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Comparison of Orthopedic and Orthodontic Treatment Outcomes Utilizing Cervical Headgear or Wilson Bimetric Distalizing Arch™

by

Corey James Low ©

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Comparison of Orthopedic and Orthodontic Treatment Outcomes Utilizing Cervical Headgear or Wilson Bimetric Distalizing Arch™** by Corey James Low in partial fulfillment of the requirements for the degree of Master of Science in Orthodontics.

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Abstract

The purpose of this research was to compare the orthopedic and orthodontic treatment outcomes of two types of class II molar correction appliances that were used in conjunction with a second phase of full fixed appliance therapy. The cervical headgear appliance and the Wilson Bimetric Distalizing Arch™ appliance were the class II molar correction appliances that were utilized and compared. In order to do so, a pilot project was completed first. For the pilot project four patients were selected. Their pre – and post – orthodontic lateral cephalometric radiographs were traced repeatedly (five times for each radiograph). The tracings were then superimposed and measurements were carried out to determine the intra – examiner measurement replication error. A Power analysis was then completed to determine the sample size required for an investigation that would be statistically significant. A sample size of thirty – eight patients or greater (nineteen per group or greater) was the determined approximate sample size.

The predetermined number of patients was selected from a patient base of a single practitioner whose records were all produced by a private imaging facility. Cephalometric analysis and superimposition measurements were then carried out. The data was subjected to statistical analysis (Student t – test) and interpreted. It was determined that there was no significant difference between the two groups with respect to orthopedic affects of treatment. There were statistically significant differences between the two groups with respect to vertical molar position change.

There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.

Niccolo Machiavelli (1469 – 1527)

Dedications

To Bernadette M. Jappell (1984 – 1998), who showed us all the true meaning of life;

And to my wife, Shannon M.F. Low, whose love, encouragement, understanding, and support have shown no boundaries.

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Chapter One

Introduction

And

Literature Review

1.1 Introduction

The prevalence of Angle's class II malocclusion has been studied as part of epidemiological surveys that have attempted to quantify the full lateral cephalometric radiograph prevalence of malocclusion.[1] It has been estimated that approximately 15 % to 20 % of children develop Angle's class II malocclusion.[1] Therefore, many patients that present to orthodontists for treatment have class II malocclusions. Treatment modalities that correct this type of malocclusion are commonly required and utilized by orthodontists. As a result, many methods have been proposed for the correction of the class II malocclusion. These include techniques that distalize maxillary molars to correct an Angle's class II dental relationship as well as techniques that attempt to modify class II skeletal relationships. Each method has its advantages and disadvantages; proponents and opponents.

According to McNamara, extraoral traction is the most common treatment for Angle's class II malocclusions.[2] Although Kingsley and Angle had used extraoral force,[1] it was not until Kloehn's work that the use of extraoral force became widely used in North America.[1,2] Since then, numerous studies were completed demonstrating the efficacy of extraoral traction for the correction of class II malocclusions.[4-6] However, the recent, long term, prospective study by Tulloch *et al* has questioned the cervical headgear's efficacy in the treatment of class II malocclusions.[7,8] As well, those that oppose headgear treatment list cooperation, molar tipping, second molar impaction, cervical damage, and resulting vertical growth as drawbacks.[4,5,9] In addition, McNamara studied the components of class II malocclusions cephalometrically.[10] He found that the majority of these individuals had normal maxillary relationships. The question is then raised that if maxillary relationships are normal, why would treatment consist of restriction of normal skeletal growth of the maxilla?

Other treatment modalities have been proposed for correction of the class II malocclusion. These include functional appliances and fixed appliances. One such fixed appliance is the Wilson Bimetric Distalizing Arch™.[11-15] This appliance consisted of an anterior arch of 0.022 inch Truchrome wire combined with a 0.040 inch distal section with intermaxillary hooks and omega adjustable stops.[14] An 0.010 inch x 0.045 inch coil spring 5mm in length is used to produce the distalizing force (see Figure 1 – 1, page 43). [14] The second component of this appliance is a mandibular holding arch, to which class II elastics are attached. These elastics are used with a very specific schedule of weights and times (see Appendix 1 – 1, page 42). W. L. Wilson and R. C. Wilson contend that this appliance arrangement will distalize molars "in a matter of weeks"[15], efficiently[15], and with minimal side effects[15]. In addition, extraoral appliances are not required.

If this appliance is as effective as Wilson and Wilson claim[15], then it would be a useful addition to the orthodontist's class II treatment armamentarium. Unfortunately, data regarding the efficacy of this appliance is limited. Other than the research conducted by Muse *et al*[16], the information regarding the efficacy of the Wilson Bimetric Distalizing Arch™ is in the form of anecdotal reports.[51] Therefore, it would be prudent to conduct research regarding this appliance to develop a data base from which an evidence – based decision could be made regarding its utility in the treatment of Class II malocclusions. In order to do this, an analysis of lateral cephalometric radiographs and superimpositions would be required that could determine and differentiate between treatment effects and growth effects. In addition, it would be useful to compare its effects to another form of class II treatment.

1.2 Statement of the Problem

The primary goal of the orthodontist is to provide efficient and timely treatment for patients using treatment modalities that have been thoroughly researched and deemed effective. Many times treatment modalities gain popularity based on anecdotal evidence, or widespread use becomes based on the most recent orthodontic 'trend'. Class II treatment, specifically, continues to be bombarded with new techniques that are promoted as the class II panacea.[2,9,11-15,29-41] Therefore, any time a new treatment modality has been developed, it should be thoroughly evaluated prior to its implementation. The Wilson Bimetric Distalizing Arch™ that was developed by Wilson, was promoted as an appliance that could rapidly and efficiently distalize molars with minimal adverse effects. [13,14] Unfortunately, there did not appear to be any solid research derived evidence to support such claims. Muse *et al* studied this appliance and concluded that molar distalization was possible using this appliance but that it was variable in nature and accomplished, in part, by molar tipping and, in part, by mesial movement of the lower molar.[16] They suspected that, long term, the molar distalization that was accomplished would have a tendency to relapse.[16]

In most instances, once molar correction has been accomplished orthodontic treatment is not complete. Usually a second phase of treatment with full fixed appliance therapy is required to complete alignment, etc.. Therefore, successful correction of a class II malocclusion should not be evaluated until all orthodontic treatment is complete. This would enable an assessment of the relapse potential of the molar distalization and allow for a comparison to be made with other class II treatment modalities. Research into the treatment effects of the Wilson Bimetric Distalizing Arch™ to this point have focused on the initial phase of treatment and have not considered either the possible orthopedic effects or the long term outcomes.[16,17] In addition, the sample sizes have been small and have not been compared to other class II treatment modalities.[16,17] Therefore, conducting research that would study complete orthodontic treatment which incorporated the Wilson Bimetric Distalizing Arch™ would be beneficial in determining its usefulness as an alternative to more conventional types of class II treatment modalities. Also, if this appliance was compared to an appliance that had been previously deemed effective, then the clinician would have a reference with which to compare it to.

