatments were evaluated in terms of overall treatment time, number of visits, and treatment outcome using the final ICON score. The number of emergency appointments, number of archwires, overjet, relative space, and extractions at treatment start were noted (Johansson et al., 2012). At the conclusion of the study, the authors observed that orthodontic treatment with passive self-ligating brackets did not reduce treatment time, the number of appointments, final ICON scores, or overall ICON improvement when compared to conventional edgewise brackets (Johansson et al., 2012).

While relatively few of the available studies independently identify a significant difference between self-ligation and conventional brackets in regards to leveling and alignment, it is important to recognize that they do not, on their own, provide a
comprehensive representation of all available literature. A more thorough, systematic review was conducted by investigators looking at all available evidence across 4 databases from 1966 to 2009 (Chen et al., 2010). Of the relevant studies, only 16 met the stringent inclusion criteria. The purpose of the meta-analysis was to identify and review the orthodontic literature with regard to the effectiveness and stability of treatment with self-ligating brackets compared with conventional brackets. They concluded that shortened chair time and slightly less mandibular incisor proclination (by about 1.5 degrees) were the only statistically significant advantages of passive self-ligating brackets (Chen et al., 2010). Although many studies were disqualified, no other differences in length of treatment time or occlusal outcome were found in this analysis.

Such contrasting outcomes between these articles raise questions as to how similarly designed, randomly controlled clinical trials can arrive at such disparate conclusions. In pursuit of an answer to this inquiry, a group of researchers conducted a retrospective investigation of the effects of passive self-ligating and conventional brackets. The results of their study suggested that the bracket system itself may not be the primary factor in determining arch dimensions, mandibular incisor inclination, occlusal outcomes, or treatment efficiency (Anand et al., 2015). Instead, they theorized that the variations in these parameters may depend more on individual patient characteristics, such as initial crowding, patient demographics, and anatomical variations. They also proposed that treatment choices made by the clinician, such as archwire sequence and form and treatment mechanics likely have a greater influence on the outcome than bracket selection alone (Anand et al., 2015).
Self-ligating VS Conventional Twin Brackets: Friction

Friction is an intricate phenomenon influenced by a litany of factors in the intraoral environment. These factors include, but are not limited to, the archwire material, bracket material, ligation method, severity of crowding, malocclusion, and the patient’s salivation rate (Henao et al., 2005, Proffit et al., 2019). Unfortunately, due to the extreme difficulty in obtaining reliable and accurate reads of frictional forces intraorally, almost no studies attempt to measure friction in this manner. Thus, it is essential to prioritize those studies which most carefully aim to duplicate the complex nature of the intraoral environment when evaluating articles that examine the role of friction in orthodontic tooth movement. One such study investigated the effect of the ligation method on friction by comparing the frictional resistance of various brackets sliding along a 0.019”x0.025” inch stainless steel archwire in both a dry state and wet state, lubricated with artificial saliva (Hain et al., 2003). They found that SPEED active self-ligating brackets demonstrated the lowest static friction when compared to Victory series, Clarity, or Mini-twin 3M Unitek .022” slot brackets using standard elastic modules for ligation. However, they also found that loosely tied stainless steel ligatures on the metal Victory series bracket had the least friction of all pairings tested (Hain et al., 2003).

Another study evaluated the static and kinetic friction of passive (Damon 2 and Smart-Clip) and active (In-ovation and Time) self-ligating brackets compared to a conventional stainless steel bracket (Gemini series, 3M Unitek). This study measured the frictional resistance of 0.019”x0.025” stainless steel, beta-titanium, and nickel-titanium wires. The authors concluded that the passive self-ligating brackets exhibited the lowest static and kinetic friction of all brackets tested, especially when using beta or nickel-
titanium wires. Even the active self-ligating brackets exhibited lower frictional resistance than conventional brackets with polyurethane elastomeric ties (Krishnan et al., 2009).

While the findings of these studies are interesting, the size of the wire used makes their relevance to friction in initial leveling and alignment questionable. One study that bears more resemblance to the objective of this thesis was conducted with the purpose of comparing the frictional force generated by various combinations of self-ligating and conventional brackets, archwire sizes and types, and the amount of displacement during the initial leveling phase of orthodontic treatment (Kim et al., 2008). This was accomplished using a customizable, metal typodont that could vary the displacement of each resin tooth independent of the others. The teeth were set to the desired degree of malocclusion by intruding canines and retracting lateral incisors by up to 3 mm. Then, 0.014” and 0.016” austenitic nickel-titanium wires were drawn through with static and kinetic frictional values recorded. The researchers observed that the combination of passive self-ligating brackets with austenitic nickel-titanium wires showed lower frictional forces at any measured degree of tooth displacement than any other combinations of brackets, wire alloy, and wire size (Kim et al., 2008).

