University of Alberta

Efficiency of Molar Distalization with the XBow Appliance Related to Second Molar Eruption Stage

by

Lisa Cecilia McGrath

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Science

in

Orthodontics

Medical Sciences - Dentistry

Fall 2012
Edmonton, Alberta

Dedication

This work is dedicated to Rich and Jaylee.

I had the easy part.

Abstract

Title: Efficiency of Molar Distalization with the XBow Appliance Related to Second Molar Eruption Stage.

Objectives: To make a quantitative evaluation on lateral cephalograms of horizontal, vertical and angular changes in the position of the maxillary first molar when it is distalized with the XBow appliance. Specifically, these changes will be evaluated and compared in the presence and absence of erupted maxillary second molars to determine if there is an optimal time to treat.

Methods: Lateral cephalograms were retrospectively obtained at the start and after completion of all active treatment with the XBow appliance. In one group of patients distal movement of the maxillary first molars was performed before the eruption of maxillary second molars; in the other group of patients both first and second maxillary molars were simultaneously moved distally. All cephalograms were superimposed on palatal plane using the method of best-fit. Changes in the position of the maxillary first molar were measured as differences between specific landmarks before and after treatment.

Results: A MANOVA revealed that the eruption stage of the maxillary second molar did not have a significant effect on the change in position of the maxillary first molar after treatment with a XBow appliance.

Conclusion: When using the XBow appliance in the late-mixed to early-permanent stage of dentition, distalization of the maxillary first molar is likely no more effective before the eruption of the maxillary second molar.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction and Literature Review

1.1 Introduction

While distalization of maxillary molars is often indicated in orthodontic therapy, successfully achieving and maintaining significant molar distalization can be considered an orthodontic challenge. Many treatment modalities exist for moving the maxillary dentition posteriorly but all unfortunately present with negative side effects and limitations.[1] Previously, factors such as patient compliance,[2] loss of anchorage,[1,3,4,5] increase in lower anterior face height,[6] and the presence of erupted second and/or third molars[1, 7-14] have all been suggested as limitations to achieving clinically effective molar distalization.

The timing of treatment with molar distalization has been reported to have an impact on how efficient it is.[7-14] While this topic still seems to be debated in the literature,[1] clinically, practitioners may tend to perceive that distalization is a more valid treatment option in younger patients prior to the eruption of maxillary second molars. The question of whether this theory is more anecdotally than evidence based appears yet to be answered.

1.2 Significance of the Study

It is probable that many clinical decisions based on the efficiency and timing of treatment with molar distalization have been passed down from generation to generation based on conversations that are largely anecdotally based and unsupported in the literature. The purpose of this research is to validate or refute the idea that the efficiency of maxillary molar distalization depends on the eruption stage of the second molar. The results from this study will either draw caution to a theory that may be, quite simply, just a theory, or add support to it. Clinical decisions based on the timing of treatment with molar distalization will potentially be impacted by the results of this study.

1.3 Research Questions

•Having controlled for pretreatment Class II severity, is the average amount of horizontal distalization (mm) of the maxillary first molar equal in patients with unerupted and erupted second molars when they are treated with a XBow appliance?

•Having controlled for pretreatment Class II severity, is the average amount of vertical (mm) and angular (^{o}) change in position of the maxillary first molar equal in patients with unerupted and erupted second molars when they are treated with a XBow appliance?

1.4 Null Hypothesis

There is no difference in the average horizontal, vertical or angular change in position of the maxillary first molar in patients with unerupted and erupted maxillary second molars when they are treated with a XBow appliance.

1.5 Literature Review

1.5.1 Appliances Used to Achieve Maxillary Molar Distalization

1.5.1.1 Extraoral Molar Distalizing Appliances

Headgear has a long history of being used to both limit the amount of anterior movement of the maxilla and to move the maxillary dentition posteriorly.[3] Since its earliest use by Kingsley[15] and Angle[16] at the end of the nineteenth century, headgear treatment to effectively distalize molars is now well documented in the literature.[17-20] Distalizing molars with headgear requires that it is worn almost full time, with approximately 300gm of force per side.[21] Using this protocol, it has been estimated that approximately 2 to 3mm of distal movement of the upper molars can be achieved.[21] A 2003 study on molar distalization with cervical headgear found that when the headgear was worn 14-16 hours per day with 500g of force, a mean of 3.15mm of molar distalization was achieved over a mean of 11.4 months of treatment.[22]

1.5.1.2 Intraoral Molar Distalizing Appliances

Intraorally, appliances used to move molars distally can be divided into two main categories; those that rely on patient compliance and those that do not. Compliance dependent devices include removable appliances with finger springs,[23] Wilson distalizing appliances,[24] and sliding jigs used in conjunction with Class II elastics.[13] Non-compliance dependent devices include intraoral repelling magnets, compressed coil springs, transpalatal arches and appliances such as the distal jet, Jones jig, pendulum and the First Class appliance.[1] Most recently, the XBow appliance has also been shown to produce maxillary molar distalization.[25]

Cetlin and Ten Hoeve[23] describe a basic compliance dependent appliance used to distalize maxillary first molars. Consisting of finger springs positioned mesial to the maxillary first molar, this removable appliance is used to essentially tip the molar crowns distally. Called the Acrylic Cervical Occipital Appliance (ACCO), it consists of an acrylic bite plate to disclude the posterior teeth, modified Adams clasps on the first premolars, a labial bow across the incisors for retention, finger springs against the mesial of the first molars, and an extraoral traction device.[23] The extraoral traction device, usually part-time headgear wear, is used to distalize the roots of the molar, thereby eliminating the degree of distal tipping.[23] A study in 2000 investigating the effectiveness of this appliance reported a mean of 3.6mm of upper first molar distalization with bodily distalization found in only 9% of the patients studied.[26] This appliance should be used with caution in patients with excessive vertical growth as the use of a bite plate, which discludes the posterior teeth to potentially allow faster distalization, could also result in clockwise mandibular rotation.[27]

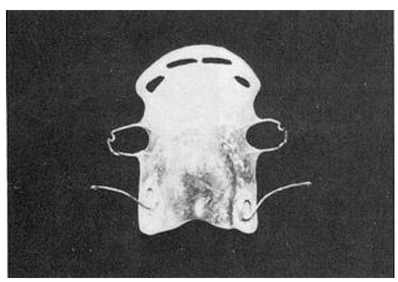


Figure 1-1: Removable Appliance with Finger Springs Mesial to Maxillary First Molar (As taken from Cetlin and Ten Hoeve; 1983[23])

The Wilson distalizing appliance, introduced in the 1980s, consists of compression springs positioned mesial to the maxillary first molar and Class II elastics, which are used to prevent loss of anchorage.[24] A lingual arch contacting the cingulum of the lower incisors is used to allow for attachment of the Cl II elastics.[24] One advantage of the Wilson appliance is that delayed bracketing of the premolars and second molars (if present) minimizes friction within the appliance which could allow for more rapid bodily movement of the molars.[28] Past studies using the Wilson appliance for molar distalization have reported 1-2mm of molar distalization, with a rate of 0.56mm of distalization per month.[28,29]

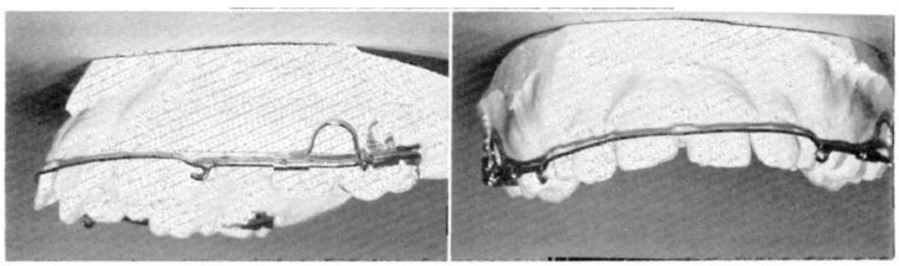


Figure 1-2: Maxillary Segment of the Wilson Distalizing Arch (as taken from Muse et al; 1993[28])

Tweed reported the use of sliding jigs as an effective method of maxillary molar distalization.[30] Using his approach, interarch Class II elastics are used in conjunction with sliding jigs after the mandibular arch is prepared for anchorage. No evidence based reports on the efficiency of sliding jigs for molar distalization, without the use of skeletal anchorage, have been found in the literature.

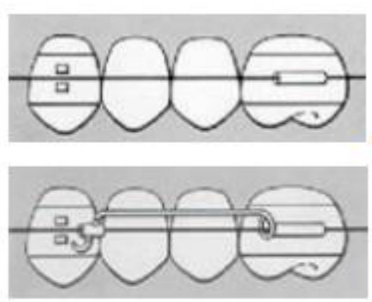


Figure 1-3: Sliding Jig Design for Molar Distalization (as taken from Salzmann, JA. 1994[31])

While all of these compliance dependent approaches have potential in at least gaining a more distal position of the molars, they all also have the major disadvantage of requiring patient cooperation for success. If compliance is lacking, then failure is inevitable with all of these treatment methods. To solve this major problem, since the mid 1980s onward most devices used to distalize molars focused on options in which patient cooperation was not necessary to achieve success.[32] The design of all of these non-compliance dependent appliances includes both active components, which actually distalize the teeth, and an anchorage unit, which is used to minimize unwanted side effects.

Using one of the earlier types of non-compliant molar distalizers, Gianelly et al.[7,33] reported on the use of intraoral repelling magnets to distalize maxillary first molars. With this approach, and indeed for most conventional distalizing treatment modalities, the teeth and the palate are used as the anchorage system. Distalizing appliances with magnets rely on a force of repulsion between two homopolar samarium/cobalt magnets, which are usually attached buccally with ribbon arches.[34,35] Gianelly et al.[7,33] found that molar distalization with intraoral magnets is achieved with an overall rate of 1.7mm per month when second molars are unerupted and 0.75 to 1mm per month when second molars are erupted. Gianelly claims that when using magnets to distalize, the percentage of distalization can further be increased with the use of intermaxillary Class II elastics.

While it appears that magnets are an effective method of molar distalization, they have also been found to be both expensive and bulky.[6] The force exerted by them drops significantly with increasing intermagnet distance,[6] therefore requiring frequent recall activations. Because of these limitations, Darendeliler[36] concluded that magnets offer no advantage over conventional systems in molar distalization.

Figure 1-4: Repelling Magnets used for Molar Distalization (as taken from Itoh et al;1991[34])

The transpalatal arch (TPA), made of rigid stainless steel 0.9mm wire, enables the clinician to distalize maxillary molars without patient compliance.[27] Unilateral molar distalization can be achieved with this appliance when a toe-in activation is unilaterally placed on one molar, producing a clockwise moment and a mesial force on this molar and a distal force on the contralateral molar (Figure 1-5).[27] Headgear can be used to minimize the side-effect on the molar that receives the toe-in activation.[27] Haas and Cisneros reported that while the TPA can produce distobuccal rotation and distal tipping of the activated molar, the distal movement produced by the TPA is very limited.[37] Distal forces were found to be only 1/4 to 1/8 of those generated with headgear.[37] More recent evidence supports the findings of Haas and Cisneros, indicating that significant distal movement with a TPA , beyond that of rotation of the buccal cusps, is unlikely.[38] In this study, the median distal movement of the first molars ranged from 0.3 to 0.5mm.

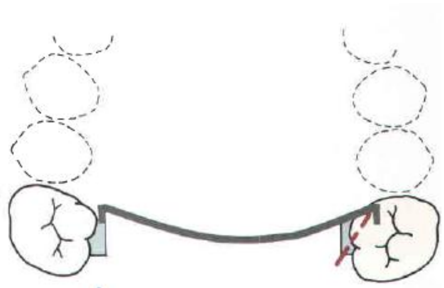


Figure 1-5: Unilateral Molar Distalization produced by Unilateral First-Order Activation of a TPA (as modified from Proffit et al., 2007[39]).

Open coil springs have been used for distalizing maxillary molars since 1934[40] and today, compressed coil springs, either on a segmented or continuous archwire, have largely replaced magnets as a method of distalizing molars.[12,41,42,43] Springs used for distalizing molars can be made from either nickel titanium or stainless steel. Nickel titanium springs have been shown to exhibit superior springback and elastic properties to springs made of stainless steel and they also have the advantage of expressing constant, light, continuous force.[44] For effective molar distalization, Gianelly and colleagues recommend placing nickel titanium coils springs on stainless steel sectional wires, extending from the first premolars to the first molars.[43] Each coil produces approximately 100g of force to distalize the molars along the wire. Using a Nance appliance for anchorage, the authors reported that the 100g coils can distalize the maxillary molars approximately 1.5mm/month.[43]

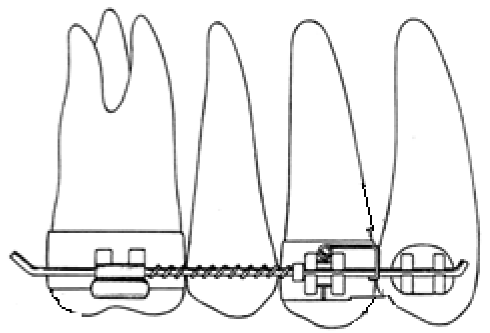


Figure 1-6: Biomechanical Force System produced by Ni-Ti Coil Springs (as modified from Sfondrini et al.;2002[27])

Also taking advantage of the properties of coil springs, the Jones Jig uses NiTi coil springs on a sectional arch wire, fitted to buccal tubes on the molars.[45] A force of 70 to 75 g, exerted by a 0.040 inch nickel titanium spring, is used to move the maxillary first molar distally.[46] Brickman et al. examined the results of 72 consecutively treated subjects with the Jones Jig appliance and found that 55% of the space created between the molar and premolar (mean of 2.51 mm) was from distal movement of the first molar crown.[46] A concomitant 7.53^{o} of tipping of the first molar was also found.[46]

