THE EFFECTS OF CROWDING ON BUCCAL TIPPING COMPARING THE DAMON BRACKET SYSTEM AND A STRAIGHT-WIRE ORTHODONTIC APPLIANCE

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ABSTRACT

In orthodontics, crowding can be resolved by extraction of teeth, decreasing tooth size, or by expansion of the arches. A side-effect of expansion is buccal tipping of the teeth. Dwight Damon created the Damon Bracket System, an expansion method that uses self-ligating brackets and Nickel-Titanium arch-wires. The Damon Bracket System is thought by some orthodontists to have the ability to expand the arches with little tipping. This retrospective study evaluates the change in buccal tipping of the teeth in non-extraction cases treated with either the Damon Bracket System or a traditional Straight-Wire appliance.

The maxillary dental casts of 60 patients (30 of each treatment modality) were selected from an orthodontic practice that has used both the Damon Bracket System and a traditional Straight-Wire appliance. The sample was selected based on a pre-treatment Class I occlusion, no posterior cross-bite, and have all permanent teeth present (except second and third molars). Measurements taken from the pre- and post-treatment models included: intercanine, interpremolar, and intermolar widths, tooth-size/arch

length discrepancy, and tipping of a central incisor, the canines, first premolars, and first molars.

Statistics showed that the two groups were similar in regards to pre-treatment crowding and inter-canine, premolar, and molar widths. The results indicate that there was not a significant difference in the amount of inter-canine, premolar, and molar expansion gain between groups treated with the Damon Bracket System and a traditional straight-wire appliance. The results also showed that the amount of expansion or crowding was not significantly associated with tipping. The results did show a significant association between inter-canine expansion and crowding in the straight-wire group, while no associations existed between crowding and tipping in the Damon group. The treatment time of the group treated with the Damon Bracket System was 6.8 months less than the group treated with a traditional straight-wire appliance.

This study suggest that correction of crowding using the Damon Bracket System or a traditional straight-wire appliance result in similar amounts of inter-arch expansion and tipping. The major

difference in the two systems seems to be a decrease in treatment time when using the Damon Bracket System.

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DEDICATION

This thesis is dedicated to my mother for her guidance and support; to my girlfriend, Stephanie, for her love and support; to my grandmother for being a strong foundation for generations of Jacksons; to my brother for serving as a role model; and to God for blessing me with the knowledge and opportunity to fulfill my dreams.

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CHAPTER 1: INTRODUCTION

A major reason why patients seek orthodontic treatment is because of crowding of the teeth. Crowding can be corrected by removal of teeth, decreasing the size of teeth, or various non-extraction methods. In general, non-extraction treatment is accomplished by dental expansion. The goal of dental expansion is to relieve crowding by increasing the arch perimeter to accommodate all the teeth.

Orthodontists can expand the arch anterior-posteriorly or transversely depending on the patients' needs. Anterior-posterior expansion involves distalization of the molars and/or proclination of the incisors. Transverse expansion can be accomplished orthopedically or orthodontically. Both types of expansion are used to correct posterior cross-bites, widen constricted arches, and increase arch perimeter.

Orthopedic expansion often involves the use of an expander. Such devices use high force to separate the palatal shelves at the mid-palatal suture, with or without surgery. Rapid palatal expansion has been investigated extensively and is considered by many to be an effective method of orthopedic expansion.

The goal of orthodontic expansion is to bodily move or tip the teeth within the bone. Orthodontic expansion is often used in patients when the mid-palatal suture can not be opened and/or when the amount of expansion needed is not great. Archwire expansion is a technique in which wires broader than the existing archform are inserted to widen the arch and relieve crowding. Archwire expansion has been used since the dawn of orthodontics, but recently a new technique has been created.

Damon theorizes that by using lighter forces delivered by super elastic wires that the facial and lip musculature would limit anterior expansion and allow great lateral expansion by restricting the buccal musculature. He stated that the teeth can be moved great distances laterally without encroaching on the buccal plates of the alveolar bone. The theory is that the light forces will not occlude the blood vessels and allow new bone to be formed. It is suggested that this method of expansion can be used to alleviate large amounts of crowding and correct posterior cross-bites.

It is generally believed that during orthodontic expansion some combination of bodily movement and

tipping occurs. When excessive crowding is present, it is believed that excessive tipping will occur. Damon claims that the Damon Bracket System does not result in excessive tipping but rather the teeth are moved bodily and the bone responds favorably. This claim challenges many long-held orthodontic conventions as to the limit of expansion and the need for tooth extractions. The question is at what point is the buccal musculatures not restricted and the facial and lip musculature overwhelmed. Specifically, with increasing amounts of crowding does incisor and buccal tipping begin to play a more significant role in the relief of crowding?

The aim of this study is to investigate the effect of increased crowding on incisor and buccal tipping in non-extraction cases treated by a traditional straight-wire orthodontic appliance or the Damon Bracket System. In order to evaluate the effects of the Damon Bracket System versus a traditional straight-wire orthodontic appliance, two samples will be compared to assess tipping of the teeth. This study is intended to assist clinicians in understanding the effects of their appliances.

CHAPTER 2: REVIEW OF THE LITERATURE

Correction of Crowding

Crowding is one of the most common reasons that patients seek orthodontic treatment. Crowding identifies a lack of adequate space for the teeth to be aligned over the apical base. Crowding can be corrected by extraction of teeth, decreasing the size of the teeth, and/or by expansion of the dental arches.

Extraction of teeth can be used to create space for correction of crowding. The teeth and number of teeth to be extracted will vary depending on the amount of crowding, the pre-existing malocclusion, and desired results. The positive effects associated with extractions are a space gain permitting a decrease in protrusion and proper alignment. The negative effects include: pain to the patient, additional cost, and the removal of healthy teeth.

To avoid extractions, many orthodontists choose to create space by decreasing the size of the teeth. The size of the teeth can be decreased by removal of enamel on the mesial and/or the distal surfaces of the

teeth. This removal of enamel is not harmful to the teeth if the proper protocol is followed. Zachrisson et al.[1] found no longterm iatrogenic damage after inter-proximal reduction.

Orthodontic Expansion

Expansion of the dental arch has been a common orthodontic treatment since the beginning of orthodontics. Edward Angle's E-arch, his first appliance, was used to expand the teeth into the desired archform. Since that time, many techniques have been developed to expand the dental arches. Expansion has been used to relieve crowding and widen arches that orthodontists deem as constricted. Expansion can be skeletal, dental, or a combination of the two.

Skeletal Expansion

Rapid palatal expansion is a skeletal expansion treatment that involves the mechanical opening of the mid-palatal suture by application of heavy forces transmitted through the teeth to the palatal shelves.[2] Rapid palatal expansion intends to correct transverse osseous deficiencies and/or increase arch perimeter.

While it is accepted that transverse deficiencies can be corrected with rapid palatal expansion, there are differing opinions on how much arch perimeter change can be gained by rapid palatal expansion.

Dental Expansion

Although the goal of rapid palatal expansion is often to cause skeletal expansion, some dental expansion also occurs. Chung and Font[3] investigated the dental and skeletal changes following rapid palatal expansion. They found that amount of dental expansion was greater than skeletal expansion. The authors concluded that the greater amount of dental expansion was due to the premolars and molars tipping buccally. They concluded that 9.7% (premolars) and 4.3% (molars) of the total expansion was due to tipping.