Another similarly designed study analyzed the frictional behavior of four conventional and four self-ligating brackets by drawing samples of 0.014”, 0.016”x0.022”, and 0.019”x0.025” austenitic nickel-titanium wires through quadrants of typodont models in dry and wet states. In order to simulate crowding in the intraoral environment, 6 different models of typodonts featuring progressively maloccluded quadrants were used (Henao et al., 2004). The investigators concluded that when coupled with the 0.014” wire, the passive self-ligating brackets demonstrated significantly lower
friction than conventional brackets in both dry and wet states. However, as the archwire
size and malocclusion increased, the discrepancy between the frictional resistance
decreased substantially. In fact, when 0.019”x0.025” wires were used, the P values of the
conventional brackets were comparable to those of the self-ligating brackets and were no
longer statistically significant. A similar finding was observed in states of increased
crowding and malocclusion. The authors declared that this outcome emphasized the
importance of completing leveling and alignment with a smaller wire before progressing
to larger wires with sliding mechanics in order to reduce frictional resistance. (Henao et
al., 2004).

In all of the aforementioned studies, it is important to note that all archwires are
being drawn through static brackets fixed to a set of immovable teeth. However, in a
clinical setting, teeth are constantly tipping and rotating in response to the applied forces,
creating new and unique sites of elastic binding as treatment progresses (Proffit et al.,
2019). In an effort to account for this phenomenon, one group of researchers developed a
testing apparatus that simulated the clinical reality in which teeth tip slightly while they
slide along an archwire. Under these specific testing conditions, the researchers found
that self-ligated steel brackets (Speed by Orec) did not demonstrate less friction than
either steel-tied or elastomeric ligated conventional steel twin brackets. (Bednar et al.,

As with the studies examining leveling and alignment efficiency, it can be
difficult to come to any clear understanding of the truth and fiction regarding the
purported low-friction benefits of self-ligating brackets by looking at independent studies
with conflicting interpretations. It is for this reason that systematic reviews, which pull
results from as much relevant literature as possible, are considered to carry the greatest
degree of clinical significance. One such systematic review looked at 70 papers across 5
databases related to the difference in expressed frictional resistance in self-ligating
brackets and conventionally ligated brackets. After vetting the quality of the studies, 19
articles were included in the meta-analysis. The researchers found that compared with
conventional brackets, self-ligating brackets exhibited lower friction when coupled with
small round archwires in the absence of significant tipping and/or torque, as is the case in
a more ideally aligned arch. However, sufficient evidence was not found to claim that
self-ligating brackets generate less friction when coupled with large rectangular wires or
in the presence of tipping and/or torque associated with considerable malocclusion
(Ehsani et al., 2009). These findings seem consistent with the general consensus of the
aforementioned studies which emphasized that any frictional benefit of self-ligating
brackets, if present, would be most evident during the leveling and alignment stage when
small round archwires are frequently employed (Prettyman et al., 2012).
CHAPTER 3
MATERIALS & METHODS

Study Design

All procedures and testing were completed in the Orthodontic Lab at Marquette University School of Dentistry. For the purpose of this study, the products that were the subject of examination include: Victory series 0.022” slot MBT conventional metal twin brackets by 3M Unitek, Damon Q2 passive self-ligating brackets by Ormco, 0.014” copper nitinol wire by Ormco, 2 sets of anatomically rooted metal typodont teeth by Kilgore, and 8 Class I crowding orthodontic wax forms by Kilgore (Figure 1). Two metal wax form articulators were also used to house the Class I wax forms. An iTero element 2 intraoral scanner was used to obtain digital copies of the models, and the frictional resistance of the wires was measured using a universal tensile testing machine (Autograph AGS-X series by Shimadzu).