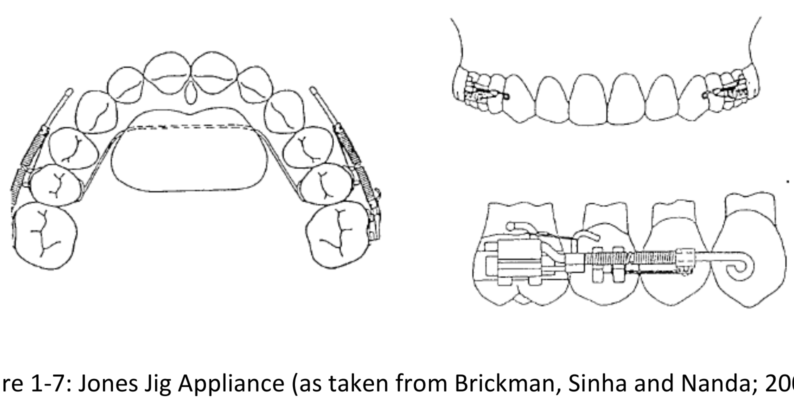


Figure 1-7: Jones Jig Appliance (as taken from Brickman, Sinha and Nanda; 2000[46])

Unlike the Jones Jig, the distal jet[47, 48,49] has force-applying coils in a palatal location. Two tubes are incorporated bilaterally into a Nance button and NiTi coil springs are placed over these tubes to deliver a palatal distalization force. A screw clamp, which is placed over each tube to allow activation of the coils, is usually reactivated once a month.[27] One advantage of the distal jet is that it can be easily converted into a Nance holding arch to maintain the position of the first molar once it has been distalized.[27] Also, since the distalization force acts closer to the centre of resistance of the molars, less molar tipping could theoretically result.[27] Since the force is applied palatally, however, the rotational control of the molars during distalization could be quite difficult.[27] Ferguson et al., examining 25 subjects treated with the distal jet, found 3.4mm of distal molar movement per side with 3.2^{o} of distal tipping.[50] Bolla et al., examining a sample of 20 subjects also treated with the distal jet, reported 3.2mm of first molar distalization with 3.1^{o}of tipping in a total treatment time of 5 months.[3]

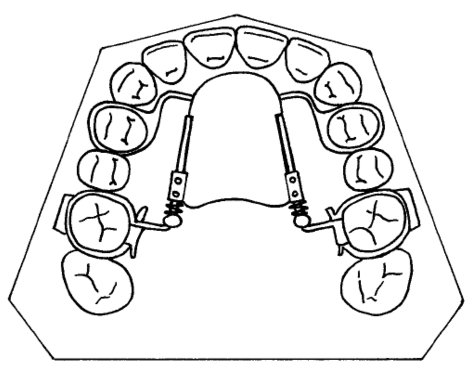


Figure 1-8: Distal Jet with Two Bilateral Tubes Embedded in a Modified Acrylic Nance Palatal Button that is Anchored to the First Premolars (as taken from Bolla et al., 2002[3]).

The pendulum appliance, first described by Hilgers in 1992[11], has also been advocated for maxillary molar distalization in noncompliant patients. This appliance consists of a palatal acrylic button with occlusal rests bonded to the first premolars with titanium molybdenum alloy (TMA) springs engaged in lingual sheaths on the bands of the first maxillary molars.[11] A force of 230 gm per side, with 60^{o} of activation is used.[11] With this appliance, Hilgers has reported as much as 5mm of molar distalization in a 3 to 4 month treatment timeframe. The ability of pendulum appliances to obtain clinically significant molar distalization has since been confirmed in a number of clinical studies.[4,6,51-57] The pendulum appliance has a long history of being modified since its original introduction in 1992, largely to reduce the amount of unwanted reciprocal side-effects. Modifications were made by Hilgers himself on several occassions[58] and later by Snodgrass,[59] Byloff et al,[55,60] Favero,[61] Grummons,[62,63] Scuzzo et al.[64,65] and Kinzinger et al.[52,67]

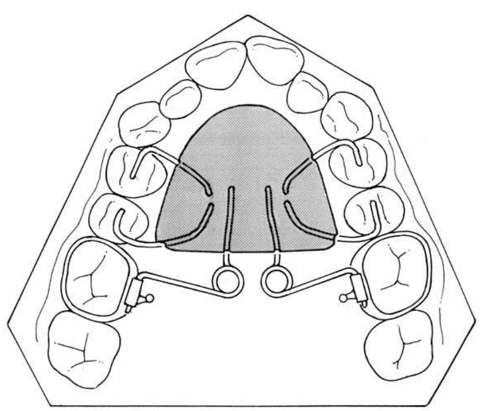


Figure 1-9: Typical Design of the Pendulum Appliance as esigned by Hilgers. Acrylic Palatal Button is Bonded to the Occlusal Surfaces of the Upper First Premolars and Bands are Placed on the Upper First Molars. (As taken from Bussick and McNamara; 2000[6])

Fortini et al.[67] describe the use of the First Class Appliance for molar distalization. A formative screw is fitted buccal to the molar tubes and premolars; this screw is the active distalizing component. NiTi springs, which are fitted palatally to spring-loaded splints, counteract the subsequent rotational moments and a Nance button is fitted to the premolar and molar bands to reinforce the anchorage. Over a 2.4 month treatment duration, Fortini et al. reported 4mm of maxillary molar distalization with the First Class Appliance, although the number of cases studied (17) was minimal.[68]

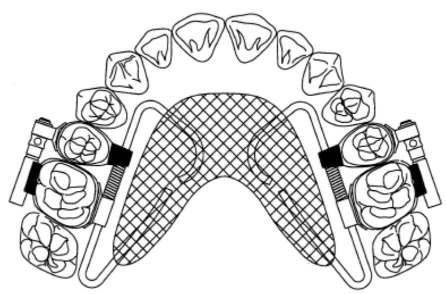


Figure 1-9-1: The First Class Molar Distalizing Appliance (as taken from Fortini et al., 1999[67])

Xbow (pronounced crossbow) is a more recently developed appliance used for Phase 1 treatment of Class II malocclusions that also has been shown to cause posterior movement of the maxillary first molars.[25] The Xbow consists of three main components: 1) a palatal jack-screw attached via orthodontic bands on the maxillary 1st premolars and molars, 2) a mandibular labial and lingual arch, and 3) Forsus FRD Springs connected to the maxillary 1st molar band head-gear tube and the mandibular labial bow in the 1st premolar area. In a prospective study of 69 consecutively treated patients with the Xbow appliance, Flores et al.

found a mean maxillary first molar distalization of 0.9mm over a mean treatment time of 4.5 months.[25]

Figure 1-9-2: Xbow Appliance: Various Views (images taken from http://www.crossboworthodontic.com/xbow.htm)

Somewhat similar to the XBow, the Herbst appliance (Figure 1-9-3) is a popular functional appliance used to correct Class II malocclusions. The maxillary and mandibular arches are splinted with frameworks (which are cemented or bonded) that are connected with a pin-and-tube device which postures the mandible forward.[69] Alternatively, the Herbst appliance can also be designed as a removable appliance. Unlike the crown or banded versions which are cemented in place, the removable version of the Herbst necessitates an interocclusal layer of acrylic which can be used as either fully or partially removable.[70] A past systematic review of the skeletal and dental changes in patients treated with splint-type Herbst appliances found that maxillary molars were significantly retruded (from 1.5 to 5.4mm) after being treated with the Herbst appliance.[71] A later systematic review, based on treatment with crown and banded type Herbst appliances, also found that the maxillary first molar moved distally within the maxillary alveolus.[72] Although the overall results with the Herbst appliance can be considered similar to those found when patients are treated with the XBow appliance, the XBow – unlike the Herbst appliance – does allow the patient to occlude in centric occlusion.

Figure 1-9-3: Herbst Appliance (as taken from Proffit et al.[69])

Today, skeletal anchorage systems for molar distalization are becoming more and more popular,[73-74] although evidence from good quality clinical trials still appear lacking in this area. While the use of skeletally anchored appliances to distalize molars will possibly become more popular in the future, the use of skeletal anchorage in molar distalization is beyond the scope of this paper.

1.5.2 Side Effects of Maxillary Molar Distalization

While it is apparent that distalization can be achieved with numerous distalizing appliances, “successful” distalization is not equivalent with the sole presence of horizontal distalization of the maxillary first molar. Mesialization of the anchorage component, tipping or intrusion/extrusion of the molars and a potential increase in lower face height are also factors for consideration in determining the success of molar distalization. (Note: A comparison of the degree to which various appliances express each of the following side-effects is presented in the next section).

Since every force causing an action has an equal and opposite reaction, it should be expected that if the molar is distalized, the anchorage unit could also be mesialized. Most conventional distalization appliances use an acrylic button on the palate, which is usually anchored to two or four more anterior teeth (primary molars or permanent premolars), as a method to increase the anchorage value of the system. Otherwise, unwanted side-effects expressed by movements in the teeth located mesial to the point of force application could occur.[1] Commonly called anchorage loss, these effects could directly cause the teeth in the anchorage system, and indirectly the incisors, to be mesialized.[1] Such mesial tipping is usually undesirable and could increase the overall treatment time by requiring further retraction of the mesially tipped incisors.

A review of non-compliance molar distalizers reported that anchorage loss occurred more markedly in the area of the incisors compared with that of the first premolars.[1] They postulated that this effect could be explained by two forces acting upon the incisors: 1) the force relayed by the dental arch itself (i.e. direct contact from the premolars to the canines and the anteriors teeth) and 2) forces exerted by the Nance button to the anterior portion of the palate, and, thereby, indirectly to the area of the anterior teeth.[1] This study also found that although outcomes are not fully consistent with each other, the side-effects in relation to anchorage loss occurred most often in studies in which only two teeth were part of the anchorage design.[1] With this finding in mind, it is apparent that most appliances should incorporate as many teeth into the anchorage system as possible to limit the degree of anchorage loss. Contrary to this, a study by Bolla et al. did not support the notion that incorporating more teeth into the anchorage system improves resistance to undesirable reactive forces.[3]

Furthermore, it has also been reported that anchorage to primary molars, or a mix of primary molars and permanent premolars, has also resulted in reduced anchorage quality.[1] For this reason, consideration should be given to using as many permanent teeth in the anchorage system as possible.[1]

In addition to anchorage loss, another potential side effect of molar distalization is a deviation of the molar in all dimensions of space, resulting in tipping, intrusion/extrusion, or molar rotations.[1] Theoretically, tipping of the molars should be expected since the distalization force is generally applied coronally from the centre of resistance of the tooth. Numerous studies in the past have confirmed that molar tipping, to some degree, is usually expected when the molars are distalized[4,6,53-55] with a range from 1^{o} to 14.5^{o} of distal crown tipping reported in the literature.[1] This particular side effect is especially important since distally tipped molars could result in more questionable stability; their use as anchorage to retract protruding anterior teeth could be compromised.[53]

It has been suggested that distal tipping of the first molar during distalization could be more a factor of the development stage of the second molar than the type of distalization appliance used.[32] According to this theory, if the second molars are unerupted they act as a fulcrum for the 6-year molars that are being distalized. As the first molar is distalized it tips over the tooth germ of the second molar. With time, as the second molar continues to erupt, the contact point between it and the first molar moves more coronally and the tipping tendency is reduced.[32] If this theory is true, distal tipping of the first molar during distalization will be greater in patients in the mixed dentition than in those with a full permanent dentition.

Vertical side effects on both the molar and the anchorage unit also appear common with distalization mechanics. In their review of non-compliance maxillary molar distalization appliances, Kinzinger et al. found that most appliances caused extrusion of the molar, while some caused intrusion.[1] They found that the range of vertical side effects on the first molar was from 1.68mm of intrusion to 1.6mm of extrusion**.** The range in vertical side-effects on the premolars was from 0.62mm to 1.88 mm of extrusion; the range in vertical side-effects on the incisors was from 1.5mm of intrusion to 1.95 mm of extrusion.[1] Interestingly, some studies based on the same type of distalization appliance quite often differed on whether the appliance expressed an intrusive or an extrusive side effect.[1] Since the vertical effects of these appliances consistently appeared less than 2mm on the molars, premolars and incisors, Kinzinger et al.[1] concluded that vertical side effects in relation to these teeth play only a minor part and may essentially be ignored in terms of molar distalization side effects.

Although not identifiable on cephalometric radiographs, first molars are often rotated as they are distalized.[32,35,48,53] Because of its' relationship to the centre of resistance of the tooth, a distalization force with a lingual point of force application, with an appliance such as the distal jet, might be expected to cause a mesiolingual rotation of the tooth. Similarly, distalization forces with a buccal point of force application, with head gear, magnets or push-coils, might be expected to cause mesiobucal rotations. Gosh and Nada[53]found that unlike other distalization appliances with a lingual point of force application, the pendulum appliance actually caused a mesiobuccal rotation instead. Kinginzer et al.[32] found similar results when they also studied the arc described by the spring of a pendulum appliance. As expected, first molar mesiobucal rotations were also found when repelling magnets, which are positioned buccal to the centre of rotation of the tooth, were used to distalize the first molar.[35] This type of rotation is often beneficial as it could lead to more space in the maxillary arch and an improved occlusal relationship.

Molar distalization may be contraindicated for hyperdivergent patients.[77] Studies have shown decreased overbite[53] and mandibular backward rotation [3,53] as a result of maxillary molar distalization. The backward mandibular rotation is likely caused by the distalization of the teeth into the wedge of occlusion which could prop open the bite[53] and increase anterior face height. Alternatively, the amount of distal tipping produced by the appliance could also be responsible for mild increases in lower anterior face height.[3] Should this be true, appliances with better control of molar inclination might lessen the risk of significant vertical changes – both dentally and facially.