1.3 Purpose

The purpose of this retrospective study is to examine the orthopedic and orthodontic treatment effects of the Wilson Bimetric Distalizing Arch™ and to compare these results to the more conventional class II treatment modality of cervical headgear. This will be accomplished through analysis of lateral cephalometric radiographs and tracing superimpositions. Analysis of the lateral cephalometric radiographs will determine the initial skeletal, molar, and incisor relationships while the superimposition of the tracings will aid in the determination of the orthopedic and orthodontic treatment effects.

The results of this investigation will provide useful information regarding the effectiveness of the Wilson Bimetric Distalizing Arch™ as compared to the cervical headgear appliance. This will provide clinicians with information on which an informed decision can be made regarding whether or not to incorporate this appliance into their repertoire.

1.4 Research Questions

1. Is there an orthopedic effect associated with the use of the Wilson Bimetric Distalizing Arch?

2. Is the amount of orthopedic effect produced by the Wilson Bimetric Distalizing Arch similar to the orthopedic effect of the cervical headgear/bite plate appliance?

3. Is there orthodontic movement of the maxillary first molars in a horizontal direction when the Wilson Bimetric Distalizing Arch is utilized?

4. Is there orthodontic movement of the maxillary first molar in a vertical direction when the Wilson Bimetric Distalizing Arch is utilized?

5. Is there orthodontic movement of the mandibular first molars in a horizontal direction when the Wilson Bimetric Distalizing Arch is utilized?

6. Is there orthodontic movement of the mandibular first molar in a vertical direction when the Wilson Bimetric Distalizing Arch is utilized?

7. Is the amount of orthodontic movement of the maxillary and mandibular first molars in a horizontal or vertical direction similar to the amount of movement seen with cervical headgear/bite plate therapy?

8. Is there linear or angular orthodontic movement of the maxillary incisors when the Wilson Bimetric Distalizing Arch is utilized?

9. Is there linear or angular orthodontic movement of the mandibular incisors when the Wilson Bimetric Distalizing Arch is utilized?

10. Is the amount of linear or angular orthodontic movement of the maxillary and mandibular incisors similar to the amount of movement seen with the cervical headgear/bite plate therapy?

Note: The treatment effects of these two treatment modalities will be evaluated after a second phase of full fixed appliance therapy.

1.5 Null Hypotheses

1. There is not a significant orthopedic effect associated with the use of the Wilson Bimetric Distalizing Arch.

2. There is no significant difference between the orthopedic effect produced by the Wilson Bimetric Distalizing Arch and that produced by the cervical headgear and biteplate.

3. There is not a significant amount of orthodontic movement of the maxillary first molars in a horizontal direction when the Wilson Bimetric Distalizing Arch is utilized.

4. There is not a significant amount of orthodontic movement of the maxillary first molar in a vertical direction when the Wilson Bimetric Distalizing Arch is utilized.

5. There is not a significant amount of orthodontic movement of the mandibular first molars in a horizontal direction when the Wilson Bimetric Distalizing Arch is utilized.

6. There is not a significant amount of orthodontic movement of the mandibular first molar in a vertical direction when the Wilson Bimetric Distalizing Arch is utilized.

7. There is no significant difference between the amount of orthodontic movement of the maxillary and mandibular first molars in a horizontal or vertical direction between the Wilson Bimetric Distalizing Arch and the cervical headgear and biteplate treatment.

8. There is not a significant amount of linear or angular orthodontic movement of the maxillary incisors when the Wilson Bimetric Distalizing Arch is utilized?

9. There is not a significant amount of linear or angular orthodontic movement of the mandibular incisors when the Wilson Bimetric Distalizing Arch is utilized?

10. There is no significant difference between the amount of linear or angular orthodontic movement of the maxillary and mandibular incisors between the Wilson Bimetric Distalizing Arch and the cervical headgear and biteplate treatment.

Note: The treatment effects of these two treatment modalities will be evaluated after a second phase of full fixed appliance therapy.

1.6 Rewiew of Literature

1.6.1 Introduction

Between 1980 and 1990 over 130 article have been published that have investigated at least 14 different treatment modalities for class II malocclusions.[7] Many more have been written since.[7-9,16,22,28,30,32-41] Even with this large amount of information, no consensus has yet been reached with respect to the treatment timing or treatment modalities for patients with class II malocclusions. The methodologies that are used to evaluate the effectiveness of a class II treatment many times are not consistent. In fact, the uncertainty about the benefit of early treatment for class II malocclusions continues.[7] Therefore, the purpose of this literature review is to provide background information on the different types of class II treatment modalities available. In addition, discussion will be completed regarding the proposed mechanism by which correction of the class II malocclusion occurs for each type of treatment modality. Also, a review of the literature pertaining to cephalometric landmark reliability and lateral cephalometric analysis and superimposition methodologies will be presented.

1.6.2 Class II Treatment Modalities

A) Introduction

Class II malocclusions can be the result of skeletal discrepancies, dentoalveolar discrepancies, or a combination thereof. Skeletal discrepancies include maxillary protrusion, mandibular retrusion or both. Similarly, dental discrepancies can be the result of an anteriorly displaced maxillary dentoalveolar complex, a posteriorly displaced mandibular dentoalveolar complex, or a combination of the two. The literature is riddled with a myriad of treatment modalities for class II malocclusions.[7-9,16,22,28,30,32-41] Certain modalities attempt to correct the underlying skeletal imbalance through growth modification, while other modalities focus their treatment on a dental camouflage of the jaw discepancy.[7] This discussion will divide the different class II treatment modalities into categories based roughly on their description. These categories include extraoral traction, functional appliances and fixed molar distalizing appliances. The first two categories attempt growth modification, whereas the third group tends to attempt correction of the dental malrelationship.