Figure 1. Class I crowding orthodontic wax forms by Kilgore
Specimen Preparation

Both Damon Q2 and Victory series 3M Unitek brackets were bonded to the typodont teeth using the following protocol: plastic conditioner by Reliance was painted with a cotton tip applicator on each tooth and left to air dry for 10 minutes, a thin coat of Assure Plus bonding agent was then applied with a cotton tip applicator and air thinned for 10 seconds with an air/water syringe, a generous amount of Transbond XT composite by 3M Unitek was placed on each bracket pad, brackets were placed on typodont teeth at the average height indicated on the MBT Versatile+ bracket placement guide by Unitek (Figure 2), excess composite flash was removed, and each bracket was individually cured for 30 seconds with an Ortholux Luminous curing light by 3M-Unitek. The typodont teeth were then placed in the Class I crowded wax forms, with the exception of upper and lower 1st bicuspids which were left out to simulate extractions, and the wax forms were placed in the metal wax form articulators (Figure 3). In order to remove any potential residue from the manufacturing process, the 0.014” copper nitinol wires were cleaned with 91% isopropyl alcohol and allowed to air dry prior to being used in any of the tests. For the conventional twin brackets, black polyurethane elastomeric ligatures by 3M Unitek were used to tie in the wires.
In order to prepare the typodonts for the measurements of frictional resistance, the post-treatment wax forms in the metal articulators with newly aligned teeth were fixed to a 2 mm thick plastic base plate using generic cyanoacrylate that sat for 2 hours prior to
being subjected to any testing. The 0.014” copper nitinol wires were cleaned with 91% isopropyl alcohol and inserted into the upper right and lower left quadrants to allow for the wire to be pulled at a vector parallel to the molar tubes (Figure 4).

![Figure 4](image.png)

**Figure 4.** Wax form and articulator fixed to the base plate in Shimadzu testing machine.

**Experimental Procedure**

Prior to being subjected to the warm water bath, each metal rooted typodont tooth was cleaned with antibacterial SoftSoap and water to remove any wax residue and was carefully placed in the wax form until fully seated. Both experimental groups reused their respective set of bracket-bonded typodont teeth in each test run to remove the variable of inconsistent bracket placement between tests. Photos were taken 20 inches superior to the occlusal table with a Nikon 7200 camera using automatic focus, intraoral scans were
obtained with an iTero element 2 scanner, and lateral cephalograms were taken of the models to properly record the pre-treatment position (Figure 5, 6, 7).

**Figure 5.** Pre-tx occlusal view of Damon Q2 brackets on typodont teeth in metal articulator

**Figure 6.** Pre-tx occlusal view of Damon brackets from intraoral scan
After the 0.014” copper nitinol wires were cleaned with isopropyl alcohol, they were placed in the Damon Q2 brackets on the typodont teeth and ligated into the traditional twin brackets with polyurethane elastomeric o-ties (Figure 8). Several trial runs were conducted to determine the appropriate temperature for the water bath to facilitate tooth movement without excessive wax softening. Ultimately, it was determined that each set of models would be placed for 10 minutes in 7 liters of water heated to 48 degrees Celsius in the Hamilton Beach electric roaster oven (Figure 9). The models were promptly removed from the water bath, dried for 30 seconds with pressurized air, and placed in a refrigerator at 4.44 degrees Celsius for 10 minutes to solidify teeth in the newly aligned position. After cooling had completed, a new set of records were obtained, including the occlusal photos, intraoral scans, and lateral cephalogram (Figure 10, 11, 12). This test was repeated 4 times for each experimental group, labeled Damon and MBT, in both upper and lower arches.
Figure 8. Wire cleaned and ligated in Damon Q2 brackets ready for water bath

Figure 9. Models with wire in Damon Q2 brackets in Hamilton Beach water bath
Figure 10. Post-tx occlusal view of Damon Q2 brackets on typodont teeth in metal articulator

Figure 11. Post-tx occlusal view of Damon group from intraoral scan

Figure 12. Post-tx lateral cephalogram of Damon brackets in metal articulator
Using the 1:1 copies of the occlusal view taken from the pre and post-treatment intraoral scans, measurements were taken in millimeters of the arch length, measured as the length of a line drawn perpendicular to a line connecting the central fossa of 1st molars to a point between the central incisors, intermolar width from the central fossa, inter-canine width from incisal tip to incisal tip, extraction space between the canines and 2nd bicuspid at the center of their distal and mesial marginal ridges respectively, and interincisal spaces, measured as the post-treatment gap between the anterior teeth from canine to canine. These measurements were taken using the Align Technology software interface in conjunction with the scans obtained by an iTero element 2 scanner. An approximation of these measurements is detailed below (Figure 13).