Gosh and Nanda,[53] in a study of 41 patients treated with a pendulum appliance, reported a 2.79mm lower anterior face height increase. Bussick and McNamara[6] and Chiu[78] also discovered a mild increase in mandibular plane angle during distalization. Opposing results have also been reported. Bolla et al.,[3] studying patients treated with a distal jet, reported an insignificant increase in lower anterior facial height (0.9mm) with no significant difference among subjects with high, neutral, or lower pretreatment mandibular plane angles. In fact, many reports have even demonstrated molar intrusion with distalizing appliances.[6,49,53,54]

Molar distalization could potentially increase the risk of impaction of unerupted maxillary second and/or third molars.[79] Surprisingly, the literature contains few articles on this topic. Cetlin found that during distalization of the maxillary first molars, the maxillary second molars erupt normally.[23] Schutze et al.,[80] studying unilateral distalization with the pendulum appliance, reported that any significant movement of the third molar tooth germ could not be established when the first molars are distalized. While the hypothesis of this study was that third molar eruption space would be restricted due to narrowing of the retromolar space, the authors did acknowledge that this theory couldn't be conclusively predicted in patients at a mean age of 12-13 years. For this reason they concluded that the distalization effect on the eruption of the third molar could not be evaluated in their patients. Studies with longer follow-up periods will likely be required to conclusively report the effects of second and third molar impaction due to first molar distalization.

1.5.3 Factors Affecting the Efficiency of Maxillary Molar Distalization Appliances

Perhaps the most obvious factor affecting the efficiency of distalizing appliances is their dependence on patient compliance. While patient cooperation is an important key to any treatment success, it seems evident that patients' willingness to comply with directions and cooperate with instructions is unpredictable at best.[2,81] Without patient compliance, treatment goals are not met and new treatment plans are often required, thereby increasing the overall treatment time. For this reason, since the end of the 1970s, distalization appliances that eliminate the need for patient compliance are favored.[1]

The type of anchorage used in conjunction with distalization mechanics could have an impact on the degree to which negative side effects are expressed, thereby affecting the efficiency of the overall system. When used as an anchorage device, the Nance-type anterior palatal button (used with appliances such as the distal jet, the pendulum appliance, etc.) may achieve the anchoring effect based on the resilience of the palatal mucosa only.[1] Since the quality of anchorage is mainly based on the amount of periodontal tissue interface,[1] factors such as the thickness of the palatal mucosa may then be an important consideration in how well the anchorage is maintained. Poor oral hygiene and tissue irritation may also result from these anchorage designs.

The number of teeth included in the anchorage unit has also been shown to have an effect on the amount of anchorage loss. Root topography of the anchor teeth, level of attachment and bone structure are also important.[1] Kinginzer et al. concluded that although outcomes are not fully consistent in all studies, the side-effects in relation to anchorage loss occurred most often in studies in which only two teeth were part of the anchorage design.[1] For this reason, appliances or mechanics that have the potential to include more than two teeth in the anchorage system could have greater efficiency in distalizing the molars and minimizing the subsequent side effects on the anterior teeth.

With the advent of newer skeletal anchorage devices to prevent mesialization of the teeth anterior to the point of force application, simplistic mechanics such as open coils springs etc. may gain more popularity in the future.

The influence of both the second and third molars on the quantity and quality of molar distalization is a matter of controversy in the literature.[11,28,32,35,53,54,56,82] Chapter 2 of this paper is devoted to this topic.

1.5.4 Comparison of the Efficiency of Maxillary Molar Distalization Appliances

While more than one literature review has been conducted on the efficiency of non-compliance based maxillary molar distalizers,[1,86] to date no review has been performed on compliance dependent maxillary molar distalization appliances. For this reason, the efficiency of each of the compliance dependent appliances will be reviewed individually.

According to Proffit,[83] the problem with relying on headgear for distal tooth movement is that extraoral force of moderate intensity with long duration is needed. Proffit proposes that skeletal effects in rapidly growing patients can be achieved with fewer hours per day of headgear wear than are necessary to successfully move teeth. In other words, headgear wear to distalize molars requires that it is worn almost full time, with approximately 300gm of force per side.[83] Using this protocol of headgear wear, it has been estimated that approximately 2 to 3mm of distal movement of the upper molars can be achieved.[83] This estimation of 2 to 3mm of molar distalization with headgear was confirmed in a 2003 study using cervical pull headgear.[22] The authors of this study found that when the headgear was worn only 14-16 hours per day with 500g of force, a mean of 3.15mm of molar distalization was achieved over a mean of 11.4 months of treatment.[22]

Besides being totally dependent on patient compliance, another drawback of molar distalization with headgear is that headgear also produces skeletal effects.[84,85] If no skeletal change is indicated , and no growth guidance is required, then caution should be used in distalizing molars with headgear.

While removable appliances have been shown to cause distalization of the maxillary molars, especially when combined with headgear to limit the amount of distal crown tipping,[23] these results have largely been demonstrated in case studies only. Since the sole use of removable appliances is not capable of producing bodily translation of a tooth, their effectiveness for molar distalization is usually considered limited. Since no clinical trial has been documented on the use of these appliances for distalization, no evidence-based conclusion on their efficiency can be made.

In a study by Rana and Becher[29] it was reported that the Wilson arch moves the molars posteriorly about 1mm with 2^{o} of distal tipping. It also produced $3.5^{o}$of flaring and 2.7mm of extrusion of the maxillary anterior teeth. An earlier study by Muse et al.[28] reported more distalization (2mm total at 0.56mm per month), but also significantly more tipping (7.8^{o}). Since bracketing of the premolars and second molars can be delayed with this appliance, friction can be minimized which could potentially allow for more rapid bodily movement of the molars.[28] Again, the requirement of patient compliance to control the loss of anchorage with this appliance should be considered.

Attempts have been made to review the literature and compare the efficiency of various non-compliance maxillary molar distalization appliances.[1,86] In 2008 Kinzinger et al.[1] reviewed the literature on the treatment effects of intraoral appliances with conventional anchorage designs (Hilgers pendulum, distal jet, pendulum K, magnets, supercoils, Jones jig, modified jig and the First Class appliance). They found that the longest linear distalization measurements for the molars (from 3.37 to 6.1mm) were reported in studies in which molars were distalized with a Hilgers pendulum appliance. In comparison, they found that the shortest linear distalization measurements (1.40mm) were reported with the use of a modified jig appliance.[1] The efficiency of coil spring designs for molar-distalizing movement was found to differ among the studies, but they concluded that the first class appliance and the palatal distal jet were more efficient than the vestibular Jones Jig.[1]

The degree to which negative side effects are expressed by different appliances is also important in understanding their efficiency. Appliances tend to vary in their degree of expression of both vertical and angular side-effects on the first molars. With the use of the appliances described above, Kinzinger et al. reported that the lowest molar vertical side effects (extrusion) were found with the use of a distal jet and the highest molar vertical side effects (intrusion) were found with the use of a pendulum appliance.[1] These values were noted at 0.01mm and 1.68mm respectively.[1]

Depending on the appliance, the extent to which tipping of the molar occurred also varied substantially. The highest amount of tipping was recorded for distalization with a Hilgers pendulum (10.6^{o} of distal crown tip), while the smallest amount of tipping was achieved with the use of supercoils (1^{o} of distal crown tip).[1]

Kinzinger et al.[1] also explored the side-effects of the various appliances on the anchorage unit. They found that the smallest amount of anchorage loss at the premolars was reported with the Jones jig and the modified pendulum appliance (1.1mm of premolar mesialization). Kinzinger et al. also reported that the least vertical side-effects for the anchorage premolars were seen with the modified jig (0.6mm extrusion) while the highest vertical side-effects on the premolars were reported with the Jones Jig (1.88mm premolar extrusion).[1] The smallest amount of tipping in the anchorage segment was seen with the distal jet (0.3°) and the pendulum appliance (1.7°) while the greatest amount of tipping was reported with the modified jig appliance (8.10°). Incisor mesialization was lowest with the Jones Jig (0.25mm) and highest with the distal jet when only two teeth were used in the anchorage unit (3.7mm). Incisor proclination occurred least with the Jones Jig (1°) while the distal jet produced the most incisor proclination (13.7°).[1]

Knowing the amount of anchorage loss, Kinzinger et al. were also able to quantify the share of molar distalization in the total movement in the sagittal dimension.[1] They found that pendulum appliances incorporating four teeth in the anchorage unit achieved the highest share of effective molar distalization (between 56.9 and 81%).

Based on the conclusions from their literature review, Kinzinger et al. made it clear that each appliance has associated advantages and disadvantages. While the pendulum appliance produced the greatest linear distalization of the molar, it also caused the greatest degree of distal crown tip.[1] The fact that part of the distal crown movement was achieved by tipping should not go unnoticed since it would be expected that a distally tipped molar would be harder to retain in position than a molar that was moved bodily in a distal direction. The Jones jig appliances reported small total distalization values and an increased trend for molar and premolar tipping while the magnetic appliances caused high anchorage loss in the area of the incisors.[1] The pendulum K appliance, a modified version of the original pendulum appliance, showed convincing treatment effects for both distalization and low levels of side effects such as tipping of the molars leading to the conclusion that with appliance modification almost bodily molar distalization can be achieved with this appliance.[1]

Also in 2008, Antonarakis and Kiliaridis did a systematic review on maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusions.[86] They noted that while a meta-analysis would better enable evidence-based decisions on this topic, it was not possible since randomized clinical trials on this topic are few. To study the effects of the various appliances, they categorized the appliances into two groups; 1) those with a buccal force application and those with a palatal force application, and 2) those with a friction-free mechanism and those with a sliding mechanism. They found that when all appliances were considered together, first molars were noted to demonstrate a mean of 2.9mm of distal movement with an associated 5.4^{o} of distal tipping.[86] Buccal acting appliances demonstrated distal movement of 2.6mm while palatal acting appliances demonstrated distal movement of 3.1mm.[86] From this they concluded that buccal and palatal acting appliances demonstrate similar results.

Palatal acting appliances did however consistently show less tipping for all teeth than did the buccal acting appliances.[86] The authors of this review explained that one possible reason for this is that the moment arm of the force produced by palatally acting appliances is smaller because its line of action is closer to the center of resistance of the specific tooth.[86]

Results of this 2008 systematic review also found that appliances with a palatally applied distalization force, with friction-free mechanics, appeared to produce better molar distalizing effects, but with a concomitant notable loss of anchorage.[86]

No comparison of the XBow to other distalizing appliances has been made to date.

1.6 References

1. Kinzinger GS, Eren M, Diedrich PR. Treatment effects of intraoral appliances with conventional anchorage designs for non-compliance maxillary molar distalization. A literature review. Eur J Orthod 2008;30:558-71.

2. Sahm G, Bartsch A, Witt E. Reliability of patient reports on compliance. Eur J Orthod 1990;12:438-46.

3. Bolla E, Muratore F, Carano A, Bowman SJ. Evaluation of maxillary molar distalization with the distal jet: a comparison with other contemporary methods. Angle Orthod 2002;72:481-94.

4. Chaques-Asensi J , Kalra V. Effects of the pendulum appliance on the dentofacial complex. J Clin Orthod 2001;35:254–57.

5. Haydar S , Uner O. Comparison of Jones jig molar distalization appliance with extraoral traction. Am J Orthod Dentofacial Orthop 2000;117:49 –53.

6. Bussick TJ, McNamara JA Jr. Dentoalveolar and skeletal changes associated with the pendulum appliance. Am J Orthod Dentofacial Orthop 2000;117:333-43.

7. Gianelly AA, Vaitas AS, Thomas WM, Berger OG. Distalization of molars with repelling magnets. J Clin Orhtod 1988;22:40-4.

8. Graber TM. Extraoral forces – facts and fallacies. Am J Orthod 1955;41:490-505.

9. Ten Hoeve A. Palatal bar and lip bumper in nonextraction treatment. J Clin Orthod 1985;19:272-91.

10. Jeckel N, Rakosi T. Molar distalization by intra-oral force application. Eur J Orthod 1991;3:43-6.

11. Hilgers JJ. The pendulum appliance for Class II non-compliance therapy. J Clin Orthod 1992;26:706-14.

12. Bondemark L, Kurol J, Bernhold M. Repelling magnets versus superelastic nickel-titanium coils in the simultaneous distal movement of maxillary first and second molars. Angle Orthod 1994;64:189-98.

13. Gianelly AA. Distal movement of the maxillary molars. Am J Orthod Dentofacial Orthop 1998;114:66-72.

14. Karlsson I, Bondemark L. Intraoral maxillary molar distalization – movement before and after eruption of second molars. Angle Orthod 2006;76:923-29.

15. Kingsley NW. A treatise on oral deformities as a branch of mechanical surgery. New York: D Appleton; 1880. p.131-4.

16. Angle EH. Treatment of malocclusion of the teeth and fractures of the maxillae. 6th ed. Philadelphia: SS White Dental Manufacturing; 1900. p.115.

17. Graber TM. Extraoral force – facts and fallacies. Am J Orthod 1955;41:490-505.

18. Graber TM. Appliances at the crossroads. Am J Orthod 1956;42:683-701.

19. Klein PL. An evaluation of cervical traction on the maxilla and the upper first permanent molar. Angle Orthod 1957;27:61-8.

20. Newcomb MR. Some observations on extraoral treatment. Angle Orthod 1958;28:131-48.

21. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 4th ed. St. Louis, Missouri: Mosby;2007. p.581.

22. Taner TU, Yukay F, Pehlivanuglu M, Cakirer B. A Comparative Analysis of Maxillary Tooth Movement Produced by Cervical Headgear and Pend-X Appliance. Angle Ortho 2003;73(6):686-91.

23. Cetlin NM, Ten Hoeve A. Nonextraction treatment. J Clin Orthod 1983;17:396-413.

24. Wilson WL, Wilson RC. Modular orthodontics (Wilson) manual. Denver: Rocky Mountains Orthodontics; 1981.

25. Flores-Mir C, Barnett G, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009;136:822-832.

26. Ferro F, Monsurro A, Perillo L. Sagittal and vertical changes after treatment of Class II, division 1 malocclusion according to the Cetlin method. Am J Orthod Dentofacial Orthop 2000;118:150-8.

27. Sfondrini MF, Cacciafesta V, Sfondrini G. Upper molar distalization: a critical analysis. Orthod Craniofacial Res 2002;5:114-26.

28. Muse DS, Fillman MJ, Emmerson WJ, Mitchell RD. Molar and incisor changes with Wilson rapid molar distalization. Am J Ortho Dentofacial Orthop. 1993;104(6):556-65.