B) Extraoral Traction

During the past 30 years, the most frequent approach to growth modification in the United States has been extraoral force (headgear).[7] In fact, McNamara believes that extraoral traction is the most common treatment for Angle's class II malocclusions.[2] Although Kingsley and Angle had used extraoral force, it was not until Kloehn's work that the use of extraoral force became widely used in North America.[1,3] Since then, numerous studies have been completed that have demonstrated the efficacy of extraoral traction for the correction of class II malocclusions.[4-6] Those that oppose this type of treatment list cooperation, molar tipping, second molar impaction, cervical damage, and resulting vertical growth as drawbacks.[4,5,9]

Graber investigated the use of extraoral force for the treatment of class II malocclusions.[4] He used a cervical headgear to treat 100 patients in hopes of answering the following five questions:

1. Can headgear alone establish normal tooth interdigitation, overbite, overjet and skeletal relationships?
2. What is the mechanism by which correction of class II malocclusion is corrected?
3. What effect does cervical headgear treatment have on the position of maxillary incisors?
4. Do maxillary second and third molars become impacted when cervical headgear treatment is conducted?
5. Does extraoral traction allow for accentuated mandibular growth?

Evaluation of the treatment outcomes was completed through analysis of dental casts and lateral cephalometric radiographs.

With respect to normalization of the class II malocclusion, the answer was an unqualified “sometimes”. Treatment of deciduous class II malocclusions was generally unsuccessful.[4] Only three of the fourteen patients that were treated in the deciduous dentition demonstrated normal dental relationships and reduced overbite and overjet relationships. Graber did emphasize however, that eleven of the fourteen patients did improve.[4] The patients that were treated in the mixed dentition stage of dental development demonstrated a much better response to headgear treatment. Graber noted that as the basal relationship, overbite and overjet deviated more from normal, the treatment results were less satisfactory.[4] Effectiveness of headgear treatment for those patients that were treated in the permanent dentition correlated closely to the presence or absence of the pubertal growth spurt.[4] Thus, Graber concludes that "correction of marked class II...malocclusions *can* [his emphasis] be accomplished, provided there is a favorable, combination of factors (growth and development, patient cooperation, etc.)."[4]

Graber believes that alteration of the apical base relationship through influence of maxillary alveolar growth is the mechanism by which headgear produces correction of the class II malocclusion.[4] Graber contends that in most instances the headgear does not distalize the molars but rather prevents them from being carried forward with the downward and forward growth of the maxilla.[4] He also suggests that absolute molar distalization can occur in some cases, although removal of maxillary second molars will make this more predictable.[4]

With respect to questions three, four, and five, Graber unequivocally answers them as follows. Lingual tipping of maxillary incisors does occur.[4] In a small percentage of cases, second molars can become impacted.[4] Headgear treatment does not produce an accentuation of mandibular growth.[4] Additionally, Graber concludes that "untoward sequelae" of incomplete correction of tooth malrelationship, excessive distal tipping of maxillary first molars, impaction of second or third molars, excessive lingual tipping of maxillary incisors, unilateral correction of the class II molar relationship and difficulty in control of the overbite can occur.[4]

When this investigation is evaluated a number of shortcomings can be identified. Firstly, there is no apparent control group with which treatment outcomes can be compared to. If the data presented by Tulloch *et al* is accurate, it is possible that a significant proportion of these treated cases would have improved on their own.[7,28] Another criticism of this article lies in its methodologies. Not only are the evaluation procedures not described, but also there does not appear to be any statistical analysis completed. In addition, many of the claims made regarding treatment mechanisms are not explained.

Poulton also investigated correction of class II malocclusions using extraoral traction.[5] It becomes apparent quickly that the mechanism of correction proposed by Poulton differs significantly from the mechanism that Graber proposed. Unlike Graber, Poulton attributes correction of the malocclusion to posterior movement of the maxillary first molars.[5] He reasons that other researchers do not reach a similar conclusion because of the timing of the cephalometric radiography. As Poulton explains, significant molar distalization can be camouflaged by ensuing maxillary growth once headgear therapy has been discontinued. He cites the work of Ricketts and Klein in addition to his own cephalometric analysis as evidence for this molar distalization.[5] Poulton does not discount partial class II correction due to changes in the facial complex. Cephalometric evidence of palatal plane tipping and distal intraalveolar movement of unerupted teeth suggest this effect. However, "such findings are important in disproving the concept of the immutability of the facial bones to orthodontic efforts, but the magnitude of the changes is very small when compared with the observed tooth movement".[5] As for growth changes in the mandible attributable to cervical headgear treatment, Poulton concurs with Graber that extraoral traction does not accentuate mandibular growth.[5] Poulton furthers this discussion. As with many orthodontic treatment extrusion of the teeth occurs to some degree. Poulton believes that condylar growth will compensate for this.[5]

As with the Graber article, Poulton's research demonstrates flawed methodologies. Specific cephalometric evaluation criteria have not been described and, again, a statistical analysis has not been presented. In fact, even the sample size on which conclusions have been drawn has not been provided.

Mitani and Brodie analyzed tooth movement, growth and angular changes that occurred when patients were treated with cervical traction.[18] This study attempted to determine changes that occurred with treatment and how stable these changes were over time. A control group was utilized. Their data demonstrated that cervical headgear treatment appeared to prevent the maxillary first molar from being carried downward and forward with the growth of the maxilla.[18] The evidence for this was the stability of the distance between the pterygomaxillary fissure and the maxillary first molar. Once the headgear treatment was discontinued the distance began to increase again by a similar rate as the control group. Further evidence was provided by the analysis of the angle formed by nasion, sella, and the maxillary first molar. In the treatment group the angle increased during treatment whereas in the control group it decreased.[18] The change in the distance between A point and the pterygomaxillary fissure was reduced during cervical traction as compared to the control.[18]

The results of this research provide evidence that supports Poulton's position that the maxillary first molar is distalized with cervical traction compared with the control group. Unfortunately, no analysis was carried out to determine if the difference was statistically significant. In addition, it did not appear that the control group was matched to the treatment group. Also confounding the conclusions is the fact that the research was conducted retrospectively which tends to bias samples in favor of positive treatment findings.[7]