![Figure 13. Sample of the measurements taken from the MBT group intraoral scans](image)

Incisor proclination was measured from the lateral cephalograms using a constructed Frankfort horizontal plane and mandibular plane from the anterior and posterior-most points on the inferior and superior borders of the upper and lower metal articulators respectively. The upper and lower central incisor root tips and incisal edges
were also identified. From these 4 points, the pre and post-treatment measurements for FH-U1 and MP-L1 were obtained (Figure 14).

![Figure 14. Pre and post-tx lateral cephalogram of MBT brackets showing FH and MP](image)

In order to test the frictional resistance of the different bracket systems, the post-treatment models of the fourth experimental group were used. A new set of 16, 0.014” copper nitinol wires was cleaned with 91% isopropyl alcohol. The wires were ligated or self-ligated into the upper right and lower left quadrants of the conventional 3M-Unitek brackets and Damon Q2 brackets respectively. 15 mm of the distal-most end of the wire was engaged into the metal clamp of the Autograph AGS-X series tensile testing machine (Figure 15). The machine was then calibrated to set the starting force to zero, and the greatest force, measured in Newtons, was recorded as a representation of the static force in that quadrant (Figure 16). This test was repeated 4 times for each experimental group, labeled Damon and MBT, in both upper and lower arches.
Figure 15. Benchtop set up for Autograph AGS-X series universal tensile testing machine

Figure 16. Model attached to base plate with wire engaged in universal testing machine
**Statistical Analysis**

After each pre and post-treatment variable was tested four times per experimental group in both upper and lower arches, all data was compiled into tables within Excel for easier statistical analysis. These data were used to calculate the mean differences between the samples. A one-way analysis of variance (ANOVA) test was performed to evaluate the equality among the two study groups and the four trials for each parameter: arch length, intermolar width, inter-canine width, extraction space, interincisal spacing, incisor proclination, and static friction. After each one-way ANOVA test, a post hoc analysis was used to determine where the differences were found between each experimental group in each individual trial. The significance was set to $p < 0.05$. The calculations and analyses were performed with IMB SPSS Statistics for Windows version 28.
CHAPTER 4
RESULTS

For all of the following test parameters subjected to investigation, statistical analysis by one-way ANOVA revealed that there was no significant difference between the Damon and MBT groups in their initial measurements prior to each test run ($p > 0.05$). This finding ensured that the change between groups was measured against a reliable and consistent baseline.

Arch Length

The mean value of arch length change of each experimental group was calculated, as well as the standard deviation and standard error (Table 1, Figure 17). The data for both upper and lower arches were independently analyzed with a one-way ANOVA and post hoc test. There were significant differences ($p < 0.05$) between the post-treatment arch lengths of Damon and conventional MBT bracket groups, with the Damon group showing less of an increase in both upper and lower arch lengths.

<table>
<thead>
<tr>
<th>Arch Length Upper</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>Arch Length Lower</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Treatment Damon</td>
<td>33.05</td>
<td>0.17321</td>
<td>0.0866</td>
<td>Pre-Treatment</td>
<td>27.95</td>
<td>0.100</td>
<td>0.050</td>
</tr>
<tr>
<td>Post-treatment Damon</td>
<td>34.45</td>
<td>0.42032</td>
<td>0.21016</td>
<td>Post-treatment</td>
<td>29.90</td>
<td>0.27080</td>
<td>0.13540</td>
</tr>
<tr>
<td>Pre-Treatment MBT</td>
<td>33.175</td>
<td>0.18932</td>
<td>0.09465</td>
<td>Pre-Treatment</td>
<td>27.80</td>
<td>0.14142</td>
<td>0.0707</td>
</tr>
<tr>
<td>Post-Treatment MBT</td>
<td>36.825</td>
<td>1.06262</td>
<td>0.53131</td>
<td>Post-Treatment</td>
<td>30.675</td>
<td>0.39476</td>
<td>0.19738</td>
</tr>
</tbody>
</table>

Table 3. Means, standard deviations, and error of arch length in mm.
The mean value of intermolar and inter-canine width of each experimental group was calculated, as well as the standard deviation and standard error (Table 2, 3, and Figure 18, 19). The data for both upper and lower arches were independently analyzed with a one-way ANOVA and post hoc test. There were no significant differences ($p > 0.05$) between the post-treatment intermolar widths of Damon and conventional MBT bracket groups in either arch. There were significant differences ($p < 0.05$) between the post-treatment inter-canine widths of Damon and MBT bracket groups, with the Damon group showing a more significant decrease in upper and lower inter-canine widths.