29. Rana R, Becher MK. Class II correction using the biometric “distalizing” arch. Semin Orthod 2000;6:106-118.

30. Tweed CH. Clinical Orhtodontics. Vol 1. St Louis: CV Mosby; 1966.

31. Salzmann JA. Practice of Orthodontics. Vol 2. Philadelphia: JB Lippincott Co.;1994.

32. Kinzinger GS, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. Am J Orthod Dentofacial Orthop 2004;125:8-23.

33. Gianelly AA, Vaitas AS, Thomas WM. The use of magnets to move molars distally. Am J Orthod Dentofacial Orthop 1989;96:161-7.

34. Itoh T, Tokuda T, Kiyosue S, Hirose T, Matsumoto M, Chaconas SJ. Molar distalization with repelling magnets. J Clin Orthod 1991;25:611-17.

35. Bondemark L, Kurol J. Distalization of maxillary first and second molars simultaneously with repelling magnets. Eur J Orthod 1992;14:264-72.

36. Darendeliler M. Contemporary mechanics: magnets and constant forces. Pac Coast Soc Orthod Bull 1995;67:43-5.

37. Haas SE, Cisneros GJ. The Goshgarian transpalatal bar: a clinical and an experimental investigation. Semin Orthod 2000;6:98-105.

38. Dahlquist A, Gebauer U, Ingervall B. The effect of a transpalatal arch for correction of first molar rotation. Eur J Orthod 1996;18:257-67.

39. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 4th ed. St. Louis, MI: Mosby Inc;2007. p.390-391.

40. Johnson J. Twin wire alignment appliance. Int J Orthodontia 1934;20:963.

41. Bondemark L, Kurol J. Class II correction with magnets and superelastic coils followed by straight-wire mechanotherapy. J Orofacial Orthopedics 1998;59:127-38.

42. Bondemark L. A comparative analysis of distal maxillary molar movement produced by a new lingual intra-arch NiTi coil appliance and a magnetic appliance. Eur J Orthod 2000;22:683-95.

43. Gianelly AA, Bednar J, Dietz VS. Japanese NiTi coils to move molars distally. Am J Orthod 1991;99:564-66.

44. Miura F, Mogi M, Ohura Y, Karibe M. The superelastic Japanese NiTi alloy wire for use in orthodontics, Part III: Studies on the Japanese NiTi alloy coil springs. Am J Orthod 1988;94:89-96.

45. Jones RD, White JM. Rapid Class II molar correction with an open-coil jig. J Clin Orthod. 1992;26:661-64.

46. Brickman CD, Sinha PK, Nanda RS. Evaluation of the Jones jig appliance for distal molar movement. Am J Orthod Dentofacial Orthop 2000;118(5):526-34.

47. Carano A, Testa M. The distal jet for upper molar distalization. J Clin Orthod 1996;30:374-80.

48. Bowman SJ. Modifications of the distal jet. J Clin Orthod 1998;32:549-56.

49. Kinzinger GS, Diedrich PR. Biomechanics of a Distal Jet appliance. Theoretical considerations and in vitro analysis of force systems. Angle Orthod 2008;78(4):676-81.

50. Ferguson DJ, Carano A, Bowman SJ, Davis EC, Gutierrez Vega ME, Lee SH. A comparison of two maxillary molar distalizing appliances with the distal jet. World J Orthod 2005;6(4):382-90.

51. Quick AN, Harris AM. Molar distalization with a modified distal jet appliance. J Clin Orthod 2000;34(7):419-23.

52. Kinzinger G, Fuhrmann R, Gross U, Diedrich P. Modified pendulum appliance including distal screw and uprighting activation for non-compliance therapy of Class II malocclusion in children and adolescents. J Orofac Orthop 2000;61:175-90.

53. Ghosh J, Nanda RS. Evaluation of an intraoral maxillary molar distalization technique. Am J Orthod Dentofacial Orhtop 1996;110:639-46.

54. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthod 1997;67:249-60.

55. Byloff FK, Darendeliler MA, Clar E, Darendeliler A. Distal molar movement using the pendulum appliance. Part 2: The effects of maxillary molar root uprighting bands. Angle Orthod 1997;67:261-70.

56. Joseph AA, Butchart CJ. An evaluation of the pendulum distalizing appliance. Semin Orthod 2000;6:129-35.

57. Kinzinger G, Wehrbein H, Diedrich PR. Molar distalization with a modified pendulum appliance – in vitro analysis of the force systems and in vivo study in children and adolescents. Angle Orthod 2005;75:558-67.

58. Hilgers JJ, Bennet RK. The pendulum appliance: creating the gain. Clinical Impressions 1994;3:14-23.

59. Snodgrass DJ. A fixed appliance for maxillary expansion, molar rotation, and molar distalization. J Clin Orthod 1996;30:156-9.

60. Byloff FK, Karcher H, Clar E, Stoff F. An implant to eliminate anchorage loss during molar distalization: a case report involving the Graz implant-supported pendulum. Int J Adult Orthod Orthognath Surg 2000;15:129-37.

61. Favero F. Lingual orthodontics in pediatric patients. In: Romano R, editor. Lingual orthodontics. Hamilton, London: B. C. Decker;1998. p. 127-34.

62. Grummons D. Maxillary asymmetry and frontal analysis. Clinical Impressions 1999;3:2-23.

63. Grummons D. Nonextraction emphasis: space-gaining efficiencies, part I. World J Orthod 2001;2:21-32.

64. Scuzzo G, Pisani F, Takemoto K. Maxillary molar distalization with a modified pendulum appliance. J Clin Orthod 1999;33:645-50.

65. Scuzzo G, Takemoto K, Pisani F, Della Vecchia S. The modified pendulum appliance with removable arms. J Clin Orthod 2000;34:244-6.

66. Kinzinger G, Fritz U, Diedrich P. Bipendulum and quad pendulum for non-compliance molar distalization in adult patients. J Orofac Orthop 2002;63:154-62.

67. Fortini A, Lupoli M, Parri M. The first class appliance for rapid molar distalization. J Clin Orthod 1999;33:322-28.

68. Fortini A, Lupoli M, Giuntoli F, Franchi L. Dentoskeletal effects induced by rapid molar distalization with the first class appliance. Am J Orthod Dentofacial Orthop 2004;125:697-705.

69. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 4th ed. St. Louis, MI: Mosby Inc;2007. p.398.

70. O'Brien K, Wright J, Conboy F, et al. Effectiveness of treatment for Class II malocclusion with the Herbst or twin-block appliances: a randomized, controlled trial. Am J Orthod Dentofacial Orthop. 2003;124:128-137.

71. Flores-Mir C, Ayeh A, Goswani A, Charkhandeh S. Skeletal and Dental Changes in Class II division 1 Malocclusions Treated with Splint-Type Herbst Appliances. Angle Orthod 2007;77(2):376-381.

72. Barnett GA, Higgins DW, Major PW, Flores-Mir C. Immediate Skeletal and Dentoalveolar Effects of the Crown- or Banded Type Herbst Appliance on Class II division 1 Malocclusion. Angle Orthod 2008;78(2):361-369.

73. Wehrbein H, Glatzmaier J, Mundwiller U, Diedrich P. The orthosystem: a new implant system for orthodontic anchorage in the palate. J Orofac Orthop 1996;57:142-53.

74. Keles A, Erverdi N, Sezen S. Bodily distalization of molars with absolute anchorage. Angle Orthod 2003;73:471-82.

75. Sugawara J, Kanzaki R, Takahashi I, Nagasaka H, Nada R. Distal movement of maxillary molars in nongrowing patients with the skeletal anchorage system. A J Orthod Dentofacial Orthop 2006;129(6):723-33.

76. Kinzinger GS, Wehrbein H, Gross U, Diedrich PR. Molar distalization with pendulum applilances in the mixed dentition: Effects on the position of unerupted canines and premolars. Am J Orhtod Dentofacial Orthop 2006;129(3):407-17.

77. Bowman SJ. Class II combination therapy. J Clin Orthod 1998;32:611-20.

78. Chiu PP, McNamara JA Jr, Franchi L. A comparison of two intraoral molar distalization appliances: distal jet versus pendulum appliance. A J Ortho Dentofacial Orthop. 2005;128(3):353-65.

79. Nanda R. Biomechanics and esthetic strategies in clinical orthodontics. St. Louis, MI: Elsevier Saunders; 2005. p.178.

80. Schutze SF, Gedrange T, Zellmann MR, Harzer W. Effects of unilateral molar distalization with a modified pendulum appliance. Am J Orthod Dentofacial Orthop 2007;131:600-8.

81. Nanda RS, Kieri MJ. Prediction of cooperation in orthodontic treatment. Am J Orthod 1992;102:15-21.

82. Worms FW, Isaacson RJ, Speidel TM. A concept and classification of centers of rotation and extraoral force systems. Angle Orthod 1973;43:384–401.

83. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 4th ed. St. Louis, MI: Mosby Inc,;2007. p.581.

84. Baumrind S, Korn EL, Isaacson RJ, et al. Quantitative analysis of the orthodontic and orthopedic effects of maxillary traction. Am J Orthod 1983;84:384-98.

85. Firouz M, Aernik J, Nanda R. Dental and orthopedic effects of high-pull headgear in treatment of Class II, division 1 malocclusion. Am J Orthod Dentofacial Orthop 1992;102:197-205.

86. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion – A systematic review. Angle Ortho. 2008;78(6):1133-1140.

87. Papadopoulous MA, Mavropoulos A, Karamouzos A. Cephalometric changes following simultaneous first and second maxillary molar distalization using a non-compliance intraoral appliance. J Orofac Orthop 2004:65:123-36.

88. Ngantung V, Nanda RS, Bowman SJ. Posttreatment evaluation of the distal jet appliance. Am J Orthod Dentofacial Orthop 2001;120:178–85.

89. Gulati S, Kharbanda OP, Parkash H. Dental and skeletal changes after intraoral molar distalization with sectional jig assembly. Am J Orthod Dentofacial Orthop 1998;114:319–27.

90. Kinzinger GSM, Gross U, Fritz UB, Diedrich PR. Anchorage quality of deciduous molars versus premolars for molar distalization with a pendulum appliance. Am J Orthod Dentofacial Orthop 2005;127:31 –23.

Chapter 2

Systematic Review

2.1 Introduction:

Maxillary molar distalization, a common treatment modality used to correct Class II malocclusions, is particularly indicated when maxillary skeletal or dentoalveolar protrusion is present. Unfortunately, molar distalization is often a challenge for the orthodontist and the question of how it is impacted by the eruption stage of the second and third molar is still a matter of controversy in the literature.[1]

The success of molar distalization has been reported to depend on two main factors: 1) the type of movement and 2) the timing of treatment.[2] Since 1955 it has been argued that when the second molar has not yet erupted, distalization of the first molar is by tipping rather than by bodily movement.[3] Several other authors have since that time agreed stating that the eruption stage of the second molar had a basic qualitative and quantitative impact on the distalization of the first molar.[1,2,4-9] Duration of therapeutic treatment has also been shown to increase if second molars have erupted and therefore distalization is often recommended prior to the eruption of the full permanent dentition.[2]

Contrary to this, there have also been many investigations that have concluded that the position of the second molar when distalizing the first molar is of little significance.[10-14] The authors of these studies all found that there is no connection between second molar budding stages, magnitude of molar distalization and duration of therapy.[1]

A 2004 clinical study further argued that the success of first molar distalization varies according to the stage of development of the second *and* the third molars.[1] As a result, germectomy of wisdom teeth was recommended to achieve bodily distalization of both molars.

Although a number of studies have been published over the years reporting on maxillary molar distalization, considerable controversy exists regarding upper first molar distalization with respect to second and third molar eruption stage. The aim of the present systematic review is therefore to investigate the efficiency of maxillary first molar distalization according to the stage of dental development of the second and/or third molars.

2.2 Methods

A systematic computerized database search was conducted using Ovid Medline (1950 through week 15 of April, 2012), all EBM reviews including Cochrane DSR, ACP Journal Club, DARE (1980 through week 15 of April, 2012), CCTR, CMR, HTA and NHSEED, PubMed (1966 through week 15 of April, 2012) and Thomsen's ISI Web of Science databases to identify articles related to molar distalization.[*1] The terms "molar distalization" and "distalizing appliances" were used. To complement this, further more specific selection terms were chosen for each specific database with the guidance of a senior librarian with expertise in health science database searches.

Once the computerized search was complete, pertinent articles were selected from the abstracts and/or titles by two researchers. Articles were selected when maxillary molar

---

[1] *EBM = Evidence Based Medicine
DSR = Database of Systematic Reviews
ACP = American College of Physicians
DARE = The Database of Abstracts of Reviews of Effectiveness
CCTR = Cochrane Controlled Trials Register
CMR = Cochrane Database of Methodology Reviews
HTA = Health Technology Assessments
NHSEED = NHS Economic Evaluation Database

distalization was studied in human subjects with Class II malocclusions with measurable pretreatment and posttreatment cephalometric values.

In cases of discrepancies in the selection process they were settled by consensus. The chosen articles were then retrieved and independently reviewed by the two researchers. Articles were selected for final inclusion and analysis if the following criteria were met:

*Mention of which appliance was used, along with a description if necessary (ie. if the appliance was not a common distalization appliance)

*Sample size identified

*Duration of treatment mentioned

*Use of conventional anchorage designs only (i.e. no bony anchorage)

*Eruption stage of maxillary second molars clearly defined and stated for sample size along with a comparison of distalization pertaining to second and/or third molar eruption

*When more than one publication about the same patient group was identified, the most informative and relevant article was selected for inclusion.

The reference lists of all the selected articles were also searched for any potential articles that might have been missed in the electronic search of the databases.

2.3 Results

The original search located five hundred and eighty-eight potential articles. From the abstracts and/or titles of these articles, only thirteen were found to be potentially relevant for this study. A hand search of the reference lists from the selected articles provided two additional articles. Out of the fifteen articles initially chosen, only four fulfilled the final selection criteria. The remaining twelve articles were rejected due to the use of skeletal anchorage systems and molar distalization methods that were not clearly defined or not related to Class II malocclusion.

Out of the four chosen articles only one was prospective; three of the four used the pendulum appliance. Key information of the selected studies can be found in Table 2-1, which provides methodological details of the selected articles and the type of appliance used to gain distalization of the molars.