Dental expansion is often desired when suture splitting is not necessary, a transverse deficiency is of dental origin, and to alleviate crowding. In dental expansion, the teeth are bodily moved and/or tipped within the alveolar bone. Several methods have been used to achieve dental expansion.

A common method of dental expansion is archwire expansion. Archwire expansion does not require that the mid-palatal suture be opened. In archwire expansion, an archwire of greater width than the arch is inserted to reshape and broaden the arch. The goal is to provide a greater arch perimeter to accommodate the teeth.

Benefits of Expansion Treatment

One of the major benefits of expansion treatment is an increase in arch perimeter. Adkins et al.[4] studied patients that were treated with a rapid palatal expansion. They found a significant increase in arch perimeter, and he also stated that the amount of arch perimeter gain can be predicted. They found that the gain in arch perimeter is about 0.7 times the amount of premolar expansion. In another prediction attempt, Germane et al.[5] mathematically analyzed intermolar expansion, inter-canine expansion, and incisor advancement effects on arch perimeter. They showed intermolar expansion is the least efficient method to increase arch perimeter while incisor advancement was the most efficient.

Most studies that evaluate palatal expansion do not include a period of fixed orthodontic appliances. A period of fixed orthodontic appliances wear is a common treatment after rapid palatal expansion to correct the remaining irregularities. McNamara investigated arch perimeter when a period of fixed orthodontic appliances follows rapid palatal expansion. McNamara et al.[6] showed an increase in arch perimeter in the maxillary and mandibular arches in patients treated with RPE followed by fixed appliance therapy. They showed that the maxillary arch had a relative increase in arch perimeter of 7.5 mm while the mandibular arch had a relative increase of 5.0 mm when compared to a control group.

An increase in arch perimeter is used to alleviate crowding and minimize the need to extract teeth. Expanding the arches to alleviate crowding is considered to be desirable because extraction of teeth is associated with risks including trauma to the patient, added costs, risk of infection, and even death. The benefits of expansion are obvious to many orthodontists, but the possible risks of expansion are less apparent.

Possible Problems

Expansion is not without its drawbacks. Excess expansion can lead to permanent and sometimes severe problems. For example, it has been suggested that a dehiscence might be created by forcing the roots of the teeth through the buccal plate of bone. In addition expansion might produce periodontal recession, the production of bimaxillary protrusion, improper occlusal relationships, and instability. Injury to the periodontal apparatus is a concern when any orthodontic treatment is attempted. Certain movements of teeth are correlated with an increase in periodontal problems. Lateral expansion greater than 3 mm in the premolar and molar areas has been shown to cause bone fenestrations.[7] Incisors that are excessively proclined are also associated with periodontal problems. Yared et al.[8] investigated gingival recession in patients that had orthodontic treatment. They found that the actual movement of the teeth was not the most important predisposing factor, but a final incisor mandibular-plane angle of greater than 95 degrees with less than .5 mm of attached keratinized gingival showed a strong correlation with recession.

The total movement of the teeth can also affect the condition of the gingiva. Dorfman[9] found that with a minimal amount of keratinized gingival(0-2 mm), the magnitude and direction of movement of the mandibular incisors can affect final gingival health.

Orthodontic expansion can also lead to improper occlusion. Proper occlusion of the maxillary and mandibular teeth is dependent on several factors, one of which is the angulations of the teeth. Andrews[10] stated that excessive proclination of the anterior or posterior teeth will lead to an inability of the teeth to properly occlude. If the anterior teeth are too upright and the posterior are properly aligned, spaces will remain when finishing the case. He feels that the residual space is often blamed on a tooth size discrepancy when in fact excess angulation is to blame. Also, excessive proclination of the anterior teeth will result in too much overjet and an inability to achieve a Class I relationship of the posterior teeth.

Stability is a major concern of orthodontists with regard to dental expansion. It is accepted that relapse will occur following any orthodontic treatment. However, relapse is an even greater

concern when the dental arches have been expanded. Ackerman and Proffit[11] have suggested that the limits of stable expansion are 2 mm and 4-5 mm of anterior-posterior and transverse expansion, respectively.

Some orthodontists choose to broaden the archform by using a standard preformed archform for all patients. In some instances the use of standard archforms can be used, but disregarding the patient's natural archform can lead to instability. De la Cruz et al.[12] studied long term changes in the archform after retention. They found that there is a rounding of archforms during treatment and there was tendency for the archform to relapse back to the patient's pretreatment archform. They also found that patients that had a greater amount of change in their archform had a greater tendency to relapse.

Some orthodontists choose to counteract the relapse tendency by placing fixed retainers. Sadowsky et al.[13] studied long term retention in patients that had mandibular and maxillary arch wire expansion. They found that there was significant relapse of the mandibular anterior teeth even with fixed retention. He stated that even though the amount of irregularity was statistically significant, it was clinically

minimal and less than other long term studies with no fixed retention.

A concern for stability following expansion treatment is believed to result from a disruption in the equilibrium state of the teeth. The teeth are in constant equilibrium with the forces in the mouth. It is widely accepted that the muscles of the oral-facial complex determine the shape of the dental arches but there are varying theories as to the influence of the oral forces on the teeth. Proffit[14] stated that in the absence of extrinsic forces such as habits, the resting position of the lips and cheeks are the largest factors influencing the dental equilibrium when considering the transverse dimension. The position of the teeth is determined not only by a lack of space, but also due to the balance of these forces. Teeth that are moved excessively into a position such that the equilibrium is disturbed are in an unstable position and a greater tendency to relapse exists. Orthodontic movement alters the dental equilibrium but how much is tolerable is still unknown. The amount of movement that is tolerable is the source of much controversy in orthodontics. Proffit[14] states the orthodontist's perceived modifiability of the

equilibrium will determine the boundaries of the orthodontist's proposed treatment.

Crowding and protrusion are examples of an imbalance in the dental equilibrium. Proffit[15] states that both crowding and protrusion are the result of a lack of space in the dental arch. It is not ideal to correct crowding by creating bimaxillary protrusion. A bimaxillary protrusion can be created in a severely crowded case if the incisors are simply proclined to alleviate the crowding. The amount of protrusion that is too much depends on the patient. Each patient can accept different degrees of protrusion depending on their peri-oral musculature, ethnic characteristics, and other individual factors.

Tipping of the teeth can also produce an inclination of teeth such that the forces of occlusion are not transmitted through the long axis of the teeth, and thus improper force distribution occurs within the bone. Several authors have shown that tipping of premolars and molars occurs after maxillary expansion.[4,16,17] Bassarelli et al.[17] found that there is a positive correlation between the amount of expansion gained and the amount of buccal tipping. It

could also be that the amount of crowding may be related to the amount of tipping.

Damon Bracket System

Recently, Damon[18] created a new expansion method. This new method, called the Damon Bracket System, uses principles from the "Straight-Wire appliance" and involves the use of super-elastic Nickel-Titanium (NiTi) wires together with passive self-ligating brackets. He theorizes that the light force produced by the archwire will not overpower the lip musculature providing the opportunity for large amounts of posterior expansion.[19] He believes that the orbicularis oris and mentalis muscles will create a "lip bumper effect", thus preventing the proclination of the anterior teeth. As anterior movements of the teeth are restricted, the posterior segments expand.