**Figure 17.** Arch length means in mm.

**Intermolar and Inter-canine Width**
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intermolar Upper</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Intermolar Lower</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Damon</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Pre-Treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment</td>
<td>47.175</td>
<td>0.12583</td>
<td>0.06292</td>
<td>Pre-Treatment</td>
<td>40.825</td>
<td>0.0750</td>
<td>0.0600</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>46.875</td>
<td>0.2500</td>
<td>0.12500</td>
<td>Post-treatment</td>
<td>40.525</td>
<td>0.2250</td>
<td>0.1430</td>
</tr>
<tr>
<td><strong>MBT</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Pre-Treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment</td>
<td>46.875</td>
<td>0.32016</td>
<td>0.16008</td>
<td>Pre-Treatment</td>
<td>40.975</td>
<td>0.1523</td>
<td>0.1124</td>
</tr>
<tr>
<td>Post-Treatment</td>
<td>46.975</td>
<td>0.3304</td>
<td>0.16520</td>
<td>Post-Treatment</td>
<td>40.675</td>
<td>0.1080</td>
<td>0.1086</td>
</tr>
</tbody>
</table>

Table 4. Means, standard deviations, and error of intermolar width in mm.

Figure 18. Intermolar means in mm.
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inter canine</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Inter canine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Upper</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Lower</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre-Treatment</strong></td>
<td>38.225</td>
<td>0.20616</td>
<td>0.10308</td>
<td><strong>Pre-Treatment</strong></td>
<td>29.70</td>
<td>0.29439</td>
<td>0.14720</td>
</tr>
<tr>
<td><strong>Post-treatment</strong></td>
<td>36.95</td>
<td>0.36968</td>
<td>0.18484</td>
<td><strong>Post-treatment</strong></td>
<td>28.65</td>
<td>0.43589</td>
<td>0.21794</td>
</tr>
<tr>
<td><strong>Pre-Treatment</strong></td>
<td>38.00</td>
<td>0.27080</td>
<td>0.13540</td>
<td><strong>Pre-Treatment</strong></td>
<td>30.05</td>
<td>0.33166</td>
<td>0.16583</td>
</tr>
<tr>
<td><strong>Post-treatment</strong></td>
<td>37.85</td>
<td>0.54467</td>
<td>0.27234</td>
<td><strong>Post-treatment</strong></td>
<td>30.25</td>
<td>0.20817</td>
<td>0.10408</td>
</tr>
</tbody>
</table>

Table 5. Means, standard deviations, and error of inter-canine width in mm.

**Figure 19.** Inter-canine means in mm

**Extraction Space and Interincisal Space**

The mean value of extraction space and interincisal spaces of each experimental group was calculated, as well as the standard deviation and standard error (Table 4, 5, and Figure 20, 21). The data for both upper and lower arches were independently analyzed with a one-way ANOVA and post hoc test. There was no significant difference ($p > 0.05$) between the pre and post-treatment extraction space changes of Damon and
conventional MBT bracket groups in the lower arch. However, there was a significant
difference ($p < 0.05$) between the pre and post-treatment extraction spaces of Damon and
MBT bracket groups in the upper arch, with the Damon group showing a more significant
decrease. There were significant differences ($p < 0.05$) between the interincisal spaces of
the Damon and MBT groups in both upper and lower arches, with the conventional MBT
bracket group showing significantly more spacing between the anterior teeth.