Kinzinger et al[1] divided all subjects into three groups according to the stage of eruption of the second *and* third molars, while Karlsson et al.[9]and Bussick et al.[13] divided all subjects into two groups, one with second molars erupted and one without second molars erupted, for statistical purposes. Gosh et al.[11] did not specifically report the amount of distalization for the groups with maxillary second molars either erupted or unerupted, but did report if there was any statistical significance between these two groups.

Treatment times for distalization in all studies ranged from 12.83 to 28 weeks with a mean of 22.9 weeks. One study[1] found treatment times to be longer, although not significantly, when first and second molars were distalized simultaneously while another[9] found that molar distalization time was significantly shorter *($P \leq 0.001$)* in patients with unerupted second molars.

Table 2-2 explores the quantitative differences in horizontal distalization for first and second maxillary molars for all chosen studies. Two[1,11] of the four studies used the same method to measure linear distalization (i.e. used the same cephalometric landmarks and references planes) while the others[9,13] differed and were somewhat less clear on the methodology used. Three[1,11,13] of the four studies showed no statistical significance in horizontal molar distalization based on the eruptive stage of the second and/or third molars while one study[9] found that the amount of distal movement of the first molars was significantly greater (*$P \leq .01$)* in the group with unerupted second molars. In this study, the mean amount of distal molar movement was 0.8mm more for the group without second molars erupted.

The amount of molar tipping that occurred as a result of distalization is detailed in Table 2-3. Kinzinger et al.[1] found that during distalization the maxillary first molars tipped more when the second molars were unerupted and that the erupted second molars tipped more when the third molars were unerupted (i.e. at the budding stage). These results were statistically significant *($P \leq 0.01$ and $P \leq 0.05$* respectively*)*. The group with second molars unerupted showed that the maxillary first molars tipped 5^{o} more (to the palatal plane) as they were distalized. Similarly, the group with third molars at the budding stage showed that the maxillary second molars tipped 5.9^{o} more as they were distalized. No other study[9,11,13] found significant results for molar tipping with respect to second or third molar eruption stage.

The effect of distalization on the maxillary third molars was extremely variable.[11]

Table 2-1: Description of Studies Included in the Final Selection

Study	Year	Sample Size and comparison groups according to molar eruption	Average Age (Yr)	Selection	Appliance Used
Kinzinger et al[1]	2004	n = 36 **Group 1** = incomplete eruption of 2nd molars, *n = 18* **Group 2** = 2nd molars erupted to level of occlusal plane & 3rd molars at budding stage, *n = 15* **Group 3** = germectomy of wisdom teeth & 2nd molars erupted, *n=3*	12.03	Prospective	Pendulum K
Karlsson et al[9]	2006	n = 40 **Group 1** = before eruption of the second molars, *n = 20* **Group 2** = first and second molars fully erupted, *n = 20*	11.4	Retrospective	NiTi Coil appliance with Nance to provide anchorage
Bussick et al[13]	*2000*	n = 101 **Group 1** = erupted second molars, *n = 57* **Group 2** = unerupted second molars, *n = 44*	12.1	Retrospective	Pendulum
Ghosh et al[11]	1996	n = 41 **Group 1** = erupted second molars, *n = 18* **Group 2** = unerupted second molars, *n = 23*	12	Retrospective	Pendulum

Listed for each study are the year of publication, the sample size (n) (and the subsequent sample size of each group defined by molar eruption stage), the average age of all subjects (in years) at the beginning of treatment, the type of study and the appliance used to gain molar distalization. In all studies, total distalization was defined after the distalization appliance was no longer active and before full fixed appliances were implemented. NiTi = Nickel Titanium

Table 2-2: Molar Horizontal Distalization for Various Stages of Second and Third Molar Eruption

Study	Group Classifications (and subheadings) According to Molar Eruption	Reference Plane for Linear Distalization	Mean Linear Distalization - mm (standard deviation)	Mean treatment duration - wks	Significance of Linear Distalization
Kinzinger et al[1]	**Group 1** = 2nd molars incompletely erupted or unerupted	PTV	M1 = 3.16 (0.77)	Group 1 = 12.8	NS
	Group 2 = 2nd molars erupted to level of occlusal plane and 3rd molars at budding stage	PTV	M1 = 3.21 (1.01) M2 = 2.26 (0.84)	Group 2 = 17.6	NS
	Group 3 = 2nd molars erupted and germectomy of 3rd molars	PTV	M1 = 2.70 (1.55) M2 = 2.27 (0.75)	Group 3 = 24	NS
Karlsson et al[9]	**Group 1** = 2nd molars not erupted (2nd and 3rd molars were present in alveolar bone)	OLp vertical	M1 = 3 (0.64)	Group 1 = 22	***
	Group 2 = 2nd molars erupted and distalized simultaneously with 1st molars (3rd molars were present, but unerupted, in the left and right side of all patients)	OLp vertical	M1 & M2 = 2.2 (0.84)	Group 2 = 26	***
Bussick et al[13]	**Group 1** = 2nd molars unerupted	Fiducial lines[13]	M1 & M2 = 5.7 (1.6)	Group 1 = 28	NS
	Group 2 = 2nd molars erupted	Fiducial lines[13]	M1 & M2 = 5.6 (2.0)	Group 2 = 28	NS
Gosh et al[11]	Groups were differentiated according to Second Molar Eruption for Discussion Purposes only. No numerical differences were given besides stating that differences were not statistically significant	PTV	M1 = 3.37 (2.1) M2 = 2.27 M3 = Ø	All = 24.8	NS

PTV = relative distal movement of the first and second molars were measured to the vertical of the pterygoid.
M1 = Maxillary first molar, M2 = Maxillary Second Molar
OLp vertical = perpendicular from Sella to the occlusal line ***$P \leq .001$ NS = not statistically significant

Table 2-3: Molar Tipping (distal crown tip) for Various Stages of Second and Third Molar Eruption

Study	Groups Classifications (and subheadings) According to Molar Eruption	Reference Plane for Angular Distalization	Mean Angular Distalization (Standard deviation)	Mean treatment duration (wks)	Significance of Angular Distalization
Kinzinger et al[1]	**Group 1** = 2nd molars incompletely erupted or unerupted	SN	M1 = 5.36° (3.49) M2 = 4.06° (2.15)	Gr 1 =12.8	** *
	Group 2 = 2nd molars erupted to level of occlusal plane and 3rd molars at budding stage	SN	M1 = 0.80° (3.40) M2 = 7.92° (5.83)	Gr 2 =17.6	** *
	Group 3 = 2nd molars erupted and germectomy of 3rd molars	SN	M1 = 0.67° (2.08) M2 = 2.00° (1.73)	Gr 3 = 24	NS NS
Karlsson et al[9]	**Group 1** = 2nd molars not erupted (2nd and 3rd molars were present in alveolar bone)	NA	M1 = 3°	Gr 1 = 22	NS
	Group 2 = 2nd molars erupted and distalized simultaneously with 1st molars (3rd molars were present, but unerupted, in the left and right side of all patients)	NA	M1 & M2 = 3°	Gr 2 = 26	NS
Bussick et al[13]	**Group 1** = 2nd molars unerupted	FH	M1 = 11.7° (5.6)	Gr 1 = 28	NS
	Group 2 = 2nd molars erupted	FH	M1 = 9.8° (5.6)	Gr 2 = 28	NS
Ghosh et al[11]	**Groups were differentiated according to Second Molar Eruption for Discussion Purposes only. No numerical differences were given besides stating that differences were not statistically significant.**	SN	M1 = 8.36° (8.37) M2 = 11.99° M3 = 2.49°	All = 24.8	NS

SN = degrees of distal molar tipping determined by measuring the angle between the longitudinal tooth axis and the anterior cranium floor (SN).
M1 = Maxillary first molar, M2 = Maxillary Second Molar
NA = Not available
FH = Frankfort Horizontal *$P \leq 0.05$, **$P \leq 0.01$ NS = not statistically significant

2.4 Discussion

This is the first review to systematically evaluate the efficiency of molar distalization related to second and third molar eruption stage. In addition to the four studies examined for this paper, there were numerous other studies[15-19] that evaluated this effect but that, among other limitations, suffered from small sample sizes. Case studies were not considered in this review because the data collected from these articles is usually biased as most of the time only successfully cases are reported.

Intraoral distalizing appliances used in the studies examined in this review include the modified[1] and conventional[11,13] pendulum appliance and a nickel titanium coil spring appliance with a Nance holding arch, used to provide anchorage[9].

Intuitively, the recommendation to move molars distally with intraoral appliances in the mixed or late mixed dentition (ie. prior to second molar eruption) largely relies on the theory that when the second molar is erupted there is a larger root surface area imbibed in the bone that must be distalized, making movement in that direction more difficult.[1] Only one[9] of the four studies in this investigation showed a statistically significant difference in the amount of maxillary first molar horizontal distalization with respect to the stage of eruption of the second molar (Table 2-2). This particular study found that the amount of distal movement of the maxillary first molars was significantly greater (3mm vs. 2.2mm) and that the distalization time was significantly shorter (5.2 months vs. 6.5 months) in subjects with unerupted second molars. None of the other three studies[1,11,13] included in this review showed a statistically significant difference in the amount of linear distalization, or the time in treatment, and the stage of dental development. Importantly, the one study that did show a difference[9] in horizontal distalization may have suffered from inadequate statistical analysis. With numerous outcome measurements, the study performed multiple t-tests, as opposed to a single MANOVA analysis which is designed for numerous outcome variables. Because of this, the chance of false positive test results may have been inflated in this study.

Further exploration of the theoretical effect of early distalization when second molars are not yet completely erupted warrants attention. Kinzinger et al.[1] concluded that first molar distalization should commence prior to the eruption of second molars despite the fact that an unerupted second molar causes a significant amount of more pronounced distal tipping of the first molar (Table 2-3). The authors' reasons for concluding this include the fact that when the first and second molars are distalized simultaneously there is a slightly greater loss of anchorage and the duration of therapy and the number of distal screw activations also increase. This study also found that the degree of distal tipping of first molars was less in patients with erupted second molars than in those whose second molars were not yet erupted.

Similarly, when eruption of the second molar was complete, tipping of the first molar was greater when a third molar bud was located in the direction of movement.[1] Based on these results, the authors of this study theorized that when distalizing a molar, a tooth bud acts on the mesial neighboring tooth in the same way as a fulcrum.[1] Because the axis of rotation of a maxillary molar is near the trifurcation of its roots, a second molar bud will likely cause more pronounced distal tipping of the first molar if it has not yet erupted beyond this vertical level of the axis of rotation.[1] This pattern of thinking is very akin to that of Graber[3] who made very similar conclusions on molar distalization tipping as early as 1955. Considering these facts, Kinzinger[1] suggested that when tipping of the first molar needs to be kept to a minimum one can either wait for eruption of the second molar or apply additional torque to the first molar. These considerations are especially important with respect to stabilization as tipped teeth are known to be less stable than those that are upright.[1] Controversially, the available evidence does not sustain these theoretical assumptions.

Other reasons have been given for early distalization. Bussick at al.[13] advised that for maximum first molar distalization with minimal increase in lower anterior facial height, distalization was most effective in patients with unerupted permanent maxillary second molars. This particular study found that the amount of horizontal and angular distalization was *not* statistically different in patients with erupted and unerupted second molars (Table 2-2 and 2-3), but that patients with unerupted second molars showed a lesser increase in lower anterior face height and mandibular plane angle and a slightly lesser decrease in overbite. The associated increase in facial height related to the eruption of maxillary second molars could be quite disadvantageous for some patients as the downward and backward positioning of the chin point could exacerbate the Class II clinical appearance. [13] Interestingly, this study had the largest sample size by over 50% (Table 2-1).

The remaining article[11] reviewed in this paper suggested that the eruption stage of maxillary second molars had minimal effect on the distalization of first molars. No statistical differences were found in either linear or angular distalization measurements. Notably, only appliances that had no damage during treatment were included in the results of this study.

The effect of distalization on the maxillary third molars and the maxillary third molars affect on distalization was determined to be extremely variable by Ghosh and Nanda in 1996.[11] In their study, no patients had more than half of root formation on the third molar teeth and none of these teeth had a significant amount of horizontal or vertical change in position after distalization. Kinzinger et al[1] disagreed with these results. Furthering their "fulcrum theory" of molar tipping, these authors found that if germectomy of the wisdom teeth had previously been carried out, almost exclusively bodily distalization of both molars was possible, even when the second molar was not banded. Since only three people were present in the group of patients with previous germectomy of the wisdom teeth, the author of this paper advises caution in interpreting the results of this study with respect to the presence or absence of third molars.

While the effect of third molar presence and eruptive stage on molar distalization still seems to be controversial, it would be interesting for future studies to follow up patients who have had distalization treatment to see if there is any effect on the timing, path of eruption or possible impaction of the maxillary third molars.[11]

One problem with combining data for this systematic review is that many methodological differences were evident among the selected studies. While three studies used the pendulum appliance, one used NiTi coil springs (Table 2-1) and the mechanisms of action of these appliances are quite different. Similarly, the choice of cephalometric landmarks used for construction of the reference planes is another potential for heterogeneity of the results (Table 2-2 and 2-3).

Also, three of the four reviewed articles[9, 11, 13] retrospectively investigated cases that were treated in several different orthodontic offices, while one article[13] investigated as many as 101 cases from 13 practitioners. Differences in treatment rendered under each of these practitioners could be a potential bias in comparing results obtained from their patients. Other factors that may influence the conclusions obtained include the number of teeth used for anchorage and the anchorage setup, the amount of force applied, and the frequency of reactivation of distalizing appliances.

As pointed out by Antonarakis and Kiliaridis[20] in their 2008 review of maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion, the initial molar relationships can also affect results in this type of study. Full cusp Class II relationships often need a different amount of movement (and likely a different force and duration of time in treatment) as compared with a cusp-to-cusp relationship. The extent of pre-treatment Class II molar relationship is often not clearly stated in studies.

Also not clearly stated in the articles was the interval between time one cephalogram and the time when active mechanics were started. Should this time be longer than what is normally accepted, there is potential that the malocclusions could have changed from what was originally thought to be present at the time of treatment. This could especially be a factor for the mixed dentition cases.