Damon believes that posterior expansion will allow the tongue to lift and move forward, creating a new equilibrium with the cheeks and lips.[19] This expansion creates arch perimeter to accommodate the teeth. He believes that the teeth will expand bodily during the development of this new equilibrium. The new equilibrium allows for stability of the expanded

arch. The mechanics of the Damon Bracket System make the expansion possible. The mechanics are a combination of super-elastic Niti wires, passive self-ligating brackets, and bracket position.

Super-elastic NiTi wires play a major role in the mechanics involved with the Damon Bracket system. Damon advocates the use of super-elastic Niti wires for the initial "arch developing" stages of treatment. The super-elastic Niti wires have the advantage of being able to be greatly distorted but while retaining their resiliency.[20] The wires will return to their original shape if enough time is allowed and is not permanently deformated. This advantage allows Niti wires to be used as the initial wires in severely crowded cases. Another advantage of Niti wires is that they are able to exert a light continuous force.

Another important component in the mechanics of the Damon Bracket System is the characteristics of the passive self-ligating brackets. Passive ligation refers to the slide or clipping mechanism used to maintain the wire in the bracket. Passive self-ligation means that the clip or slide does not actively seat the wire in the bracket. Damon states that the passive self-ligating bracket, when closed,

acts like a tube permitting greater rotational control.

Because the Damon Bracket System is relatively new, there is little research to support its tenets. One theory that has been investigated is that the Damon Bracket System can produce intermolar expansion without excessive inter-canine expansion. Pandis et al.[21] evaluated the alleviation of mandibular crowding in 54 non-extraction patients that were treated with the Damon 2 system and a conventional straight-wire appliance. They found that conventional brackets and the Damon 2 system produced similar amounts of inter-canine expansion, but the Damon 2 system produced more intermolar expansion. They do not state what portion of the expansion is bodily or tipping.

The Straight-Wire Appliance

Many of the current fixed orthodontic appliances, including the Damon Bracket System, are adaptations of Andrew's Straight-Wire Appliance. Andrews investigated six characteristics of normal occlusion that have become a treatment guide for orthodontists.[10] After identifying these "Six Keys to Normal Occlusion," he set out to incorporate them into a

bracket system. Each bracket had built-in tip, torque, angulation, and first order component to accommodate for the different characteristics found in varying teeth.[22] He called his appliance, "The Straight-Wire Appliance." Several alterations have been made to the original design to account for what different orthodontists deem as the ideal occlusion. The Straight-Wire Appliance and similar variations are still among the most popular type of fixed orthodontic appliance in use today.

Purpose

The Damon Bracket System is proposed to offer significant advantages over the traditional straight-wire orthodontic appliances. The Damon bracket system challenges many long-held beliefs in orthodontics. The large amount of expansion created during treatment with the Damon system is thought by its proponents to occur by bodily movement with little tipping. A substantial amount of research has been focused on how much tipping of the teeth occurs when using other treatment modalities such as rapid palatal expanders, W-arches, and quad-helices, but very little research

has been done to evaluate tipping associated with the Damon bracket system.

In 2005, a Master's thesis by David Mikulencak evaluated the tipping of posterior teeth in the Damon bracket system compared to that found in rapid palatal expansion.[23] He found that the amount of tipping caused by the Damon bracket system, compared to that of rapid palatal expansion, was not significantly different.

Another common side-effect of many non-extraction techniques is an increase in incisor angulation. Increasing the incisor angulation is the most efficient type of expansion to alleviate crowding,[24] but excess proclination is undesirable due to the possible periodontal, esthetic, and occlusal problems. The Damon bracket system also claims to produce minimal incisor proclination as crowding is relieved. Pandis et al.[21] found that there is no statistical difference in the amount of incisor proclination of the Damon 2 bracket system and a conventional bracket system.

A question not yet answered is, does the amount of tipping and incisor proclination increase with the Damon system as the amount of crowding increases? If

so, is this increase different than that found in traditional straight-wire appliances? The purpose of this study is to evaluate the amount of tipping canines, premolars, and molars and incisor proclination that occurs when using the Damon Bracket system compared to a traditional straight-wire orthodontic appliance.

Evaluating the inclination of teeth will provide insight as to whether the teeth are expanded bodily or tipped. The amount of tipping will be evaluated in relation to the amount of crowding, in order to investigate whether the amount of tipping increases as the crowding increases.

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CHAPTER 3: JOURNAL ARTICLE

Abstract

In orthodontics, crowding can be resolved by extraction of teeth, decreasing tooth size, or by expansion of the arches. A side-effect of expansion is buccal tipping of the teeth. Dwight Damon created the Damon Bracket System, an expansion method that uses self-ligating brackets and Nickel-Titanium arch-wires. The Damon Bracket System is thought by some orthodontists to have the ability to expand the arches with little tipping. This retrospective study evaluates the change in buccal tipping of the teeth in non-extraction cases treated with either the Damon Bracket System or a traditional Straight-Wire appliance.

The maxillary dental casts of 60 patients (30 of each treatment modality) were selected from an orthodontic practice that has used both the Damon Bracket System and a traditional Straight-Wire appliance. The sample was selected based on a pre-treatment Class I occlusion, no posterior cross-bite, and have all permanent teeth present (except 2nd and 3rd molars). Measurements taken from the pre- and post-

treatment models included: intercanine, interpremolar, and intermolar widths, tooth-size/arch length discrepancy, and tipping of a central incisor, the canines, first premolars, and first molars.

Statistics showed that the two groups were similar in regards to pre-treatment crowding and inter-canine, premolar, and molar widths. The results indicate that there was not a significant difference in the amount of inter-canine, premolar, and molar expansion gain between groups treated with the Damon Bracket System and a traditional straight-wire appliance. The results also showed that the amount of expansion or crowding was not significantly associated with tipping. The results did show a significant association between inter-canine expansion and crowding in the straight-wire group, while no associations existed between crowding and tipping in the Damon group. The treatment time of the group treated with the Damon Bracket System was 6.8 months less than the group treated with a traditional straight-wire appliance.

This study suggest that correction of crowding using the Damon Bracket System or a traditional straight-wire appliance result in similar amounts of

inter-arch expansion and tipping. The major difference in the two systems seems to be a decrease in treatment time when using the Damon Bracket System.

Introduction

A major reason why patients seek orthodontic treatment is because of crowding of the teeth. Crowding can be corrected by removal of teeth, decreasing the size of the teeth, or various non-extraction methods. In general, non-extraction treatment is accomplished by dental expansion. The goal of dental expansion is to relieve crowding by increasing the arch perimeter to accommodate all the teeth.

Orthodontists expand the arch anterior-posteriorly or transversely depending on the patients' needs. Anterior-posterior expansion involves distalization of the molars and/or proclination of the incisors. Transversely expansion can be accomplished orthopedically or orthodontically. Both types of expansion are used to correct posterior cross-bites, widen constricted arches, and increase arch perimeter.

The goal of orthodontic expansion is to bodily move or tip the teeth within the bone. Orthodontic expansion is often used in patients when the mid-palatal suture can not be opened and/or when the amount of expansion needed is not great. Expansion by

the use of archwires is a technique in which wires broader than the existing arch-form are inserted to widen the arch and relieve crowding. Archwire expansion has been used since the dawn of orthodontics, but recently a new technique has been theorized.