<table>
<thead>
<tr>
<th></th>
<th>Ext Space Upper</th>
<th></th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>Ext Space Lower</th>
<th></th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damon</td>
<td>Pre-Treatment</td>
<td>9.6875</td>
<td>0.21747</td>
<td>0.10873</td>
<td>Pre-Treatment</td>
<td>7.925</td>
<td>0.100</td>
<td>0.050</td>
</tr>
<tr>
<td></td>
<td>Post-treatment</td>
<td>8.150</td>
<td>0.28577</td>
<td>0.14289</td>
<td>Post-treatment</td>
<td>6.9125</td>
<td>0.27080</td>
<td>0.13540</td>
</tr>
<tr>
<td>MBT</td>
<td>Pre-Treatment</td>
<td>9.400</td>
<td>0.14720</td>
<td>0.07360</td>
<td>Pre-Treatment</td>
<td>7.8625</td>
<td>0.14142</td>
<td>0.0707</td>
</tr>
<tr>
<td></td>
<td>Post-Treatment</td>
<td>9.0719</td>
<td>0.25166</td>
<td>0.12583</td>
<td>Post-Treatment</td>
<td>6.8025</td>
<td>0.39476</td>
<td>0.19738</td>
</tr>
</tbody>
</table>

**Table 6.** Means, standard deviations, and error of extraction space in mm.

**Figure 20.** Extraction space means in mm.
### Table 7. Means, standard deviations, and error of interincisal space in mm.

<table>
<thead>
<tr>
<th></th>
<th>Interincisal space Upper</th>
<th></th>
<th>Interincisal space Lower</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Standard Error</td>
<td>Mean</td>
</tr>
<tr>
<td>Damon</td>
<td>Post-treatment</td>
<td>0.9875</td>
<td>0.33510</td>
<td>1.250</td>
</tr>
<tr>
<td>MBT</td>
<td>Post-treatment</td>
<td>2.475</td>
<td>0.35237</td>
<td>3.250</td>
</tr>
</tbody>
</table>

**Figure 21.** Interincisal space means in mm.

### Incisor Proclination

The mean value of incisor proclination of each experimental group was calculated, as well as the standard deviation and standard error (Table 6, Figure 22). The data for both upper and lower arches were independently analyzed with a one-way ANOVA and post hoc test. There were significant differences ($p < 0.05$) between the post-treatment incisor proclination of Damon and conventional MBT bracket groups,
with the MBT group showing a greater increase in both upper and lower incisor proclination as measured in degrees.

![Table 8](image)

<table>
<thead>
<tr>
<th></th>
<th>FH-U1</th>
<th></th>
<th></th>
<th>MP-L1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Standard Error</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Standard Error</td>
</tr>
<tr>
<td><strong>Damon</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>123.375</td>
<td>0.29861</td>
<td>0.1493</td>
<td>Pre-treatment</td>
<td>106.975</td>
<td>0.36856</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>128.7250</td>
<td>2.62091</td>
<td>1.31045</td>
<td>Post-treatment</td>
<td>112.650</td>
<td>0.8544</td>
</tr>
<tr>
<td><strong>MBT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>123.350</td>
<td>0.23805</td>
<td>0.11902</td>
<td>Pre-treatment</td>
<td>106.925</td>
<td>0.45735</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>132.6750</td>
<td>1.28938</td>
<td>0.64469</td>
<td>Post-treatment</td>
<td>116.325</td>
<td>1.08743</td>
</tr>
</tbody>
</table>

*Table 8. Means, standard deviations, and error of incisor proclination in degrees.*

![Figure 22](image)

*Figure 22. Incisor Proclination means measured in degrees.*
Static Friction

The mean value of static friction of each experimental group was calculated, as well as the standard deviation and standard error (Table 7, Figure 23). A one-way ANOVA test was performed to evaluate the equality among the two study groups and the four trials. There was a significant difference ($p < 0.05$) between the static friction of the two bracket systems, with the Damon group displaying less frictional resistance. There was also a significant difference ($p < 0.05$) between the recorded static friction for the upper arch and lower arches within the MBT bracket group, with the upper arch exhibiting a significantly greater amount of static friction than the lower arch. No such difference was noted between the upper and lower arches of the Damon bracket group.

<table>
<thead>
<tr>
<th>Static friction</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>Static friction</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>Damon</td>
<td>Post-treatment</td>
<td>0.5975</td>
<td>0.04113</td>
<td>0.02056</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MBT</td>
<td>Post-treatment</td>
<td>3.5725</td>
<td>0.19822</td>
<td>0.19822</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td></td>
<td>Post-treatment</td>
<td>0.6025</td>
<td>0.04349</td>
<td>0.02175</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-treatment</td>
<td>3.2575</td>
<td>0.14705</td>
<td>0.07353</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Means, standard deviations, and error of static friction in Newtons.