For all of these reasons a meta-analysis of the data was not advisable.

Ideally, the studies used for this type of a systematic review should be randomized, controlled clinical trials with a sufficient number of subjects. Because of the small number of prospective clinical trials available on this topic, investigators had to compromise and chose to include retrospective trials also. Future studies, ideally prospective with larger sample sizes are required to add further insight into this discussion. Future studies could also focus on loss of anchorage in molar distalization treatment with respect to second and third molar eruption. This query, anterior anchorage loss, is obviously very clinically relevant but was beyond the scope of this review. In addition, the long-term stability of dental movements achieved is a critical aspect of this type of movement (especially when distal molar tipping is noted) but it too was beyond the scope of this paper. Another consideration for future research would be to compare the efficiency of distalization with respect to more clearly defined eruptive stages of the first and second molars.

It's possible that the critical timing of distalization has less to do with gaining more horizontal and less angular distalization and more to do with minimizing deleterious side effects (such as increased molar tipping, increased loss of anchorage, increased treatment duration times and increased lower anterior face height) in some selective cases.

2.5 Conclusion

The effect of maxillary second and third molar eruption stage on molar distalization, both horizontal and angular distalization, appears to be minimal. The large variability in the outcomes should be clinically considered.

2.6 References

1. Kinzinger GS, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. Am J Orthod Dentofacial Ortho. 2004;125:8-23.

2. Gianelly AA, Vaitas AS, Thomas WM, Berger OG. Distalization of molars with repelling magnets. J Clin Orhtod 1988;22:40-4.

3. Graber TM. Extraoral forces – facts and fallacies. Am J Orthod 1955;41:490-505.

4. Ten Hoeve A. Palatal bar and lip bumper in nonextraction treatment. J Clin Orthod 1985;19:272-91.

5. Jeckel N, Rakosi T. Molar distalization by intra-oral force application. Eur J Orthod 1991;3:43-6.

6. Hilgers JJ. The pendulum appliance for Class II non-compliance therapy. J Clin Orthod 1992;226:706-14.

7. Bondemark L, Kurol J, Bernhold M. Repelling magnets versus superelastic nickel-titanium coils in the simultaneous distal movement of maxillary first and second molars. Angle Orthod 1994;64:189-98.

8. Gianelly AA. Distal movement of the maxillary molars. Am J Orthod Dentofacial Orthop 1998;114:66-72.

9. Karlsson I, Bondemark L. Intraoral maxillary molar distalization – movement before and after eruption of second molars. Angle Orthod 2006;76:923-29.

10. Muse DS, Fillman MJ, Emmerson WJ, et al. Molar and incisor changes with Wilson rapid molar distalization. Am J Orthod Dentofacial Orhthop 1993;104:556-565.

11. Ghosh J, Nanda RS. Evaluation of an intraoral maxillary molar distalization technique. Am J Orthod Dentofacial Orhtop 1996;110:639-46.

12. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthod 1997;67:249-60.

13. Bussick TJ, McNamara JA Jr. Dentoalveolar and skeletal changes associated with the pendulum appliance. Am J Orhtod Dentofacial Orhtop 2000;117:333-43.

14. Joseph AA, Butchart CJ. An evaluation of the pendulum distalizing appliance. Semin Orthod 2000;6:129-25.

15. Bolla E, Muratore F, Carano A, Bowman SJ. Evaluation of maxillary molar distalization with the distal jet: a comparison with other contemporary methods. Angle Orthod 2002;72:481-494.

16. Schutze SF, Gedrange T, Zellmann MR, Harzer W. Effects of unilateral molar distalization with a modified pendulum appliance. Am J Orthod Dentofacial Orthop 2007;131:600-8.

17. Muse DS, Filman MJ, Emmerson WJ, Mitchell RD. Molar and incisor changes with Wilson rapid molar distalization. Am J Orthod Dentofacial Orthop 1993;104:556-65.

18. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthod 1997;67(4):249-260.

19. Byloff FK, Darendeliler MA, Clar E, Darendeliler A. Distal molar movement using the pendulum appliance. Part 2: The effects of maxillary molar root uprighting bends. Angle Orthod 1997;67(4):261-270.

20. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in Class II malocclusion – A systematic review. Angle Orthod 2008;78(6):1133-1140.

Chapter 3

XBow Study

3.1 Introduction

A common orthodontic treatment objective is distalization of the maxillary molars. The question of how the second molar impacts distalization of the first molar is still a matter of controversy in the literature.[1]

The rate and efficiency of molar distalization has been reported to depend on two main factors; one being the type of movement (tipping versus bodily movement) and the other being the timing of treatment (before or after the eruption of the maxillary second molars).[2] As early as 1955 Graber argued that when the second molar has not yet erupted, distalization is by tipping rather than by bodily movement.[3] Since that time, it has been theorized that the unerupted second molar acts as a fulcrum distal to the first molar, thereby increasing its tipping movement.[1] As it is distalized, the first molar is thus tipped over the germ of the second molar. According to this theory, as the second molar continues to erupt, the contact point between the molars shifts more coronally, and the tipping tendency is reduced.[1]

Over the last number of years, several other authors have agreed with Graber stating that the eruption stage of the second molar had a basic qualitative and quantitative impact on the distalization of the first molars.[1,2,4-9] Duration of therapeutic treatment has also been shown to increase if second molars have erupted and therefore distalization has been recommended before this stage has been reached.[2]

Contrary to this, there have also been many investigations that have concluded that when distalizing the first molar, the position of the second molar is of little consequency.[10-14] The authors of these studies found that there is no connection between second molar budding stage, magnitude of linear or angular molar distalization and duration of therapy.[1]

Over the years, various methods have been used to distalize maxillary molars. Popular appliances such as headgear, distal jet and pendulum/pendex appliances have been well-studied in the orthodontic literature. Since 2002, the CrossBow (or XBow) appliance has been gaining attention as a fixed Cass II corrector with the ability to distalize maxillary molars.[16] Using Forsus FRD springs bilaterally to connect a maxillary hyrax expander and a mandibular labial and lingual bow, the XBow can be used as a phase 1 appliance for Class II malocclusion in the late mixed to early permanent dentition. Dentally, one aspect of the Class II correction in patients treated with a XBow has been shown to include maxillary molar distalization.[16]

Although a number of studies have been published over the years reporting on molar distalization, controversy still exists regarding maxillary first molar distalization with respect to second molar eruption stage. The aim of the present study is therefore to investigate the efficiency of maxillary molar distalization according to the stage of dental development of the second molar, in patients treated with a Xbow appliance. Specifically, a quantitative evaluation on lateral cephalograms of horizontal, vertical and angular changes in the position of the first molar when it is distalized with the XBow appliance will be made. These changes will be analyzed and compared in the presence and absence of erupted maxillary second molars.

3.2 Material and Methods

In this study, subjects were divided into two groups. In Group 1, treatment was performed before the eruption of second molars (GR 1); in Group 2 both first and second maxillary molars were erupted at the beginning of treatment (GR 2). All patients were treated with a XBow appliance in the late-mixed to early permanent stage of dentition.

All patient records were retrospectively obtained from the private practice of Dr. D.W. Higgins (the inventor of the XBow appliance) and Dr. L Williams. All consecutively treated patients having both pretreatment (T1) and posttreatment (T2) lateral cephalograms taken between January 2005 and December 2010 were included. The inclusion criteria for all patients were: (1) the exclusive use of a XBow appliance in the late-mixed to early permanent stage of dentition with the only exception of possible placement of brackets on maxillary anterior teeth to gain extra OJ; (2) a Class II molar relationship defined by at least a molar end-to-end relationship; (3) no previous orthodontic treatment. No extractions were performed on any patients prior to or during this phase of treatment.

Radiographs were taken with the same kind of equipment (Orthoceph OC100D, General Electric) and under equivalent conditions. All cephalograms were superimposed using “best fit” superimposition on palatal plane registered at ANS. Similar to the methods of Nielsen[17], the best fit superimposition was made as the optimal fit of the hard palate with the nasal floors aligned and registered at ANS and the region between ANS and point A. All measurements were recorded in random order by one investigator at two different time points, with at least 4 weeks between the recordings. All measurements were estimated to the nearest 0.5mm or 0.5^{o}. Any measurements taken from a bilateral image were bisected. Correction for linear enlargement was made (7%) and therefore all recorded measurements were assumed based on true patient size. This enlargement factor was determined by calculating the linear difference between the nosepiece ruler on the cephalograms and a true ruler used to manually produce all measurements.

Changes in the measuring points were measured as differences between landmarks before and after treatment. The changes in position of the maxillary first molars were recorded for all patients in the horizontal, vertical and angular direction. For the horizontal change in position of the maxillary first molar, the most mesial point on the crown of the tooth was used as a reference point; for the vertical change in position of the maxillary first molar, the most mesial point of the cementoenamel junction was used as the reference point; and for the angular change in position of the maxillary first molar, the angle formed by the long axis of the tooth (created by a line connecting the furcation area and the midpoint of the crown in a mesial-distal direction) and the palatal plane was used as a reference point (Appendix A).

The molar relationship of all patients, prior to treatment, was also recorded by measuring the horizontal millimeter distance from the mesial contact point of the maxillary and mandibular first molars at T1. A measurement of 0 indicated a molar end-to-end relationship and anything above 0 indicated a more severe Cl II relationship. These measurements were used as a way to control for the potential impact of the pretreatment Class II severity on the degree of molar distalization achieved.

To detect a mean difference of 1mm in horizontal distal molar movement between GR 1 and GR 2 a required sample size was calculated for each group. This calculation was based on an alpha significance level of 0.05 and a beta of 0.1 to achieve 90% power at detecting the 1mm mean difference. Since the subjects available for the study exceeded the required number of patients for both GR 1 and GR 2, random selection was used to determine the final selection of the subjects studied.

Means and standard deviations were calculated for each outcome variable (horizontal, vertical and angular change in position of the maxillary first molar). In order to compare the mean horizontal, vertical and angular changes in molar position between the treatment groups (GR 1 vs. GR 2) and the genders, a multivariate analysis of covariance (MANCOVA) was performed with the pretreatment Cl II severity used as a covariate**.** Regression analysis was also performed to further explore any possible relationships between the predictor variables and the quantity and quality of distalization. *P* values with a significance level of $\alpha = 0.05$ were considered statistically significant.

Although previous reports on maxillary molar distalization had demonstrated no significant difference in treatment effects between males and females with respect to the quality/quantity of distalization[1], the data in this study was none-the-less analyzed to compare the effects of gender on distalization to confirm the results from these previous reports.

Intra-rater reliability was assessed using intra-class correlation coefficients (ICC) from three repeated measures of the horizontal, vertical and angular change in the position of the maxillary first molar in 20 randomly selected subjects. Each of the three sets of measurements was taken at least four weeks apart. Error measurements were also evaluated by calculating the standard deviation of the three repeated measurements for each type of movement (horizontal, vertical and angular) for 20 randomly selected subjects. For each plane of movement, the standard deviations of all 20 patients were then further averaged to get an approximation of the overall degree of land marking error.

3.3 Results

It was determined that 51 patients would be required in each group to detect a mean difference of 1mm in horizontal distal molar movement between GR 1 and GR 2 (Appendix B).

Intraclass correlation coefficient results are shown in Table 3-1.

Table 3-1: Intraclass Correlation Coefficients for Horizontal, Vertical and Angular Measurements of the Change in Position of the Maxillary First Molar in Subjects Treated with a XBow Appliance.

	Intraclass Correlation Coefficients	95% Confidence Interval
Horizontal (mm)	0.832	(0.686, 0.923)
Vertical (mm)	0.448	(0.178, 0.700)
Angular (^{o})	0.842	(0.703, 0.928)

Figures 1, 2, and 3, in Appendix C, provide a visual interpretation of these ICC results.

Intra-rater reliability was moderate to strong for both horizontal and angular changes in the position of the maxillary first molar; the measured change in the vertical position of the maxillary first molar showed poor intra-rater reliability. Given these results, a second method to measure the vertical displacement of the first molar was attempted to improve the reliability of the measurements. Specifically, the change in the distance from the occlusal surface of the molar to the palatal plane was measured for each patient. Unfortunately, the calculated ICC using this method was weaker than the ICC that was calculated using the original method of measurement. For this reason, the original method to measure the vertical change in the position of the maxillary first molar was chosen for this study (Appendix A). Despite the apparent poor reliability of the vertical measurements the data was none-the-less collected and analyzed.

The results for the horizontal, vertical and angular error measurements are presented in Table 3-2.

Table 3-2: Errors Measurements for the Horizontal, Vertical and Angular Change in Position of the Maxillary First Molar.

	Error Measurement
Horizontal	0.53mm
Vertical	0.41mm
Angular	0.87^{o}

Table 3-3 shows summary statistics of GR 1 and GR2, prior to treatment.

Table 3-3: Summary Statistics for GR1 and GR2, Prior to Treatment.

	GR 1	GR 2
Number of Female Patients	34	26
Number of Male Patients	17	25
Mean Class II Severity*	1.4mm	1.0mm

**0= Molar End/End Relationship and anything above 0 indicates a more severe Cl II malocclusion, in mm. Since Initial Cl II severity was used as a covariate in our statistical analysis, any differences between the groups in this regard were statistically accounted for*

Descriptive statistics, including mean and standard deviation for the change in each outcome variable are shown in Table 3-4. The average time of treatment was 4.7 months and the mean time between radiographs was 13.5 months. No method of retention was used between deactivating the XBow and taking the post-treatment radiographs.

Table 3-4: Mean and Standard Deviation for the Change in Horizontal, Vertical, and Angular Position of the Maxillary First Molar in Patients Treated with the XBow Appliance.