Damon[1] theorizes that by using lighter forces delivered by super elastic wires that the facial and lip musculature would limit anterior expansion and allow great lateral expansion by restricting the buccal musculature. It is stated that the teeth can be moved great distances laterally without encroaching on the buccal plates of alveolar bone.[2] The theory is that the light forces will not occlude the blood vessels and allow new bone to be formed.

There are several concerns when doing any type of dental expansion treatment. It is generally believed that during orthodontic expansion some combination of bodily movement and tipping occurs. When excessive crowding is present, it is believed that excessive tipping will occur. Damon claims that the Damon Bracket System does not result in excessive tipping but rather the teeth are moved bodily and the bone responds favorably. This claim challenges many long-

held orthodontic conventions as to the limit of expansion and the need for extractions. The question is at what point is the buccal musculature not restricted and the facial and lip musculature overwhelmed. Specifically, with increasing amounts of crowding does tipping begin to play a more significant role in the relief of crowding?

The aim of this study is to investigate the effect of crowding on incisor and buccal expansion in non-extraction cases treated by a traditional straight-wire orthodontic appliance or the Damon Bracket System. In order to evaluate the effects of the Damon Bracket System versus a traditional straight-wire orthodontic appliance, two samples will be compared to assess tipping of the teeth. This study is intended to assist clinicians in understanding the effects of their appliances.

Methods and Materials

The sample consisted of 60 pre- and post-treatment maxillary dental casts. All cases were treated by the same private practitioner. The selection criteria were that the patients must be Class I, have no posterior cross-bite, and the

treatment must be non-extraction. All permanent teeth, except second and third molars, must be present.

The sample was separated by cases treated with the Damon Bracket System and a traditional straight-wire appliance. The standard torque prescription was used for all cases treated with the Damon Bracket System. The Roth prescription was used for all cases treated with the traditional straight-wire appliance.

Collection of Data

The following measurements were taken from the dental casts:

1. Inter first molar width
2. Inter first premolar width
3. Inter canine width
4. Tooth Size-Arch Length Discrepancy
5. Tipping of the first molars, first premolars, canines, and a central incisor.
6. Treatment time

Arch width was measured from the junction of tooth's palatal surface and palatal mucosa to the same contra-lateral junction. For the first molars, the junction of the lingual groove and palatal mucosa was

used as the landmark. For the first premolars and canines, the junction of the center of the lingual surface of the crown and palatal mucosa was the landmark.

Crowding was measured using a tooth-size/ arch length discrepancy (TSALD).[3] The TSALD is a calculation of the amount of space needed minus the amount of space available. The amount of space needed was calculated by measuring and then summing the mesio-distal widths of each tooth. The amount of space available was calculated by measuring the length of the alveolar ridge.

A measuring apparatus (Figure 3.1) was constructed to ensure that the dental casts had the proper orientation and the photographs were standardized. For orientation on the occlusal plane, the casts were placed tooth-side down, and then the model holder was lowered without contacting the base of the cast and then tightened to grasp the model. Once the cast was secured in the model holder, the cast and model holder were placed tooth-side up. The photographs were taken using a tripod from a fixed height (57 cm) and distance (80 cm).

Figure 3.1: Measuring apparatus used to standardize model orientation

Incisor and buccal tipping was measured using a flowable composite coping made from teeth on the pre-treatment model. A digital photograph was taken to quantify the initial amount of tipping. Each coping was then transferred to the post-treatment model, a digital photograph was taken, and the angular difference between pre and post-treatment was measured to signify the amount of tipping change. Figures 3.2-3.5 are photos depicting how the measures were made. The amount of tipping was measured by three different methods: per individual tooth (right and left canine, premolar, molar, and a central incisor), a sum of all

the teeth directly measured (small model), and an full arch estimate of all teeth from first molar to first molar(large model). The full arch estimate was calculated by using the tipping values for the first premolars as the the value for the second premolars. The tipping value for the central incisor was used as the value for the contralateral central incisor. The value for the lateral incisors was calculated by averaging the tipping value for the central incisor and canine.

Figure 3.2: Photograph representing measurement method for the canines

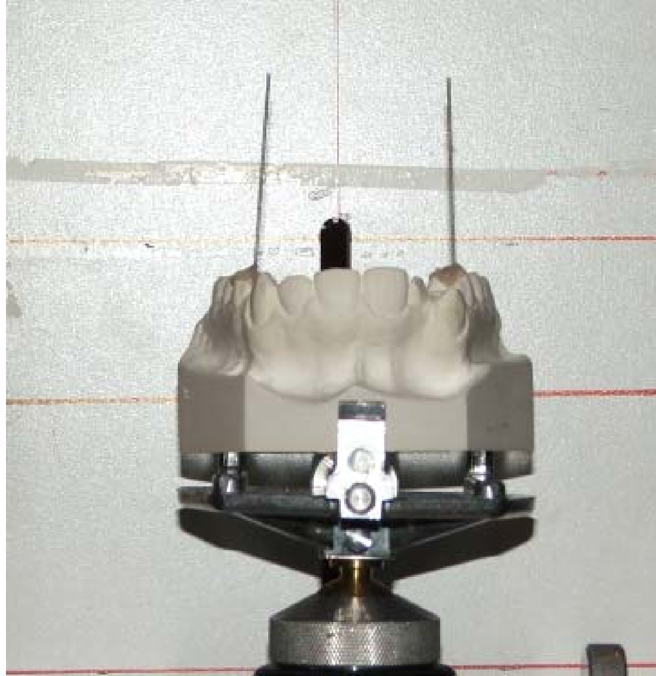

Figure 3.3: Photograph representing measurement method of the premolars.

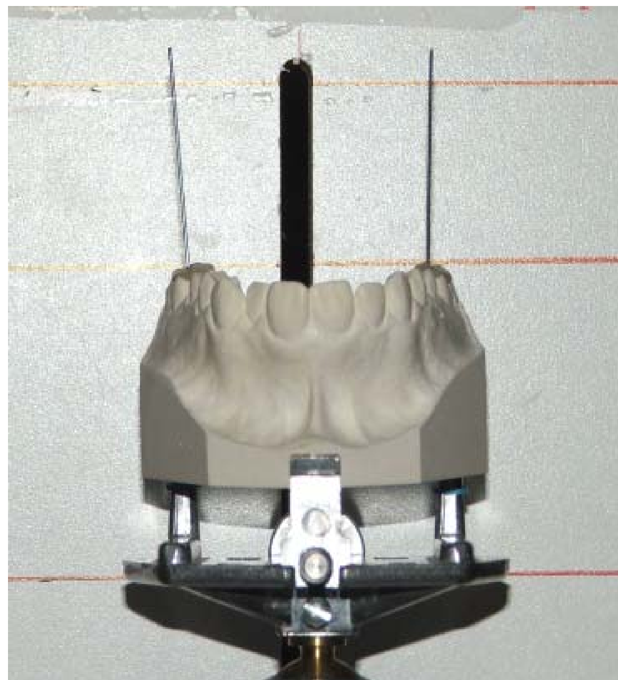

Figure 3.4: Photograph representing measurement method for the molars.