![Post-Treatment - Static Friction](image)

Figure 23. Static friction means measured in Newtons.
CHAPTER 5
DISCUSSION

In recent years, much has been made of the benefits of self-ligating brackets over conventional twin brackets. As stated, some of the proposed advantages include: increased patient comfort, faster treatment times, shorter chair time, enhanced oral hygiene, reduced need for extractions, greater arch form expansion, and less incisor proclination, all due to the reduced frictional resistance (Ormco, 2022). Within the orthodontic profession, there is a wide range of opinions regarding the validity and significance of these claims. In order to obtain a greater understanding of the orthodontic community’s perception of self-ligating brackets, a detailed survey of 430 orthodontists was conducted (Prettyman et al., 2012). The researchers found that passive self-ligating brackets were preferred during the initial stage of treatment due to shorter adjustment appointments and faster initial treatment progress during leveling and alignment ($p < 0.0001$). Orthodontists also reported that they prefer self-ligating brackets for purposes of enhanced oral hygiene and notable assistant preference during archwire changes. Conventional brackets were much preferred during the finishing and detailing stages of treatment ($p < 0.0001$), and because they were cheaper and resulted in fewer emergency appointments due to easier bracket-wire engagement when using larger finishing wires (Prettyman et al., 2012). No statistically significant difference was noted for which bracket system provided the greatest long-term stability or less relapse potential.

The results of this study are similar in many ways to the assertions of the surveyed orthodontists. The conventional twin bracket group (MBT) showed a significantly greater increase in arch length, incisor proclination, interincisal spacing, and
static friction for both upper and lower arches ($p < 0.05$). These findings support the claim that Damon brackets may be more efficient at initial leveling and alignment when compared to conventional edgewise systems. One study attempted to simulate the required force for canine retraction by replicating the resistance from the alveolar bone and calculating the amount of force lost to friction in an intricate in-vitro experiment. The researchers in this study concluded that 60% of the force required to move a tooth is lost to friction, which is consistent with the long-held belief that approximately 50% of the orthodontic force is spent attempting to overcome friction and elastic binding (Kojima et al., 2005, Proffit et al., 2019). With an understanding of the role of friction in orthodontics, one can appreciate how these findings might be interrelated. The more profound frictional resistance of the MBT bracket system in this study would necessitate a greater force to move a tooth a given distance than would the Damon bracket system, which has considerably less static friction to overcome. This excess force would exert appreciably greater pressure on the surrounding wax, taxing its integrity and causing more significant displacement of teeth in the process.

The MBT bracket group also exhibited greater static friction in the upper arch as compared to the lower, whereas the Damon bracket group displayed no such difference between arches. This is likely due to the fact that the amount of frictional resistance encountered within a system is directly proportional to the applied load on the contact area (Proffit et al., 2019). When tying in the wire, the elastomeric ligatures must be stretched to a greater degree to fully engage the larger brackets of the upper arch than the smaller brackets of the lower arch. This results in more pressure at the wire bracket interface with more substantial elastic binding to surmount than is produced by the
passive metal gates of the Damon bracket system, especially when small, round wires are used that do not fill the slot (Ehsani et al., 2009).

Interestingly, no difference was found in either arch between the groups’ pre and post-treatment intermolar width. These findings are notably different from the balance of available studies which indicate that treatment with passive self-ligating brackets is likely to yield a more significant change in intermolar arch width compared to conventional edgewise brackets (Chen et al., 2012, Fleming et al., 2009, Pandis et al., 2007). Furthermore, the Damon Q2 bracket system in this study exhibited a greater decrease in upper arch extraction space and inter-canine width in both arches ($p < 0.05$).

At first blush, these findings may seem confusing when paired with the common assertion that self-ligating brackets lead to naturally wider arch forms and decrease the need for extraction therapy (Ormco, 2022). However, it is important to note that the referenced studies only observed a difference in intermolar arch widths at the completion of treatment, which was not the objective of this study (Chen et al., 2012, Fleming et al., 2009, Pandis et al., 2007). Instead, this study focused on the initial treatment stage of leveling and alignment, and thus began treatment with severely displaced canines, which would require both vertical extrusion and palatal intrusion in order to become properly aligned within the arch. Therefore, the decreased inter-canine width exhibited by the Damon bracket group is more likely a reflection of efficient leveling and alignment than of the system’s ability to produce more significant arch expansion. Similarly, the decrease in upper extraction space is most probably attributable to the decreased incisor proclination and interincisal spacing seen in the Damon bracket group due to the more efficient force distribution and lower frictional resistance. It is plausible that this study
may have generated more notable changes in arch width expansion among the groups had it proceeded to full-size rectangular archwires.