Wieslander focused his research on the effects of skeletal structures within the nasomaxillary complex from cervical headgear treatment of class II malocclusions.[19] Using a well matched sample of treatment and control patients he measured treatment effects based on measurements from lateral cephalometric radiographs.[19] He concluded that cervical headgear treatment produced a change in growth pattern that resulted in the maxilla being positioned more posterior and slightly more inferior. In addition, the ANB angle reduced, the anterior nasal spine descended, and the maxillary first molars were positioned more posteriorly. Wieslander attributed the total change in the molar position (5 mm) to be partly due to the change in the maxillary position (2 mm) and partly due to distal dental movement (3 mm).[19] Thus, the implication being that the mechanism of class II correction from cervical headgear is both dentoalveolar as well as skeletal. In a later study, Wieslander concludes that cervical headgear treatment is more favorable in the early mixed dentition than in the late mixed dentition although he did find great individual variation.[6]

Baumrind and his associates have produced at least two papers that present data about treatment of class II malocclusions using cervical headgear in addition to other treatment modalities.[20,21] In the first study, a comparison of annual rates of change in linear measurements between a control group and five groups that were treated with different class II treatment modalities was completed.[20] One of the treatment modalities was cervical headgear. With respect to the comparison between the control group and the cervical headgear group they found that the following measurements had statistically significant differences. The cervical traction group had a greater annual increase in upper face height, ramus height, condyle to pogonion distance, and total face height than the control group. It is interesting to note the contradictory finding that the mandibular body length of the cervical headgear group had an annual increase that was statistically lower than the control group. Baumrind *et al* postulated that the annual increase in the total face height would not be larger in the headgear group than the control group. This was based on the results of a previous study that showed an insignificant increase in the mandibular plane angle with cervical headgear use.[20] They did not provide a opinion as why this occurred. Baumrind *et al* did not provide an explanation for the apparent greater increase in ramus height in the headgear group either. They also indicate that the cervical group shows a significant increase in the rate of growth of the mandible (as measured by the condyle pogonion distance). This finding was both surprising to and unexpected by the researchers and could not be accounted for by them. [20]

In the other article, Baumrind *et al* concentrate on the change in molar position.[21] Using the same sample as the previous study,[20] they conclude that their data does *not* support "the hypothesis that heavy forces produce ortho*pedic* displacement while light forces produce ortho*dontic* displacement [their emphasis]".[21]

They also demonstrate that an orthopedic change has occurred. The direction of displacement of the anterior nasal spine has become more vertical when compared to the control and the anterior displacement is significantly reduced.[21] In addition, the mesial migration of the maxillary first molar was halted by cervical headgear treatment when compared to the amount of mesial migration of the maxillary first molar in the control group. Baumrind *et al* attribute the difference to orthodontic movement of the molar due to cervical traction.[21]

More recently, the long term, prospective study by the North Carolina group has provided some interesting insight into treatment of class II malocclusions.[7,8,28] The advantage of this research over previous studies, according to the authors, is that the study is a prospective, randomized, clinical trial.[7] In addition, the study is long term which enables the researchers to establish not only treatment effects but the stability of the class II correction after treatment completion. Their conclusions emphasized that "children with class II malocclusion experience considerable variation in growth during the preadolescent period, both with and without treatment".[7] This is not to say that treatment was not deemed successful within the context of their study. The patients treated with extraoral traction did demonstrate reduction of the severity of the class II malocclusion with an approximate chance for improvement of 75%.[7] As was expected, the headgear group saw greater change in the maxilla.[7] It is interesting to note however that approximately 30 % of the children in the control group also demonstrated spontaneous improvement.[8]

Keeling *et al* also presented data from a randomized clinical trial.[22] Unlike the Tulloch *et al* study which attributed class II correction from headgear treatment to be the result of change in maxillary growth,[7] this study attributed correction to mandibular growth.[22] However, as Keeling *et al* discuss, their headgear treatment included a flat biteplate which was not used to by Tulloch *et al* to treat their patients. Keeling *et al* postulate that this difference may account for the conflicting results.[22]

C) Functional Appliance Therapy

Whereas cervical traction has been the treatment modality of choice in North America for the correction of class II malocclusions, "the European approach has more generally favored the positioning of the lower jaw [functional appliance therapy] to stimulate mandibular growth".[7] The functional regulator – 2 (FR-2), developed by Frankel, the Bionator, developed by Balter, and more recently, the Twin Block appliance, popularized by Clark, are examples of the functional appliance genera. According to functional appliance therapy theory, all of these appliances produce their treatment effects by posturing the mandible forward.

In addition to comparing cervical headgear treatment effect to a control group, Baumrind *et al* also compared a functional appliance to the same control.[20] His data demonstrated that the functional appliance produced less of an increase in the dimension of the upper face height than the cervical headgear group but that there was no statistically significant difference when compared to the control group. Their research also demonstrated that statistically significant increases in ramus height and condyle to pogonion distance were noted when compared to the control.[20] These results tend to support the theory that mandibular growth is stimulated by functional appliance therapy. However, two important caveats should be made. Firstly, the headgear group also demonstrated increases in the same two measurements (i.e. ramus height and condyle to pogonion distance). Secondly, the long term stability of the class II correction was not studied as part of this research. Therefore, it may be possible that, ultimately, growth was not stimulated but *accelerated* as per Proffit.[1]

The Frankel appliance was investigated by Creekmore and Radney in an attempt to determine whether the treatment effects were orthodontic or orthopedic in nature.[23] They compared patients that were treated with a FR – 2 appliance to an untreated sample that consisted mainly of class I occlusions. They found that "there was no significant difference in the forward growth of the mandible in the...class II Frankel [FR – 2] and the untreated sample".[23] They also concluded that the forward growth of the maxilla was significantly reduced in the FR – 2 group compared to the control as was indicated by the ANB angle. The mechanism of correction of the class II malocclusion was determined to be the result of retraction of the maxillary incisors, proclination of the mandibular incisors, orthopedic retraction of the maxilla and normal growth of the mandible and not accentuated mandibular growth.[23]

In reviewing this research, a number of shortcomings can be noted. Most significantly, the selection criteria biased the study from the outset. Selecting cases retrospectively that were deemed to have been treated successfully may bias the samples in favor of positive treatment findings.[7] In addition, the control group consisted mainly of patients that presented with a class I occlusion. Therefore, the comparison was not of a matched sample since it has been postulated that fundamentally different growth patterns may exist between class I and class II patients.