	Horizontal Change (mm)*	Vertical Change (mm)**	Angular Change (°)
GR 1			
Male (n= 17)	1.8 (1.3)	0.8 (0.5)	2.2 (2.9)
Female (n= 34)	1.7 (1.0)	0.8 (0.5)	3.6 (2.5)
Total (n = 51)	1.7 (1.1)	0.8 (0.5)	3.1 (2.7)
GR 2			
Male (n= 25)	1.6 (1.0)	1.0 (0.8)	3.5 (2.3)
Female (n= 26)	1.7 (0.9)	0.9 (0.5)	2.8 (2.3)
Total (n= 51)	1.6 (0.9)	0.9 (0.7)	3.1 (2.3)
GR 1 & GR 2 Combined			
Female (n= 60)	1.7 (1.0)	0.8 (0.5)	3.3 (2.4)
Male (n= 42)	1.6 (1.1)	0.9 (0.7)	3.0 (2.6)
Total (n= 102)	1.7 (1.0)	0.8 (0.6)	3.1 (2.5)

GR 1 *indicates patients with unerupted second molars at the start of treatment*
GR 2 *indicates patients with erupted second molars at start of treatment.*
() *= standard deviation*
**All horizontal changes were in a distal direction*
*** All vertical changes were in an Intrusive direction*

Results of the MANCOVA analysis showed that neither the treatment group (GR 1 vs. GR 2) nor the gender had a significant effect on the overall change in position of the maxillary first molar after treatment with a XBow appliance (p = 0.236 and p = 0.870 respectively) (Appendix D). As expected, initial Class II severity was a significant predictor of the amount of change in position of the maxillary first molar ($p < 0.001$).

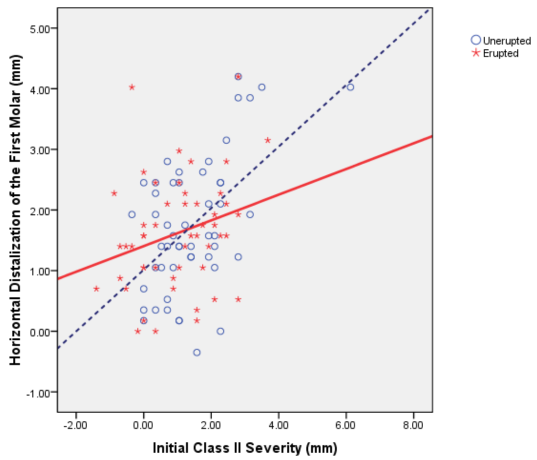
Removing gender from the model, a second MANCOVA was performed (Appendix E). Once again, the treatment group (GR 1 vs. GR 2) did not have a significant effect on the overall change in position of the maxillary first molar (p = 0.328). From this model, the partial eta squared for the initial Class II severity was 0.188, indicating that approximately 19% of the change in position of the maxillary first molar can be explained by the degree of pretreatment Class II severity.

Pairwise comparisons were made to determine the actual differences in change in the position of the first molar between the two treatment groups for all three directions of movement. These mean differences between GR 1 and GR 2 are highlighted in Appendix F.

To further explore the significant relationship between the initial Class II severity and the quantity and quality of distalization, linear regression analysis was applied to evaluate any trends that may be present. Similar to the MANCOVA results, the regression analysis also showed that the eruption stage of the second molar did not have a significant effect on the horizontal distalization of the maxillary first molar ($p = 0.155$). The interaction between the Class II severity and the eruption stage did however show a generalized trend ($p = 0.069$) that as the Class II severity initially increased beyond a molar end-to-end relationship, the subjects with erupted second molars had greater horizontal distalization than subjects with unerupted second molars (Figure 3-1). This effect continued up to the point that the Class II was approximately 2mm beyond a molar end-to-end relationship at which point the trend reversed and the subjects with unerupted second molars showed a greater amount of distalization. Approximately 20% of the variation in the horizontal distalization of the first molar can be explained by this regression model ($R^2 = 0.198$).

Figure 3-1: Horizontal Distalization of the Maxillary First Molar as a Function of Pretreatment Class II Severity, in Patients with Erupted and Unerupted Second Molar

Erupted: $\beta_0 + \beta_1 + (\beta_2 + \beta_3)$(Initial Cl II severity
Unerupted: $\beta_0 + \beta_2$ (Initial Cl II severity)

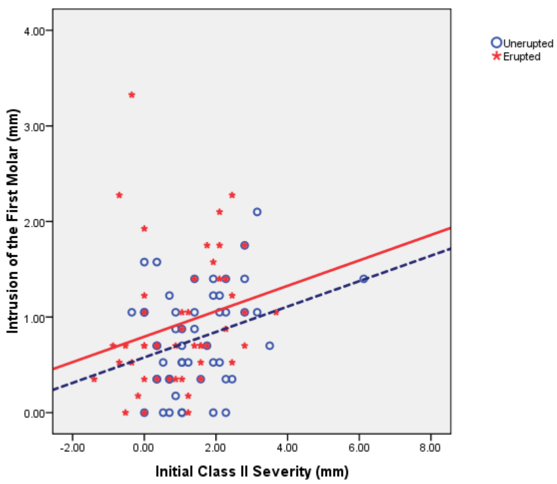


----- = GR 1 (Unerupted Maxillary Second Molars)
_____= GR 2 (Erupted Maxillary Second Molars)

For the vertical change in the position of the first molar it appeared that the subjects with erupted second molars consistently had more intrusion (approximately 0.2mm) than subjects with unerupted second molars (Figure 3-2). This effect was not statistically significant ($p = 0.174$) and was below the measured 0.41mm of measurement error. Approximately 8% of the variation in the vertical movement of the first molar can be explained by this regression model ($R^2 = 0.08$)

Figure 3-2: Vertical Change (Intrusion) in the Position of the Maxillary First Molar as a Function of Pretreatment Class II Severity, in Patients with Erupted and Unerupted Second Molars

Erupted: $(\beta_0 + \beta_1) + (\beta_2)$(Initial Cl II severity)
Unerupted: $\beta_0 + \beta_2$ (Initial Cl II severity)

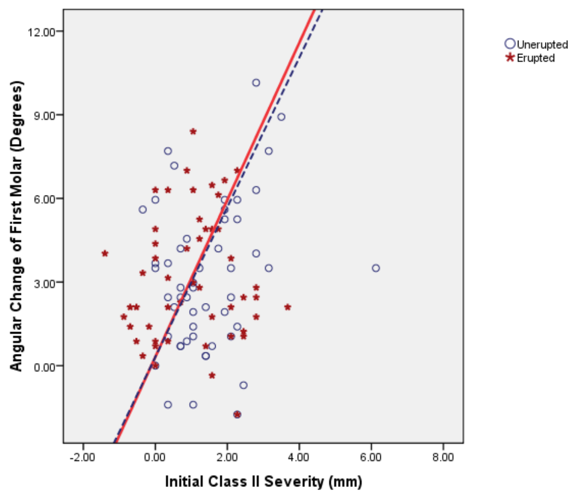


----- = GR 1 (Unerupted Maxillary Second Molars)
_____= GR 2 (Erupted Maxillary Second Molars)

No difference was present between subjects with erupted and unerupted second molars with respect to the angular change in position of the first molar (Figure 3-3).

Figure 3-3: Angular Change in the Position of the Maxillary First Molar as a Function of Pretreatment Class II Severity, in Patients with Erupted and Unerupted Second Molars

Erupted: $(\beta_0 + \beta_1) + (\beta_2)$(Initial Cl II severity)
Unerupted: $\beta_0 + \beta_2$ (Initial Cl II severity)



----- = GR 1 (Unerupted Maxillary Second Molars)
_____= GR 2 (Erupted Maxillary Second Molars)

3.4 Discussion

The main findings of this study were that the presence of erupted versus unerupted second molars (GR1 vs. GR2) and the gender of the patients did not have an effect on the amount or direction of distalization of the maxillary first molar.

The measured change in the vertical position of the maxillary first molar was less than the change evident in either the horizontal or angular direction (Table 3-3). Vertical change also showed poor intra-rater reliability in measurement (Table 3-1) and thus any conclusions based on vertical change should be made with caution. One possible explanation for the minimal change in the vertical position of the molars could be based on the chosen method of superimposition. Nielsen[17] compared the traditional best fit method of cephalogram superimposition with both the implant and the “structural method” (an anatomic method in which the films were registered on the anterior surface of the zygomatic process of the maxilla) and found that the displacement of the selected landmarks in both vertical and horizontal directions varied greatly depending on the method used for superimposing the head films. The results of his study were that the best fit superimposition showed the smallest displacement of both the skeletal and dental landmarks in the vertical direction.[17] Nielsen postulated that the vertical displacement of the dental landmarks were underestimated (by as much as 30% for the landmarks representing the maxillary first molars) as a result of bony modeling of the maxilla due to continuous downward modeling of the nasal floor. In addition to this bony modeling, continued eruption of the subject's teeth also occurred throughout our study period. Therefore, as the alveolar processes were positioned more downward and forward it is possible that the amount of intrusion in this study was actually underestimated. Similarly, some mesial migration of the dentition may have occurred between the time that the T1 cephalogram was actually taken and the time that the XBow was actually inserted and activated. Group 1, where the second molars had not yet erupted, may have experienced more mesial migration of the maxillary first molar than Group 2. This would especially be true if the maxillary second premolar had not yet erupted. In this way, the actual amount of distalization may have also been underestimated – especially for the patients in Group 1.

The findings of this current study are similar to the findings from previous authors[2-6] that concluded that the position of the second molar when distalizing the first molar is of little significance. Based on these results, the idea that the unerupted second molar acts as a fulcrum and causes more distal tipping of the distalizing first molar is not supported.

All patients in this study were consecutively treated with a XBow appliance. All these treated patients were included in the total sample size, from which random selection was used to choose the final sample of patients. No lost-to-follow up patient was identified therefore no intention-to-treat analysis was required in this study. In other words, all patients that started treatment continued to completion. Importantly, results from this study should be taken as accurate only for patients treated with the Xbow appliance.

With respect to maxillary molar distalization, results from this study are similar to previous results found with the Herbst appliance. A systematic review of patients treated with splint-type Herbst appliances found that the molars moved distally approximately 1.5 to 5.4mm.[19] Although the range of distalization with the Herbst has reported higher values than was observed in this XBow study, the XBow treatment protocol allowed for several months of relapse prior to measuring the total distalization. This difference in study design could explain the higher values of distalization found with the Herbst.

There are several limitations that exist in this study. As previously stated, all data collected was done so retrospectively. Ideally, a randomized controlled clinic trail is the preferred method to accurately assess the efficiency of molar distalization between the two groups. Designing a study in this way would, however, require randomly designating certain patients to wait until their second molars were erupted before starting treatment – this experimental design could, therefore, have ethical considerations. As the later group (those waiting for second molar eruption) would have to wait some time before treatment, there is a risk that new malocclusions could develop and therefore the two treatment groups would not be comparable prior to all treatment.

All patients were in the late-mixed to early permanent stage of dentition and therefore no attempt was made to compare the efficiency of distalization among adult patients. Also, based on the fact that the selection of the patients (who were recruited from a specific Orthodontic Clinic) and the allocation of the patients to a particular group (who were allocated to a group based on the eruption of their teeth) were not random in nature, no causal inference or inference to the general population can be made from this study.

Pretreatment Class II severity, which was used as a covariate in our statistical analysis, was measured on cephalograms. Ideally, any future study based on this topic should also access patient models pre and post treatment to potentially allow more accurate measurements of molar classification. These records would also allow an assessment of potential rotations of the first molar during treatment.

Recent advances in the application of three-dimensional analysis have made more accurate assessment of tooth positional changes a reality.[20] Mavropoulos et al.[21], although only studying ten subjects, showed that 3D cast analysis was associated with significantly less variation and error than cephalometric assessment. Future studies that take advantage of these and other 3D analyses could potentially provide more insight into this topic and reduce the significant error associated with measuring small linear distances on conventional two-dimensional radiographs and cast models.

This study did not measure mandibular plane angle prior to treatment. Future studies that investigate the effects of the eruption stage of the second molars on distalization efficiency could measure pre and post treatment mandibular plane angle to assess any potential differences in face height based on eruption stage.

Although a number of studies have been published over the years reporting on maxillary molar distalization, some controversy still exists regarding upper molar distalization with respect to second molar eruption stage. Clinically, practitioners may tend to perceive that distalization is a more valid treatment option in younger patients before the second molars have erupted. More recently however, this theory seems to be more anecdotal than evidence based. More studies are required to help confirm the idea that there may be no optimal time to treat when molar distalization is a treatment objective.

3.5 Conclusion

When distalizing maxillary first molars with a Xbow appliance, there is no difference in the quantity or quality of distalization in patients with erupted and unerupted maxillary second molars. We suggest that based on these results that there is no optimal time to treat patients in the mid-mixed to early permanent stage of dentition with a XBow appliance when distalization is the main treatment objective.

3.6 References

1. Kinzinger GS, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. Am J Orthod Dentofacial Orthop 2004;125:8-23.

2. Gianelly AA, Vaitas AS, Thomas WM, Berger OG. Distalization of molars with repelling magnets. J Clin Orhtod 1988;22:40

3. Graber TM. Extraoral forces – facts and fallacies. Am J Orthod 1955;41:490-505.

4. Ten Hoeve A. Palatal bar and lip bumper in nonextraction treatment. J Clin Orthod 1985;19:272-91.

5. Jeckel N, Rakosi T. Molar distalization by intra-oral force application. Eur J Orthod 1991;3:43-6.

6. Hilgers JJ. The pendulum appliance for Class II non-compliance therapy. J Clin Orthod 1992;226:706-14.

7. Bondemark L, Kurol J, Bernhold M. Repelling magnets versus superelastic nickel-titanium coils in the simultaneous distal movement of maxillary first and second molars. Angle Orthod 1994;64:189-98.

8. Gianelly AA. Distal movement of the maxillary molars. Am J Orthod Dentofacial Orthop 1998;114:66-72.

9. Karlsson I, Bondemark L. Intraoral maxillary molar distalization – movement before and after eruption of second molars. Angle Orthod 2006;76:923-29.

10. Muse DS, Fillman MJ, Emmerson WJ, et al. Molar and incisor changes with Wilson rapid molar distalization. Am J Orthod Dentofacial Orhthop 1993;104:556-565.

11. Ghosh J, Nanda RS. Evaluation of an intraoral maxillary molar distalization technique. Am J Orthod Dentofacial Orhtop 1996;110:639-46.