There are some limitations to this study, the most glaring of which is the extra-oral, benchtop nature of the experimental design. In a clinical scenario, the force mechanics of both bracket systems would be heavily influenced by biologically variable, genetic factors such as alveolar bone density, bone turnover rate, patient age, sex, perioral musculature, and salivation rate, none of which are exhibited by our wax typodont system (Dudic et al., 2013). An in-vitro study necessarily removes these variables from consideration and is, therefore, not an accurate depiction of what might be observed clinically. However, it might be argued that a benchtop design may occasionally provide unique insights into the force mechanics of different brackets systems by limiting these confounding variables, simplifying and streamlining the experimental process (Henao et al., 2005).

Another limitation is that the measurements of frictional resistance were obtained from properly aligned quadrants in both groups, rather than from crowded or displaced quadrants, which would be more clinically relevant. This study also suffers from the common issue of drawing a wire through fixed brackets in a static system for frictional measurements, which is markedly different from the more dynamic intraoral system that consists of sequential “sticking and slipping” of a wire as the tooth tips and rotates in response to orthodontic forces (Bednar et al., 1991, Olson et al., 2012). A systematic review found that although small, round wires encountered lower frictional resistance in passive self-ligating brackets, sufficient evidence does not exist to support the claim that
the decreased frictional resistance is clinically relevant when larger wires are used, or in a
crowded arch with significant malocclusion (Ehsani et al., 2009).

Given these limitations, there are several potential modifications that could be
made to this study in the future. If this study were to be reexamined, one might consider
examining the frictional resistance of the bracket system before and after initial alignment
had taken place, in order to gain a greater appreciation for the difference in friction
between the groups in both a crowded and aligned arch. In addition, one could progress
from small, round wires to larger, rectangular finishing wires in an effort to more
accurately appreciate the differences between self-ligating and conventional brackets in
the finishing and detailing stages of treatment. Unfortunately, these later stages of
orthodontic treatment were beyond the scope of this study.

With all of the conflicting voices in the orthodontic community today, it behooves
the modern practitioner to familiarize him or herself with as much non-biased, scientific
evidence as possible before utilizing a company’s claims as a tool to market a specific
bracket system to patients. Though this study identified several significant differences
between the Damon and MBT groups, the legitimacy and relevance of these findings in a
clinical scenario remains questionable. Even with all of the existing research that
examines the pros and cons of self-ligating brackets compared to conventional edgewise
brackets, additional clinical studies are still needed to sufficiently sift through all of the
existing claims surrounding the potential superiority of self-ligating brackets in order to
discern what is true, and what is false.
CHAPTER 6
CONCLUSION

When compared to the conventional MBT bracket group, the Damon Q2 group showed significantly less increase in arch length, incisor proclination, interincisal spacing, and static friction for both upper and lower arches at the conclusion of leveling and alignment ($p < 0.05$). In addition, the MBT bracket group exhibited greater static friction in the upper arch as compared to the lower arch ($p < 0.05$), whereas the Damon bracket group demonstrated no such difference between arches. The Damon bracket system in this study also exhibited a significantly greater decrease in upper arch extraction space and inter-canine width in both arches ($p < 0.05$). This disparity might be construed as evidence that Damon brackets allow for more equivalent space redistribution during the alignment of crowded arches. No difference was found in either arch between the groups’ pre and post-treatment intermolar width ($p > 0.05$).

On the basis of the statistical data and analysis presented in this study, the null hypothesis, that there is no difference between Damon and conventional MBT brackets during in-vitro leveling and alignment, is rejected. This study supports, in theory, some of the claims made by Ormco concerning the superiority of Damon brackets during the initial stages of leveling and alignment when compared to conventional edgewise systems in orthodontic therapy. These findings may indicate that patients with severely crowded, proclined incisors would benefit from treatment with passive self-ligating brackets. However, the clinical relevance of these findings remains in question, and similar studies are needed to construct a more clinically accurate depiction of the dichotomy between conventional edgewise and passive self-ligating bracket systems.
REFERENCES