McNamara *et al* investigated the FR –2 treatment modality.[24] They compared cephalometric radiographs of patients treated with the FR – 2 appliance to "reasonably matched controls".[24] Contrary to Creekmore and Radney,[23] the data produced by the McNamara group did not demonstrate any significant change in maxillary development. Instead they found that the mechanism of class II correction was due, in part, to reduced anterior displacement of the maxillary first molar, net anterior displacement of the mandibular first molar, and increase in the mandibular length through displacement of the mandibular body parallel to itself along the facial axis.[24]

McNamara *et al* compared the FR – 2 appliance to class II treatment modalities other than cervical headgear.[26] They determined that the Frankel appliance had measurable dentoalveolar and skeletal effect on the class II malocclusion.[26] It appeared to increase mandibular length and had no profound effect on the development of the maxilla. The mandibular length had a mean annualized increase of 4.3 mm whereas the control group value for the same measurement was 2.1 mm.[26]

Contrary to the findings of McNamara *et al* and Creekmore and Radney,[23,24,26] Hamilton *et al* did not find any significant class II skeletal correction for patients that were treated with the FR – 2 appliance.[25] In a retrospective study of 25 consecutively treated case they concluded that treatment results produced by the FR –2 appliance were primarily dental in nature.[26] Hamilton *et al* found no restraining headgear effect and no "statistically or clinically significant increase in mandibular length".[25] The confounding variable that may have been, in part, responsible for the conflicting conclusions among these investigators was sample selection. It may be that using consecutively treated cases may reduce the inherent bias found in retrospective studies. This study also investigated joint position using tomographs. They found an increased posterior and superior joint space. This increase, however, was small and not statistically significant.

The Bionator functional appliance has also been studied.[7,8,22,27,28] For example, Mamandras compared two groups of patients that were treated with Bionator appliances. Both groups were treated to a class I molar relationship. The amount of growth, as determined cephalometrically by change in the position of pogonion, was the characteristic that Mamandras used to separate the sample into two groups. Each group was subsequently analyzed separately, and then compared to each other. One group had a much larger increase in mandibular length than the other.[27] From the cephalometric analysis, it was determined that the group that demonstrated a larger amount of mandibular growth were initially more retrognathic with respect to published norms. This group therefore demonstrated a significant delay in the mandibular development with respect to published mandibular size standards at the outset of treatment.[27] Thus, Mamandras concluded that growth was accelerated more in those patients that had mandibles that had not yet reached a level of development that coincided with their peers.[27]

The random clinical trial by Tulloch *et al* examined the treatment effects of the Bionator functional appliance in addition to the cervical headgear appliance.[7,8,28] At the end of phase I treatment, the group of patients treated with a functional appliance demonstrated an increase in the forward positioning of the mandible with an increase in the mandibular unit length.[7] Tulloch *et al* stress, however, that a large variation was seen within both the functional appliance and the control groups.[7] At the end of the second phase of treatment the data is significantly different. That is, "the skeletal effects of early treatment, on average, are not maintained. Instead, the ANB differences between the early-treatment and observation groups diminish, so that little if any difference remains after comprehensive treatment is completed".[28] Although time in fixed appliances is reduced in the functional appliance group, only small differences were noted in the anteroposterior jaw position.[28] Thus, they concluded that modification of growth did not occur, but rather growth was accelerated.[28]

Keeling *et al* also conducted a randomized clinical trial that demonstrated that the Bionator could successfully correct class II malocclusions.[22] Their data seems initially to correlate with the data of the Tulloch research. As noted, Tulloch found that initially, the mechanism of correction appeared to be from accentuated mandibular growth. According to Keeling *et al*, the Bionator "enhanced mandibular growth without detectable relapse a year after the end of active treatment".[22] This does not correlate with data produced by Tulloch which demonstrated no appreciable sustained change in mandibular growth after treatment.[28]

The Twin block functional appliance has recently been promoted by Clark.[29] He presents a series of case reports demonstrating its efficacy in treating class II malocclusions. Unfortunately, sample size and method of evaluation was not presented. Mills and McCulloch have also investigated this appliance.[30] They demonstrated that mandibular growth was on average 4.2 mm greater in the treated group compared to the untreated class II control group with two thirds of this length increase resulting from an increase in ramus height and the other one third from an increase in mandibular length.[30] Mills and McCulloch also noted that the maxilla was restricted via a "headgear effect".[30]

D) Fixed Appliances

Fixed appliances have also been advocated for the correction of class II malocclusions. Examples of these fixed appliances include the Herbst appliance, superelastic nickel-titanium springs and wires, the Pendulum appliance, rare earth repelling magnets, and the Wilson Bimetric Distalizing Arch™ among others.[9,11-16,26,31-41]

Although the Herbst appliance is considered to be functional in nature because of the mandibular posturing effect, it will be discussed in this section because it is usually cemented in place. Pancherz demonstrated that a class I molar relationship could be achieved in six months using the "Herbst bite jumping appliance".[31] He determined that the mechanism of class II correction was both skeletal and dental. He also concluded that treatment effects were seen in both arches. Pancherz presented data that demonstrated that 43 percent of the correction was skeletal with most of the change occurring in the mandible.[31] The other 57 percent of correction was dental in nature with the maxillary molar being displaced significantly more than the mandibular molar.[31] These changes were statistically significant. Pancherz noted that the restraining effect on the maxilla was minimal. Those that oppose this type of treatment implicate postural effects and possible temporomandibular joint damage as adverse reactions.

Numerous other fixed appliances have been presented. Many of these were in the form of case studies and were not supported by thorough investigations. Locatelli *et al* illustrated the use of superelastic nickel-titanium wire to correct a class II molar relationship.[32] The technique involved using a superelastic nickel-titanium wire that is stopped with excess wire length. The wire is then deflected, and inserted into the molar buccal tube. The excess, deflected wire produces the distalizing force. The sample size was one and there was no control group. In a similar fashion, Giannelly presents a molar distalization technique using nickel-titanium coils in place of the stopped superelastic nickel-titanium wire.[33] Again, this was a technique proposal and not a thorough investigation. Both of the previous techniques stress the importance of monitoring anchorage loss since labial movement of the anterior segment can occur. To provide enhanced anchorage, Jeckel and Rakosi used a thermoplastic splint to engage the palatal tissues and the anterior teeth.[34] The Pendulum appliance,[35] and the appliance developed by Snodgrass[36] are other examples of this appliance type where the anchorage is partially derived from palatal coverage. The Pendulum and Snodgrass appliances use premolar bonding in addition to acrylic on the palate to reinforce anchorage.[35,36]

The use of repelling rare earth magnets has been studied by Bondemark *et al*,[37] Bondemark and Kurol,[38] Erverdi *et al*,[39] and Itoh *et al*.[40] This technique appeared to be a promising class II treatment modality because the magnets provided a force that acted over a relatively long range and enabled easier activation.