12. Byloff FK, Darendeliler MA. Distal molar movement using the pendulum appliance. Part 1: Clinical and radiological evaluation. Angle Orthod 1997;67:249-60.

13. Bussick TJ, McNamara JA Jr. Dentoalveolar and skeletal changes associated with the pendulum appliance. Am J Orhtod Dentofacial Orhtop 2000;117:333-43.

14. Joseph AA, Butchart CJ. An evaluation of the pendulum distalizing appliance. Semin Orthod 2000;6:129-25.

15. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment: A cephalometric investigation. A J Orthod 1982;82(2)104-113.

16. Flores-Mir C, Barnett G, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009;136:822-832.

17. Nielsen I. Maxillary superimposition: A comparison of three methods for cephalometric evaluation of growth and treatment change. Am J Orthod Dentofac Orthop 1989;95(5):422-431.

18. Cook AH, Sellke TA, BeGole EA: The variability and reliability of two maxillary and mandibular superimposition techniques. Part II. Am J Orthod Dentofac Orthop 1994;106(5):463-471.

19. Flores-Mir C, Ayeh A, Goswani A, Charkhandeh S. Skeletal and Dental Changes in Class II division 1 Malocclusions Treated with Splint-Type Herbst Appliances. Angle Orthod 2007;77(2):376-381.

20. Kuroda T, Motohashi N, Tominanga R, Iwata K. Three-dimensional dental cast analyzing system using laser scanning. Am J Orthod Dentofacial Orthop 1996;110:365-369.

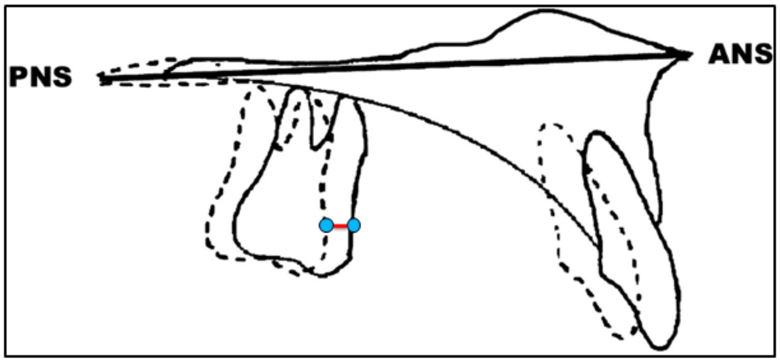
21. Mavropoulos A, Karamouzos A, Kiliaridis S, Papadopoulos M. Efficiency of Noncompliance Simultaneous First and Second Upper Molar Distalization: A Three-dimensional Tooth Movement Analysis. Angle Orthod 2005;75(4):532-539.

3.7 Appendix to Chapter 3

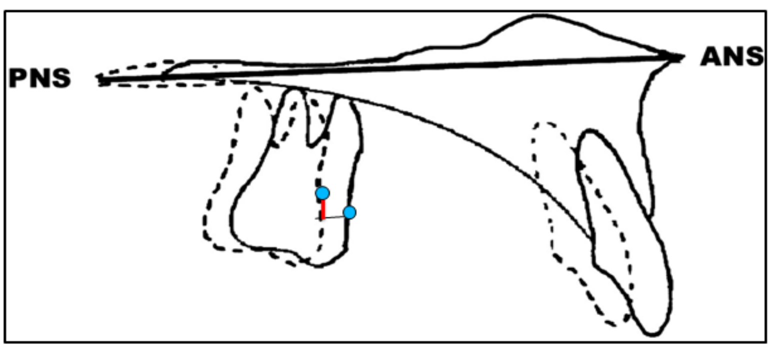
3.7.1 Appendix A:

Cephalometric Superimposition of Patients Treated with the XBow Appliance to Analyze the Horizontal, Vertical and Angular changes in the Position of the Maxillary First Molar. (All superimpositions were based on palatal plane: ANS-PNS)

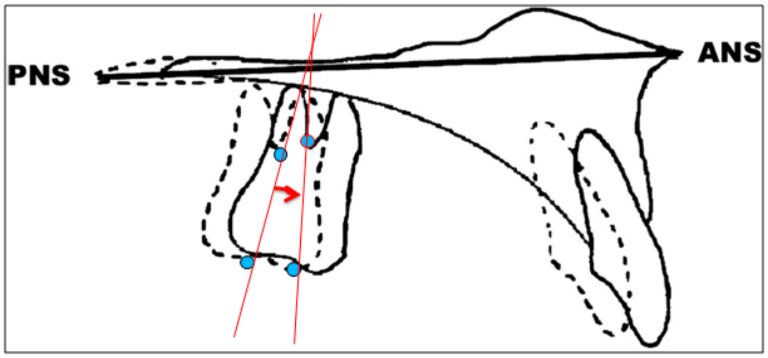
a) Diagrammatic representation of the calculation of the horizontal change in the maxillary first molar position (red line mm distance). The most mesial point on the crown of the tooth was used as the measuring point.



b) Diagrammatic representation of the calculation of the vertical change in the maxillary first molar position (red line mm distance). The cementoenamel junction was used as the measuring point.



c) Diagrammatic representation of the calculation of the angular change in the maxillary first molar position (red angle in degrees). The angle formed by the long axis of the tooth and the palatal plane was used as the measuring point.


PNS
ANS

3.7.2 Appendix B:

Sample size calculation

Using:
α = Level of acceptability of a false positive result (0.05)
β = Level of acceptability of a false negative result (0.10)

S_1 = 1.64 standard deviation of **horizontal** distance of molar distalization, based on the average of three pilot trial measurements of ten randomly selected patients for GR 1
S_2 = 1.45 standard deviation of **horizontal** distance of molar distalization, based on the average of three pilot trial measurements of ten randomly selected patients for GR 2
Δ = 1 based on clinical significance of molar distalization

$$n = \frac{(S_1^2 + S_2^2)(Z_{1-\alpha/2} + Z_{1-\beta})^2}{\Delta^2}$$

$$n = \frac{(1.64^2 + 1.45^2)(1.96 + 1.28)^2}{1^2}$$

$$n = \frac{(4.79)(10.5)}{1}$$

n = 51 per group

3.7.3 Appendix C:

Figure 1: Visual Interpretation of ICC Results for the Change in Horizontal Position of the Maxillary First Molar (mm measurements)

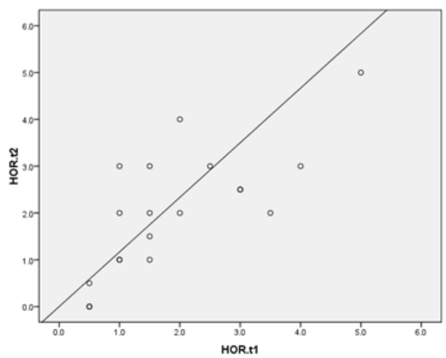


Figure 2: Visual Interpretation of ICC Results for the Change in Vertical Position of the Maxillary First Molar (mm measurements)

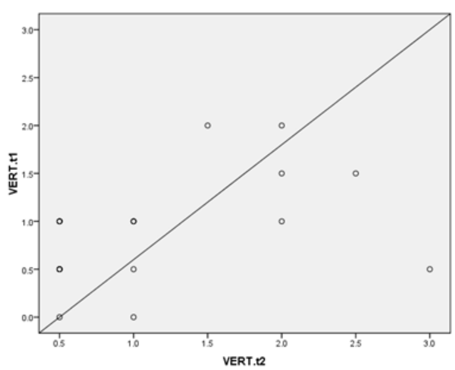
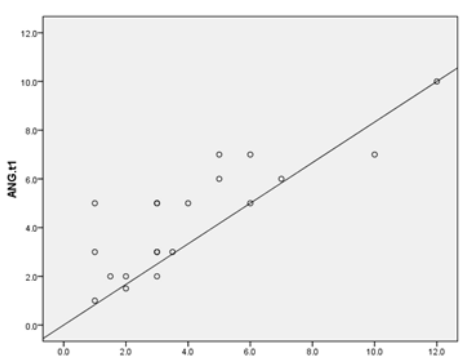


Figure 3: Visual Interpretation of ICC Results for the Change in Angular Position of the Maxillary First Molar (^{o} measurements)



3.7.4 Appendix D:

Table 1: MANCOVA Results for the Overall Change in Position of the Maxillary First Molar after Treatment with a XBow appliance.

Factor	Wilk's Lambda	F	p-value
Treatment Group (GR 1 vs. GR 2)	0.956	1.442	0.236
Gender (Male vs. Female)	0.992	0.238	0.870
Initial Class II severity (mm)	0.810	7.361	**‹0.001***
Interaction between Treatment Group and Gender	0.931	2.315	0.081

GR 1 indicates patients with unerupted second molars at the start of treatment, GR 2 indicates patients with erupted second molars at start of treatment.
**statistically significant at p <0.05 significance*
F = F statistic

3.7.5 Appendix E:

Table 1: MANCOVA Results for the Change in Position of the Maxillary First Molar after Treatment with a XBow appliance with “Gender” Removed from the Model.

Factor	Wilk’s Lambda	F	p-value	Partial Eta Squared
Treatment Group (GR 1 vs. GR 2)	0.965	1.16	0.328	0.035
Initial Class II severity (mm)	0.812	7.4	**‹0.001***	**0.188**

GR 1 indicates patients with unerupted second molars at the start of treatment, GR 2 indicates patients with erupted second molars at start of treatment.
**statistically significant at p <0.05 significance*
F = F statistic

3.7.6 Appendix F:

Table 1: Average Horizontal, Vertical and Angular Change in Position of the Maxillary First Molar in Patients Treated with a XBow Appliance

	GR 1 (n = 51)		**GR 2 (n = 51)**		**Mean Difference***
	Mean	**SD**	**Mean**	**SD**	***p* *[CI]***
Avg. Horizontal Change (mm)	1.7	1.1	1.6	0.9	**-0.030** *p*=0.874 [-0.410, 0.349]
Avg. Vertical Change (mm)	0.8	0.5	0.9	0.7	**-0.215** *p*=0.074 [-0.021, 0.451]
Avg. Angular Change (^{o})	3.1	2.7	3.1	2.3	**-0.133** *p*=0.791 [-1.127, 0.861]

GR 1 indicates patients with unerupted second molars at the start of treatment, GR 2 indicates patients with erupted second molars at start of treatment.
** = One-way ANCOVA results for effect of treatment group on first molar change in position, covariate = initial Cl II severity*
p= probability value,
[]= Confidence interval
All horizontal changes were in a distal direction
All vertical changes were in an Intrusive direction
-=greater change in position for the group with erupted second molars (GR 2)

Chapter 4
General Discussion and Recommendations

4.1 General Discussion

This retrospective investigation was conducted to compare the efficiency of molar distalization in patients with erupted and unerupted maxillary second molars. All patients were treated with a XBow appliance in the late-mixed to early-permanent stage of dentition. From the data, it appears that the presence of erupted versus unerupted second molars did not have an effect on the amount or direction of distalization of the maxillary first molar.

The results of this study are consistent with the findings from other investigations[1-3] that concluded that the position of the second molar when distalizing the first molar is of little significance. Opposing the results of this study, a 2006 investigation by Karlsson and Bondemark[4] found a statistically significant difference in the amount of maxillary first molar horizontal distalization with respect to the stage of eruption of the second molar.

4.2 Limitations

There are several limitations that exist in this study. Due to the fact that all data was collected retrospectively, caution should be used in interpreting the results from this study as a true causal inference can only be made based on randomized controlled clinical trials.

Records assessed in this study did not include patient models. Pretreatment Class II severity, used as a covariate in our statistical analysis, was measured from two-dimensional radiographs. Perhaps a more accurate recording of molar classification could be made from cast or digital models of all patients, taken at both T1 and T2. At the very least, models could be used as a verification tool for various measurements taken from the radiographs.

No attempt was made to measure or compare loss of anchorage, increase in anterior face height, or changes in molar rotation in the patients treated in this study.

Since only the XBow appliance was used in this study, the results stated herein are only suggestive of outcomes maintained in patients treated with this specific appliance. Similarly, no adults were included in this study and therefore all conclusions are only valid for patients in the late-mixed to early permanent stage of dentition.

More than one clinician was involved in the care provided to the patients of this study. Although the protocol of treatment was said to be the same for both practitioners, there is potential that differences in outcomes could be present based on which particular care provider was involved in treatment.

4.3 Future Research

Ideally, a randomized controlled trial would be implemented to provide more insight into the efficiency of molar distalization in patients with erupted and unerupted maxillary second molars. Any ethical considerations in having patients wait for treatment until the second molars are erupted should be considered in the study design. Having only one person provide the care for all patients in the study would also eliminate any potential bias that could be present from having more than one clinician involved.

More patient records, such as stone or digital models and three-dimensional radiographs, should be considered for any future studies conducted on this topic. Potentially, more accurate diagnosis could be made from recent advances in three-dimensional analysis.[5] New outcomes, such as molar rotations, could also be evaluated with three-dimensional records.

To provide more information on loss of anchorage and change in anterior face height, more measurements (such as premolar and incisor position in all dimensions and mandibular plane angle) could be studied. Longer follow-up studies that assess long-term stability of the distalization mechanics could also shed light on this topic. Lastly, another consideration for future research would be to compare the efficiency of distalization with respect to more clearly defined eruptive stages of the first and second molars.

4.4 References

1. Kinzinger GS, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. Am J Orthod Dentofacial Ortho. 2004;125:8-23.

2. Ghosh J, Nanda RS. Evaluation of an intraoral maxillary molar distalization technique. Am J Orthod Dentofacial Orhtop 1996;110:639-46.

3. Bussick TJ, McNamara JA Jr. Dentoalveolar and skeletal changes associated with the pendulum appliance. Am J Orhtod Dentofacial Orhtop 2000;117:333-43.

4. Karlsson I, Bondemark L. Intraoral maxillary molar distalization – movement before and after eruption of second molars. Angle Orthod 2006;76:923-29.

5. Kuroda T, Motohashi N, Tominanga R, Iwata K. Three-dimensional dental cast analyzing system using laser scanning. Am J Orthod Dentofacial Orthop 1996;110:365-369.