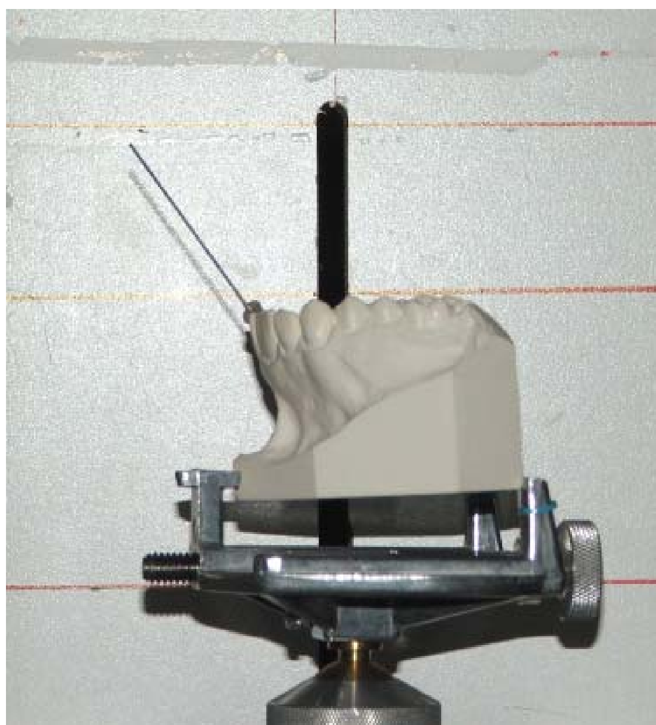

Figure 3.5 Photograph representing the measurement method for a central incisor

Treatment time was measured by calculating the number of months from the placement of full fixed appliances to the removal of all appliances.

Statistical Analysis

Two-sample t-tests were used to determine if the treatment groups were statistically different with regards to pre-treatment values and the change (pre-treatment versus post-treatment) in inter-molar, inter-canine, and inter-premolar widths. A paired t-test was also used to determine whether the changes in

inter-molar, inter-canine, and inter-premolar were significant within each group.

Linear regression was used to test whether a significant association exists between tipping and crowding in both groups. The groups were also compared to examine if the associations of each group were significantly different.

A two-sample t-test was used to determine if the difference in treatment times were statistically different.

Results

A two-sample t-test did not show a statistically significant difference in the pre-treatment crowding between the two groups (Table 3.1).

Table 3.1: Descriptive statistics of crowding for both treatment groups.

	T1 TSAL				T2 TSAL			T2-T1		
	x	SD	t	sig	x	SD	t	x	t	sig
Damon	-5.22	2.61	-1.6	0.12	0	0	0	5.22	-1.6	0.12
SW	-4.12	2.78			0	0	0	4.12		

A paired t-test found that the change in inter-molar, -canine, and –premolar widths was significant within each group (Table 3.2 and 3.3). A two-sample t-test showed no statistically significant difference

in the pre-treatment value or the change in values for the inter-molar, canine, and premolar widths between the groups treated with the Damon Bracket System and the group treated with a traditional Straight-wire appliance(Tables 3.4).

Table 3.2: Descriptive statistics of arch width for Damon treatment

Damon (mm)							
	T1		T2		T2-T1		
	X	SD	X	SD	X	t	Sig
I-canine	24.9	2.81	26.1	1.56	0.4	-2.57	.016
I-pre	25.4	2.37	28.7	1.86	3.3	-11.0	.000
I-molar	34.3	2.86	35.6	2.63	1.3	-4.98	.000

Table 3.3: Descriptive statistics of arch width for Straight-wire treatment

Straight-Wire (mm)							
	T1		T2		T2-T1		
	X	SD	X	SD	x	t	Sig
I-canine	24.7	2.37	25.5	1.63	0.8	-2.34	.026
I-pre	25.7	2.06	28.1	1.76	2.4	-6.88	.000
I-molar	33.6	2.52	34.2	2.51	0.6	-2.72	.011

Table 3.4: Descriptive statistics for the difference in arch width at each time point.

Difference (Damon –SW) (mm)									
	T1				T2		T2-T1		
	x	SD	t	sig	X	SD	x	t	sig
I-can	.2	.44	.23	.25	.6	1.6	.4	.64	.53
I-pre	-.3	.31	-.62	.82	.6	1.8	.9	1.8	.08
I-molar	.7	.34	1.18	.54	1.4	2.5	.7	-.32	.75

A two-sample t-test showed a statistically significant difference in the treatment time for the two groups (Table 3.5)

Table 3.5: Descriptive statistics for treatment time is shown for both groups.

	X months	SD months	t	sig
Damon	18.2	4.67	-4.87	.000
SW	25	6.98		

A two-sample t-test did not find a statistically significant difference between the two groups with regard to the amount of tipping of the individual teeth (canines, premolars, molars, or a central incisor) (Table 3.6). An two-sample t-test also did not show a significant difference in amount of total tipping(small model) or full arch tipping (large model) between the two groups.

Table 3.6: Descriptive statistics for tipping are shown for both groups

	Damon T2-T1		SW T2-T1		Difference Damon-SW		Damon-SW	
	X	SD	x	SD	x	SD	t	Sig.
UR3	0.9	7.9	3.7	10.1	-2.8	2.2	-1.2	.23
UR4	7.2	7.5	7.8	6.2	-.6	1.2	-0.3	.75
UR6	1.5	6.9	0.0	7.4	1.5	1.6	0.8	.42
U1	7.5	7.9	11.3	8.9	3.8	1.0	-1.8	.09
UL3	2.7	9.6	4.3	10.7	-1.7	1.1	-0.6	.53
UL4	7.6	5.6	6.9	7.4	1.3	1.6	0.4	.67
UL6	0.1	6.3	0.8	6.7	-0.7	0.4	-0.4	.67
Small Model	27.4	27.2	35.1	24.3	-7.7	2.9	-1.4	.17
Large Model	58.9	47.6	76.3	47.5	-17.4	0.1	-0.4	.67

A regression analysis did not demonstrate a significant relationship between total tipping and crowding for either treatment group. Figure A.1 and A.2 show a plot of the data points for true tipping and crowding in both groups. Figure A.3 and A.4 show a scatterplot of the data points for estimated tipping and crowding in both groups.

Correlations between all variables measured for each group are found in Appendix B. The results showed that a significant correlation exists regarding the amount of crowding present and the inter-canine

width change for straight-wire sample, but no correlation between the amount of crowding and any of the inter-arch measurements.

Discussion

The results of this study did not show a significant difference between the two groups with regards to pre-treatment crowding or inter-canine, premolar, and molar widths. These results indicate that the two groups were not significantly different at the start of treatment. In addition, the sample was not selected based on the amount of crowding resulting in a typical mean with a range from -1 to -13 mm. The average amount of intermolar expansion in this group would be classified as neutral for adolescents.[4] All the patients were typical adolescents.

Expansion

The results found in this study indicate that the increase of inter-arch widths across the canine, premolars, and molars was significant within each group, but there was no significant difference between

groups. Each appliance expanded the arches a small yet significant amount.

Damon claims that the Damon Bracket System will increase arch perimeter in a manner different than a traditional straight-wire appliance.[1] Damon states that in the Damon Bracket System the patient's anatomy will determine the amount of expansion.