Bondemark *et al* found that superelastic nickel-titanium coils were more effective at molar distalizing than the magnets.[37] The comparison was completed by using both appliances in each patient (i.e. one appliance per side). The coils spring side averaged 3.2 mm of molar distalization while the magnet side only averaged 2.2 mm.[37] It should be noted that all of the cases that were treated in this study had fully erupted first and second molars. A negative affect of this type of treatment was an increase in overjet due to labial tipping of the maxillary incisors. Molar tipping and molar rotation appeared to be minimal. Bondemark and Kurol achieved a class I molar relationship using samarium-cobalt magnets to produce the distalizing force.[38] The average molar distalization was 4.2 mm which was achieved in approximately four months.[38] This amount of molar movement achieved was larger in the previous study but was attained partially by distal crown tipping. Bondemark and Kurol demonstrated that "one-half of the distal movement of molar treated with magnets is related to tipping, with the obvious risk of relapse".[37] A similar study was conducted by Erverdi *et al*.[39] They found the nickel-titanium coils more effective than the magnets in producing molar distalization. These results were similar and the conclusions that were made concurred with previous works. Itoh *et al* also investigated repelling magnets.[40] They investigated which appliance (nickel-titanium coil or repelling magnets) was more effective at molar distalization by comparing the amount of time required to achieve a class I molar relationship by using one appliance on each molar (i.e. intrapatient comparison). The amount of molar distalization produced averaged 2.1 mm. This amount was less than in previous studies. Contrary to the findings of Bondemark and Kurol,[38] Itoh *et al* found that molar distalization “was almost entirely a bodily movement”.[40] Adverse dental movements were noted however. These included labial bodily movement and tipping of the maxillary incisors. The distal tipping and rotation of the molar appeared to be minimal. In addition, the patients reported an increased level of discomfort on the magnet side as compared to the super elastic coil side. It should be noted that there also appears to be controversy as to the biocompatibility of rare earth magnets. Opposing and conflicting opinions as to adverse biologic reactions have been noted.[37-40] In addition, cost and bulkiness of the rare earth magnets have also been noted as detractors to this molar distalizing technique.[40]

A modified Jones jig was investigated by Gulati *et al* as a class II treatment modality.[41] Using this appliance they were able to distalize maxillary first molars, on average, 2.78 mm at a rate of 0.86 mm per month.[41] As with the rare earth magnets and nickel-titanium coils molar tipping, molar rotation and anterior displacement of the anchorage unit were adverse affects of molar distalization via this method.

As part of his Modular Orthodontic Systems, Wilson introduced the Wilson Bimetric Distalizing Arch™.[11-15] This arch consisted of an anterior arch of 0.022 inch Truchrome wire combined with a 0.040 inch end section with intermaxillary hooks and omega adjustable stops. An 0.010 inch x 0.045 inch elgiloy coil spring 5mm in length is used to produce the distalizing force. Class II elastics that are attached from an elastic hook on the anterior portion of the Wilson Bimetric Distalizing Arch™ to a lower holding arch are also used. These elastics are used with a very specific schedule of weights and times (see Appendix 1 – 1, page 42).
W. L. Wilson and R. C. Wilson contend that this appliance arrangement will distalize

molars quickly ("in a matter of weeks") and efficiently with minimal side effects.[15] Other advantages of the Wilson Bimetric Distalizing Arch™, as purported by Wilson, are: unilateral or bilateral class II molar correction can be accomplished, no headgear or removable appliances required, very adaptable to existing bracket and molar tube systems, no root resorption, no temporomandibular joint iatrogenics, and no patient discomfort.[14] Muse *et al* studied this appliance.[16] They concluded that a class II molar relationship corrects to a class I molar relationship in 16 weeks or less. However, they also concluded that molar distalization was variable and accomplished partly by molar tipping and by mesial movement of the lower molar. Wilson responded to this article with a letter to the editor.[11] He cited six inconsistencies in the treatment methodology that was used by Muse *et al* that led to their contradictory findings. These inconsistencies included: not following the specific elastic schedule, using elastics that were too heavy, using a non-passive Bimetric Distalizing Arch, using tip back bends, not using a passive lingual holding arch, and not prudently using the leeway space.[11]

E) Summary

Class II malocclusions can be the result of skeletal discrepancies, dentoalveolar discrepancies, or a combination thereof. Skeletal discrepancies include maxillary protrusion, mandibular retrusion or both. Similarly, dental discrepancies can be the result of an anteriorly displaced maxillary dentoalveolar complex, a posteriorly displaced mandibular dentoalveolar complex, or a combination of the two. According to Proffit, if a skeletal malocclusion is present only three approaches are available to the clinician.[1] These options are growth modification, dental camouflage or compensation of the skeletal discrepancy, or surgical correction. If the malocclusion is the result of a dentoalveolar discrepancy, maxillary molar distalization or mandibular molar advancement or both can be utilized to correct the malocclusion. Treatment modalities for the correction of class II malocclusions that have been discussed have attempted to modify growth or distalize maxillary molars. The treatment effects that have been reported for these differing modalities are varied. Growth modification through restriction or redirection of maxillary growth or stimulation of mandibular growth has been demonstrated. Recently though, research has been presented that questions whether growth modification actually occurs or can be maintained.[27] Many maxillary molar distalization methods have been proposed. Unfortunately, few have been thoroughly investigated.

1.6.3 Lateral Cephalometric Radiology Analysis and Superimposition

A) Introduction

"Since the introduction of cephalometrics by Broadbent in 1931, a number of different analyses have been devised".[42] This is exemplified by the range of analyses used by the authors cited above in their investigation of different methods of class II correction and by the immense number of analyses available in general. Discussion will focus on types of cephalometric analyses that have been used and on the reliability of the analyses and their landmarks. In addition, a synopsis of superimposition methodologies will be provided. It should be noted that this review will not be exhaustive, but rather, provide the reader with a framework.

B) Lateral Cephalometric Radiographic Landmark Reliability

To critically evaluate lateral cephalometric radiographs requires some type of analyses from which an evaluation can be based. Therefore the analysis must be reliable. Reliability of the cephalometric analysis used depends on the ease and reproducibility of the landmarks on which the analysis is based. It is interesting to note that until the 1970's "the nature and magnitude of the differences in the precision with which we identify the different landmarks used in standard cephalometric analyses have never...been quantitatively measured".[43]

Baumrind and Frantz investigated the reliability of head film measurement in a series of two papers.[43,44] The first paper discusses landmark identification. They identified two classes of error which occur in the estimation of cranial dimensions from head films (lateral cephalometric radiographs): errors of projection and errors of identification.[43] The former error (projection error) results from the fact that the lateral cephalometric radiograph is a two dimensional representation of a three dimensional object. Therefore, "head films are always distorted enlargements" because the radiation produced from an x-ray tube head is nonparallel.[42] In addition, this error is confounded by further distortion from foreshortening of distances between points lying in different planes and by radial displacement of all points and structures not on the principle axis.[43] The latter error (identification error) results from the apparently straightforward process of identifying specific anatomic landmarks on head films.[43] With repeated identification of numerous landmarks and analysis of the resulting scattergrams Baumrind and Frantz found that reliability of many landmarks varied greatly but systematically. They concluded that errors in landmark identification are too great to be ignored, that the magnitude of error varies greatly between landmarks, and that the distribution of the errors is systematic and noncircular for each landmark.[43]

In their second paper, Baumrind and Frantz investigate the impact these errors have on conventional angular and linear measurements.[44] In addition to errors in projection and identification discussed in the previous article, a third type of error is added – mechanical error.[44] Mechanical error occur from inaccurate tracing lines and measurement devices. As with landmark identification, great variation can be seen in the values produced for the different angular and linear measurements. In fact, Baumrind and Frantz conclude that the "most noteworthy observation, mirroring our landmark study, is the fact that angular and linear measurements from head films contain considerable errors – errors which are far too great to be overlooked or disregarded".[44]

More recently, Houston analyzed the errors of orthodontic measurements.[45] He stresses that consideration must be given to the differentiation between validity and reproducibility. Validity is the extent to which the value obtained represents the object of interest in the absence of measurement replication error whereas reproducibility is the closeness of successive measurements of the same object.[45] Validity depends on both what is being measured and the method used to measure that particular object.[45] Reproducibility will vary depending on the quality of the records, the condition under which they are measured and the care and skill of the measurer.[45] Therefore, Houston concludes, that "every study should include an assessment of reproducibility, even if standard measurements are being utilized".[45] He also makes several suggestions regarding how error can be controlled. These include: standardized radiographic technique, appropriate conditions for landmark identification, replication of measurement to reduce random errors, randomization of records to reduce systematic error, and not using duplicate radiographs.[45] Unlike previous works, Houston does not provide error values produced by using these methods.

Trpkova *et al* conducted a meta analysis of cephalometric landmark identification and reproducibility.[46] Using previously published data they calculated the standard mean errors and ninety-five percent confidence interval for fifteen cephalometric landmarks. Trpkova *et al* determined that variability was greater in the horizontal direction and less in the vertical direction. They concluded that 0.59 mm of total error for the x coordinate and 0.56 mm of total error for the y coordinate were acceptable levels of accuracy.[46] They also suggest that certain landmarks (on each axis) that would be considered more reliable for cephalometric analysis of lateral head films than others.[46] These more reliable landmarks included A point, B point, pterygomaxillary fissure, sella, and gonion on the x coordinate and A point, pterygomaxillary fissure, and sella on the y coordinate.[46]

C) Cephalometric Radiographic Analyses

It is not within the scope of this review to discuss all previous lateral cephalometric analyses that have been presented to date. Instead, those analyses that have been used to evaluate class II treatment effects will be considered.

In his study of cervical traction, Wieslander used the anterior portion of the anterior cranial base, the most posterior point on the posterior outline of the frontal sinus and the Bolton point for superimposition.[6] In addition, a line perpendicular to the Frankfurt horizontal (FH) through articulare was used for linear measurements. The angular measurements that were made included ANB, mandibular plane to FH, and palatal plane to FH were. Baumrind *et al* used a lateral cephalometric analysis that was different from Wieslander.[20] Only linear measurements were made to study the effects of extraoral traction. Nine measurements were completed which included measurements made within the skull (SN distance, upper face height), measurements made within the mandible (ramus height, mandibular body length, condylion-pogonion distance, menton-pogonion distance), and measurements made between the skull and the mandible (total face height, lower face height, condylion-sella distance). No measurements were made of the dentition. Creekmore and Radney made numerous linear and angular measurements on pre – and post – treatment lateral cephalometric radiographs.[23] The angular measurements included SNA, SNB, ANB, SN-MP and FH-NPg. The linear measurements included Co-Gn, Co-A, ANS-Me, ANS to upper incisor and lower incisor to Me. To determine maxillary and mandibular growth Creekmore and Radney calculated "mandibular length (condylion-gnathion), maxillary length (condylion-point A), maxillomandibular differential, and lower face height (ANS-menton) as advocated by McNamara".[23] To monitor tooth position they used portions of analyses by Steiner, McNamara and Ricketts. These measurements included upper incisor to NA, lower incisor to NB, Pg-NB (from Steiner), lower incisor to APg (from Ricketts) and A- and Pg- N perpendicular (from McNamara).[23] It is interesting to note that they completed their superimpositions "along SN, registering at S".[23]

Mamandras and Allen constructed a vertical and horizontal coordinate system to evaluate cephalometric changes induced by Bionator treatment.[27] The constructed x-axis was 8 degrees above SN. The y-axis was perpendicular to the x-axis, using sella as the anteroposterior determinant. Linear measurements were then completed from the vertical and horizontal reference lines.