Although the amount of expansion that was achieved was not statistically different between the groups, its relationship to crowding was. The straight-wire appliance showed a significant association between crowding and inter-canine expansion with but not with inter-premolar and molar expansion. The Damon Bracket System did not show any association between crowding and any of the inter-arch widths.

These findings suggest that the correction of crowding is expressed mainly through canine expansion in the straight-wire appliance, but through more generalized expansion in the Damon Bracket System.

Tipping Changes

A two-sample t-test found that the amount of tipping was not significantly different between the two groups. Both groups caused tipping of the teeth, but not to different extent.

Although not significantly different, a trend of more incisor proclination in the straight-wire appliance (an average of 4 degrees) when compared to the Damon Bracket System was found. A larger sample may show a greater or lesser difference. It should be noted that the Roth and Damon prescriptions differ in that the Damon prescription has 2 more degrees of labial crown torque.

The large standard deviation in tipping of both samples suggests that the amount of tipping is not dependent on appliance but the pre-existing position of the teeth.

It is general accepted that arch-wire expansion can be used to increase arch length to alleviate crowding.[5-7] Expansion has also been shown to cause varying degrees of tipping of the teeth.[8] Some believe that the amount of expansion and the amount of tipping are associated. This study found that arch-wire expansion and tipping showed no association.

Some orthodontists believe that greater amounts of crowding will result in increased tipping. The findings of this research suggest that the crowding and tipping are not associated. Both methods of treatment produced similar amounts of tipping but neither treatment related to crowding

One possible reason for the lack of association between crowding and tipping may be the low amount of crowding in the sample. The amount of crowding was 5.2 and 4.1 mm for the Damon and Straight-Wire groups, respectively. The difference in crowding was not significant and can be categorized as mild crowding.

Treatment Time

Two factors to be considered when evaluating treatments are effectiveness and efficiency.[3] Effectiveness is the ability to produce the desire result. The efficiency of each treatment deals with the doctor's and patient's time needed to achieve the desire result. If two treatments are equally effective, the treatment that accomplishes the desired result in less time would be deemed more efficient.

The results suggest that the Damon Bracket System and traditional straight-wire appliances are equally

effective in relief of crowding. The results also indicate that the Damon Bracket System is more efficient in relieving crowding. The cases treated with the Damon Bracket System took an average 6.8 months less than the traditional Straight-wire appliance to alleviate the crowding.

It is unclear why the Damon Bracket System was found to more efficient. One possibility may be the smaller amount of friction produced. Recent studies have found that the Damon bracket produced less friction than traditional brackets with elastomeric or steel ligatures.[9,10] It is still unclear what exactly role friction plays in treatment time and results.

Suggestions for Future Studies

New technology such as Cone Beam C.T. scans and electronic models may provide a more accurate method of assessing the amount of tipping. This technology may allow three dimensional measuring where as the current study’s measurements were only in two dimensions. If a patient had a three dimensional scan prior to treatment and one following treatment, the effects of the various treatments might be better analyzed.

Another possible study would be to evaluate the effects of greater amounts of crowding on tipping and expansion. A threshold may exist where greater crowding produces a greater tipping.

Conclusions

1. The pre-treatment crowding and inter-canine, premolar, and molar widths were similar in both groups.
2. The inter-arch change and tipping did not show a significant difference between the two groups.
3. The amount of inter-canine, premolar, and molar expansion and tipping did not show a significant association in either group.
4. Crowding and tipping did not show a significant association in either group.
5. There was a significant association between crowding and inter-canine expansion in the straight-wire group, but no significant association between crowding and any inter-arch expansion in the Damon Group was found.
6. Treatment time for cases treated with the Damon Bracket System was on average 6.8 months shorter than

those treated with a traditional Straight-wire appliance.

7. The results of this study suggest that similar amounts of expansion and tipping occur independent of the appliance used.

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APPENDIX A

Damon Scatterplot: Crowding and Tipping (True)

Dependent Variable: Crowding

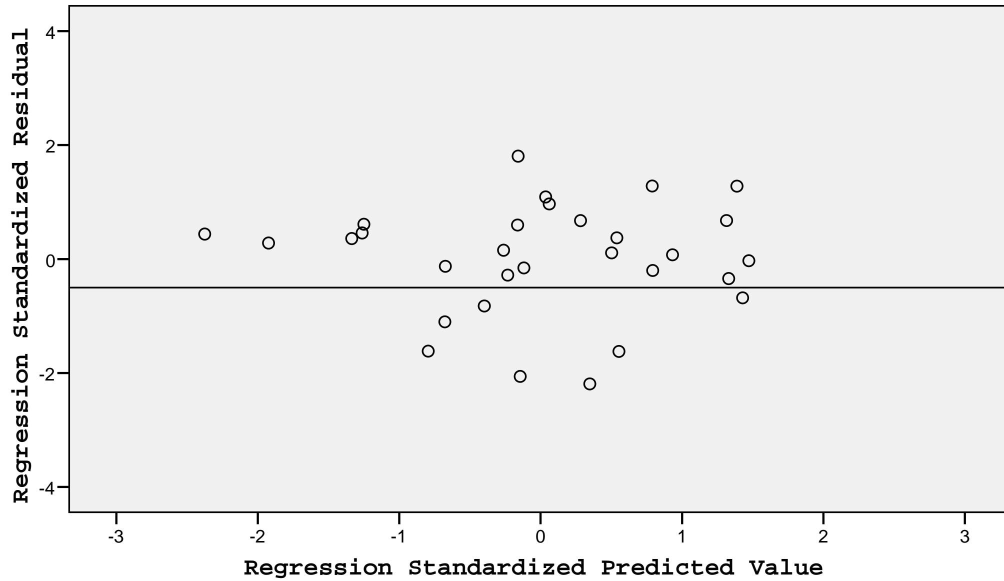

Figure A.1: Regression scatterplot of crowding with true tipping for the Damon Group

Straight-Wire Scatterplot: Crowding and Tipping(true)

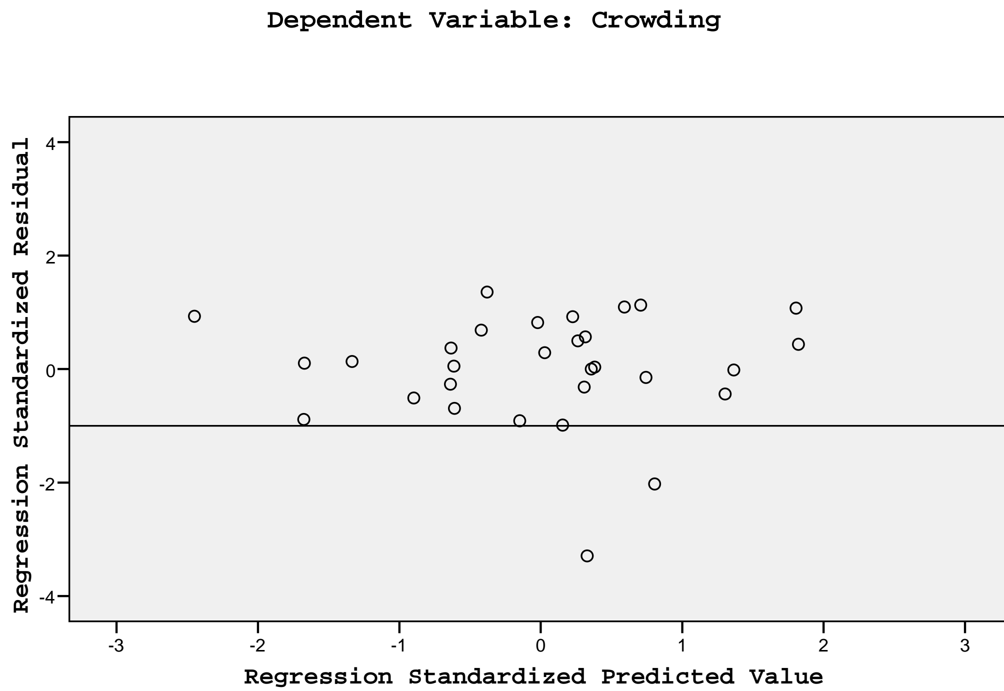

Figure A.2: Regression scatterplot of crowding and true tipping for the Straight-wire group

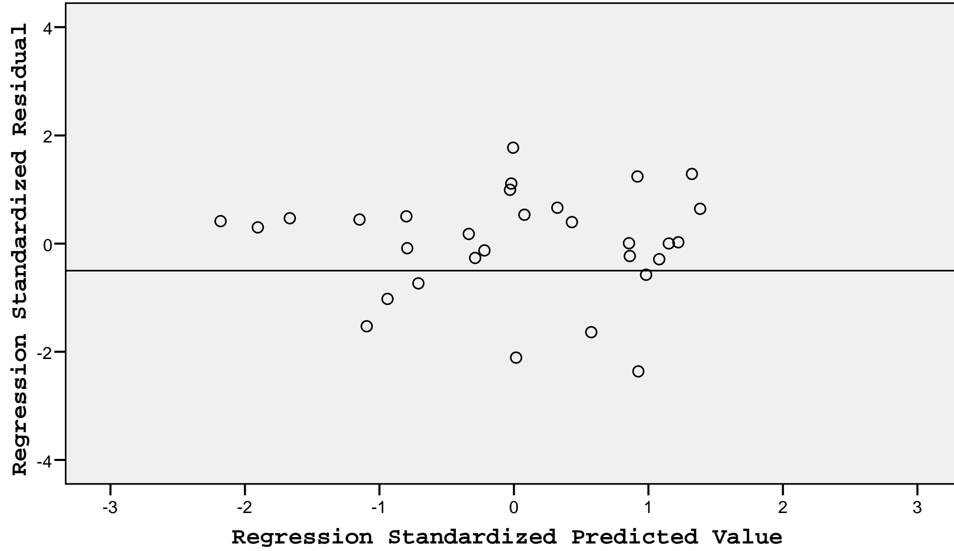

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Figure A.3: Regression scatterplot for crowding with estimated tipping for the Damon Group

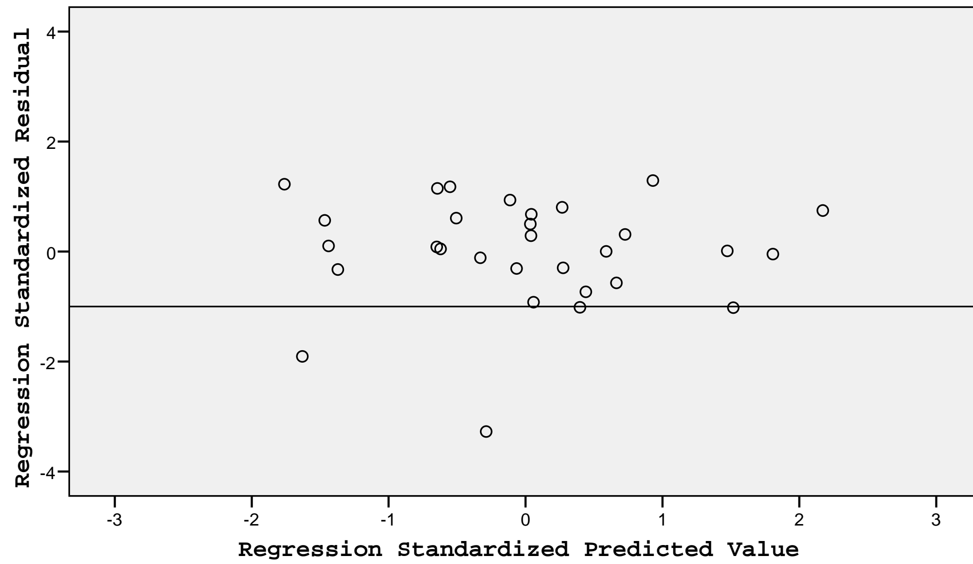

Figure A.4 Regression scatterplot for crowding with estimated tipping for the Straight-wire group

Straight-wire Correlations

		UR6t2-UR6t1	UL6t2-UL6t1	UR4t2-UR4t1	UL4t2 - UL4t1	UR3t2-UR3t1	UL3t2-UL3t1	U1t2-U1t1	small	large	i-canine	i-premolar	i-molar	TSALD	tx time
UR6t2-UR6t1	Pearson Correlation	1	.134	.262	-.210	.102	-.041	.063	.411(*)	.240	-.021	.191	-.093	-.231	-.364(*)
	Sig. (2-tailed)		.481	.162	.265	.591	.828	.742	.024	.201	.913	.313	.624	.218	.048
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL6t2-UL6t1	Pearson Correlation	.134	1	.181	.029	-.406(*)	-.177	.190	.201	.139	.026	-.033	-.243	-.078	.143
	Sig. (2-tailed)	.481		.337	.879	.026	.349	.315	.288	.465	.890	.864	.196	.684	.450
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UR4t2-UR4t1	Pearson Correlation	.262	.181	1	.235	.144	-.105	.462(*)	.621(**)	.663(**)	-.083	-.041	-.098	-.038	-.020
	Sig. (2-tailed)	.162	.337		.212	.447	.582	.010	.000	.000	.664	.829	.606	.842	.916
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL4t2 - UL4t1	Pearson Correlation	-.210	.029	.235	1	-.344	-.036	.105	.170	.272	-.042	-.266	.150	-.014	.031
	Sig. (2-tailed)	.265	.879	.212		.062	.850	.582	.370	.146	.825	.155	.429	.940	.869
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UR3t2-UR3t1	Pearson Correlation	.102	-.406(*)	.144	-.344	1	.292	.145	.446(*)	.387(*)	.022	-.107	.271	.254	-.143
	Sig. (2-tailed)	.591	.026	.447	.062		.118	.444	.014	.035	.908	.572	.148	.176	.449
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL3t2-UL3t1	Pearson Correlation	-.041	-.177	-.105	-.036	.292	1	.015	.462(*)	.366(*)	-.347	-.433(*)	.177	-.137	.303
	Sig. (2-tailed)	.828	.349	.582	.850	.118		.939	.010	.047	.061	.017	.350	.472	.103
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
U1t2-U1t1	Pearson Correlation	.063	.190	.462(*)	.105	.145	.015	1	.631(**)	.794(**)	.080	-.204	-.317	.188	.105
	Sig. (2-tailed)	.742	.315	.010	.582	.444	.939		.000	.000	.676	.280	.088	.319	.579
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
small	Pearson Correlation	.411(*)	.201	.621(**)	.170	.446(*)	.462(*)	.631(**)	1	.956(**)	-.150	-.331	.008	-.017	.040
	Sig. (2-tailed)	.024	.288	.000	.370	.014	.010	.000		.000	.430	.074	.968	.930	.835
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
large	Pearson Correlation	.240	.139	.663(**)	.272	.387(*)	.366(*)	.794(**)	.956(**)	1	-.100	-.354	-.057	.069	.081
	Sig. (2-tailed)	.201	.465	.000	.146	.035	.047	.000	.000		.598	.055	.765	.718	.669
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-canine	Pearson Correlation	-.021	.026	-.083	-.042	.022	-.347	.080	-.150	-.100	1	.665(**)	-.281	.512(**)	-.206
	Sig. (2-tailed)	.913	.890	.664	.825	.908	.061	.676	.430	.598		.000	.133	.004	.275
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-premolar	Pearson Correlation	.191	-.033	-.041	-.266	-.107	-.433(*)	-.204	-.331	-.354	.665(**)	1	-.256	-.041	-.279
	Sig. (2-tailed)	.313	.864	.829	.155	.572	.017	.280	.074	.055	.000		.173	.828	.136
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-molar	Pearson Correlation	-.093	-.243	-.098	.150	.271	.177	-.317	.008	-.057	-.281	-.256	1	.091	-.126
	Sig. (2-tailed)	.624	.196	.606	.429	.148	.350	.088	.968	.765	.133	.173		.631	.507
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
TSALD	Pearson Correlation	-.231	-.078	-.038	-.014	.254	-.137	.188	-.017	.069	.512(**)	-.041	.091	1	-.120
	Sig. (2-tailed)	.218	.684	.842	.940	.176	.472	.319	.930	.718	.004	.828	.631		.527
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
tx time	Pearson Correlation	-.364(*)	.143	-.020	.031	-.143	.303	.105	.040	.081	-.206	-.279	-.126	-.120	1
	Sig. (2-tailed)	.048	.450	.916	.869	.449	.103	.579	.835	.669	.275	.136	.507	.527	
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30

* Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Damon Correlations

		UR6t2-UR6t1	UL6t2-UL6t1	UR4t2-UR4t1	UL4t2 - UL4t1	UR3t2-UR3t1	UL3t2-UL3t1	U1t2-U1t1	small	large	i-canine	i-premolar	i-molar	TSALD	tx time
UR6t2-UR6t1	Pearson Correlation	1	.237	.246	.203	.163	.264	.169	.609(**)	.507(**)	.479(**)	.218	.078	-.119	-.178
	Sig. (2-tailed)		.207	.189	.282	.389	.158	.373	.000	.004	.007	.247	.682	.532	.346
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL6t2-UL6t1	Pearson Correlation	.237	1	.273	.218	-.272	.050	.118	.385(*)	.310	.140	.004	-.233	.062	.183
	Sig. (2-tailed)	.207		.145	.247	.145	.792	.533	.036	.095	.460	.985	.215	.745	.334
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UR4t2-UR4t1	Pearson Correlation	.246	.273	1	.220	.007	.348	.126	.606(**)	.607(**)	.092	.124	-.013	-.237	.234
	Sig. (2-tailed)	.189	.145		.243	.972	.060	.505	.000	.000	.630	.515	.946	.206	.213
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL4t2 - UL4t1	Pearson Correlation	.203	.218	.220	1	.152	.338	-.101	.504(**)	.454(*)	.119	.297	-.226	-.003	.297
	Sig. (2-tailed)	.282	.247	.243		.424	.068	.596	.005	.012	.533	.110	.230	.987	.111
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UR3t2-UR3t1	Pearson Correlation	.163	-.272	.007	.152	1	.232	.122	.421(*)	.407(*)	.051	.181	.035	-.223	-.174
	Sig. (2-tailed)	.389	.145	.972	.424		.218	.521	.021	.026	.790	.338	.856	.237	.357
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
UL3t2-UL3t1	Pearson Correlation	.264	.050	.348	.338	.232	1	.044	.676(**)	.616(**)	.151	.329	-.093	-.206	.300
	Sig. (2-tailed)	.158	.792	.060	.068	.218		.819	.000	.000	.426	.076	.624	.275	.107
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
U1t2-U1t1	Pearson Correlation	.169	.118	.126	-.101	.122	.044	1	.426(*)	.599(**)	-.087	-.217	.033	-.137	.014
	Sig. (2-tailed)	.373	.533	.505	.596	.521	.819		.019	.000	.647	.250	.861	.469	.942
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
small	Pearson Correlation	.609(**)	.385(*)	.606(**)	.504(**)	.421(*)	.676(**)	.426(*)	1	.972(**)	.247	.257	-.098	-.259	.181
	Sig. (2-tailed)	.000	.036	.000	.005	.021	.000	.019		.000	.189	.170	.608	.167	.338
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
large	Pearson Correlation	.507(**)	.310	.607(**)	.454(*)	.407(*)	.616(**)	.599(**)	.972(**)	1	.160	.178	-.080	-.271	.196
	Sig. (2-tailed)	.004	.095	.000	.012	.026	.000	.000	.000		.399	.347	.675	.148	.300
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-canine	Pearson Correlation	.479(**)	.140	.092	.119	.051	.151	-.087	.247	.160	1	.195	.129	.282	-.273
	Sig. (2-tailed)	.007	.460	.630	.533	.790	.426	.647	.189	.399		.301	.497	.131	.145
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-premolar	Pearson Correlation	.218	.004	.124	.297	.181	.329	-.217	.257	.178	.195	1	-.339	.018	.216
	Sig. (2-tailed)	.247	.985	.515	.110	.338	.076	.250	.170	.347	.301		.067	.926	.251
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
i-molar	Pearson Correlation	.078	-.233	-.013	-.226	.035	-.093	.033	-.098	-.080	.129	-.339	1	-.206	-.198
	Sig. (2-tailed)	.682	.215	.946	.230	.856	.624	.861	.608	.675	.497	.067		.275	.294
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
TSALD	Pearson Correlation	-.119	.062	-.237	-.003	-.223	-.206	-.137	-.259	-.271	.282	.018	-.206	1	-.048
	Sig. (2-tailed)	.532	.745	.206	.987	.237	.275	.469	.167	.148	.131	.926	.275		.802
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30
tx time	Pearson Correlation	-.178	.183	.234	.297	-.174	.300	.014	.181	.196	-.273	.216	-.198	-.048	1
	Sig. (2-tailed)	.346	.334	.213	.111	.357	.107	.942	.338	.300	.145	.251	.294	.802	
	N	30	30	30	30	30	30	30	30	30	30	30	30	30	30

* Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

VITA AUCTORIS

Alfred Jackson was born on October 13, 1978 in Hattiesburg, MS. He moved frequently because his mother was an officer in the United States Air Force. By the time he completed high school, the total number of schools attended had reached 11 ending at Mascoutah High School in Illinois. He attended and graduated from the University of Florida (UF) in 2001. He entered dental school at the University of North Carolina (UNC) and graduated in 2005. While at UNC, he was accepted to the Saint Louis University to complete his academic dream of becoming an orthodontist. He will begin his career path in Chapel Hill, NC.