Pancherz constructed his horizontal reference line using the occlusal plane.[31] The vertical reference line was perpendicular to the occlusal plane through sella. Linear measurements were then made from these lines. To measure post-treatment changes, measurements were made from the reference lines of the original lateral cephalometric radiograph by superimposing on SN at sella. Pancherz states that this reference system was used because "it was close to the problem area" and it enabled evaluation of "the interrelationship between skeletal and dental changes in and between the two jaws".[31] A similar analysis was used by Bondemark and Kurol and by Bondemark *et al.*[37,38]

Localized measurements were made by Erverdi *et al* and by Itoh *et al.*[39,40] Erverdi *et al* measured changes in molar position using Ricketts molar to PTV measurement.[39] Both linear and angular measurements were made. In order to distinguish between upper right and left molars wire markers were incorporated into the molar bands at the time the radiographs were taken. Like Pancherz, Itoh *et al* developed a localized analysis to measure molar and incisor movements.[40] Lines perpendicular to FH at the mesial of the first molar, at the incisal tip of the upper incisor and at ANS were measured. Haynes measured changes resulting from FR – 2 treatment using "cephalometric landmarks described by Broadbent, Broadbent, and Golden".[47] He measured both angular and linear dimensions on the lateral cephalometric radiographs. The measurements made evaluated skeletal, skeletodentoalveolar, and dentoalveolar changes.[47]

Muse *et al* used "portions of the Ricketts analysis" to evaluate treatment changes incurred using the Wilson Bimetric Distalizing arch.[16] In addition, the "Ricketts four-step method of superimposition was used to measure molar and incisor changes and to distinguish orthodontic changes from natural growth".[16] To determine the amount of maxillary molar and incisor movement, superimposition of the palatal plane at the incisive canal was used. Mandibular dental movements were evaluated by superimposing tracings on the corpus axis at Pm.[16] Molar tip was measured by the angle made by a line tangent to the distal of the first molar extended to FH.[16]

D) Lateral Cephalometric Superimpositions

Determining changes in the position of dental or skeletal structures resulting from treatment effects, growth, or both can be completed via the individual film method or the superimposition method.[48] The individual film method consists of measuring the same set of linear and angular values for each lateral cephalometric radiograph and comparing the difference in the resulting absolute values. The superimposition method consists of tracing each lateral cephalometric radiograph and overlying one on the other at specific anatomic locations to determine changes that may have occurred. According to Baumrind *et al*, sophisticated investigators prefer to employ the superimposition method because this method makes it easier to identify precisely the areas in which changes have occurred and this method is generally more sensitive for identifying small displacements in landmark position.[48] In addition to the errors of projective displacement and landmark identification previously discussed, two additional errors develop when conducting superimpositions – primary errors and secondary errors. Primary errors result from errors in judgement by the one conducting the superimposition in weighting certain anatomic landmarks over others in accordance with our biologic concepts.[48] Secondary errors are mathematical constructs that relate systematically to the primary errors.[48] In the investigation by Baumrind *et al*, three superimpositions were conducted.[48] The first was an anterior cranial base superimposition on the anterior cranial base; the second was on the palatal plane and the third was on the mandibular border. With respect to an full lateral cephalometric radiograph superimposition, they concluded that using the entire anterior cranial base produced less error than using the SN plane. Baumrind *et al* reasoned this occurred because the former method (anterior cranial base superimposition) has a greater number of points along which the superimposition is made. Therefore, an error made at any point would not greatly affect the full lateral cephalometric radiograph superimposition. An error created at either S or N could create a significant error since the superimposition relies so heavily on only these two points.[48] Superimposition along the mandibular plane produced errors that were usually rotational in nature.[48] The palatal plane superimposition was least accurate and produced both translational as well as rotational errors.[48]

With specific reference to the maxillary superimposition, Baumrind *et al* attempted to quantitate maxillary remodeling first with metallic implants and then without.[49,50] The investigation that used patients that had metallic implants produced data that enabled Baumrind *et al* to conclude that there appeared to be a modal downward remodeling of the palate, the hard palate elongates at its posterior terminus, and (as would be expected) there appeared to be great variation.[49] This evidence included a downward and backward remodeling at ANS, PNS and A point.[49] They also suggested that there are evidentiary trends which indicate that there was a difference between treated and untreated groups.[49] These conclusions then led them to investigate the 'anatomical' method of superimpostion.[50] They found that the 'anatomical best fit' superimposition method under estimates the downward trend slightly and completely masks the small backward growth trend of anterior landmarks.[50]

Ghafari *et al* compared four methods of superimposition of lateral cephalometric radiographs.[51] The four methods compared were best fit of anterior cranial base anatomy, superimposition on SN line which was registered at S, superimposition on registration point R with the Bolton-nasion planes parallel, and superimposition on basion-nasion registered at point CC.[51] Although they did not suggest a preference to any one particular method based on their data , Ghafari *et al* state that the best fit of anterior cranial base structure is superior to the other methods because it takes into account detailed anatomy rather than simplifying this anatomy to a line or plane.[51] This coincides with the conclusions of Baumrind *et al.*[48]

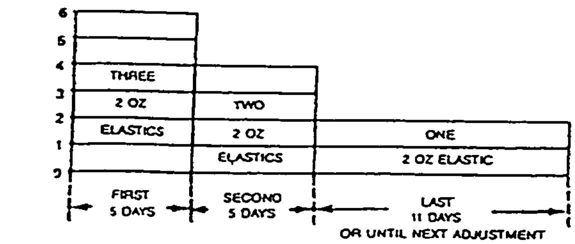
E) Summary

Great variation in lateral cephalometric radiographic analysis and superimposition technique has been demonstrated. This variation can be attributed to investigator bias and specific cephalometric areas of interest. In addition, the great number and variety of analyses indicates that, as of yet, no ideal method has been developed. Therefore, regardless of the technique chosen and utilized, the important factor to consider is that every analysis has shortcomings. These shortcomings, therefore, must be recognized and accounted for during the interpretation of the resulting data.

Appendix 1 – 1 Schedule of Class II Elastic Wear*

SCHEDULE #1 (2 oz. elastics) Used with:

- •Flaring lower incisors
- •Small mandibular roots



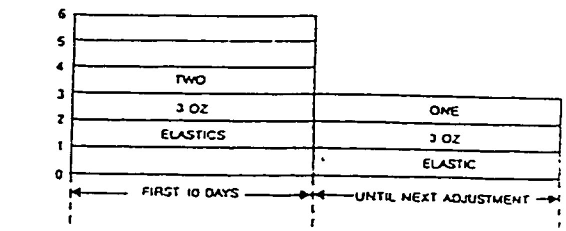
Using 2 oz. elastics, three elastics should be used during the first five days, two during the second five days and one during the final eleven days of the treatment plan. Fresh elastics are applied daily. Elastics must be worn 24 hours each day between appointments, including during meals.

Use 5/16" 2 oz. elastics for non-extraction cases.

Use 1/4" 2 oz. elastics for extraction cases.

SCHEDULE #2 (3 oz. elastics) Most Common Usage:

- •Class II Div. 2
- •Class II Div. 1 with close bite
- •Cases with steep cusps
- •Adult cases



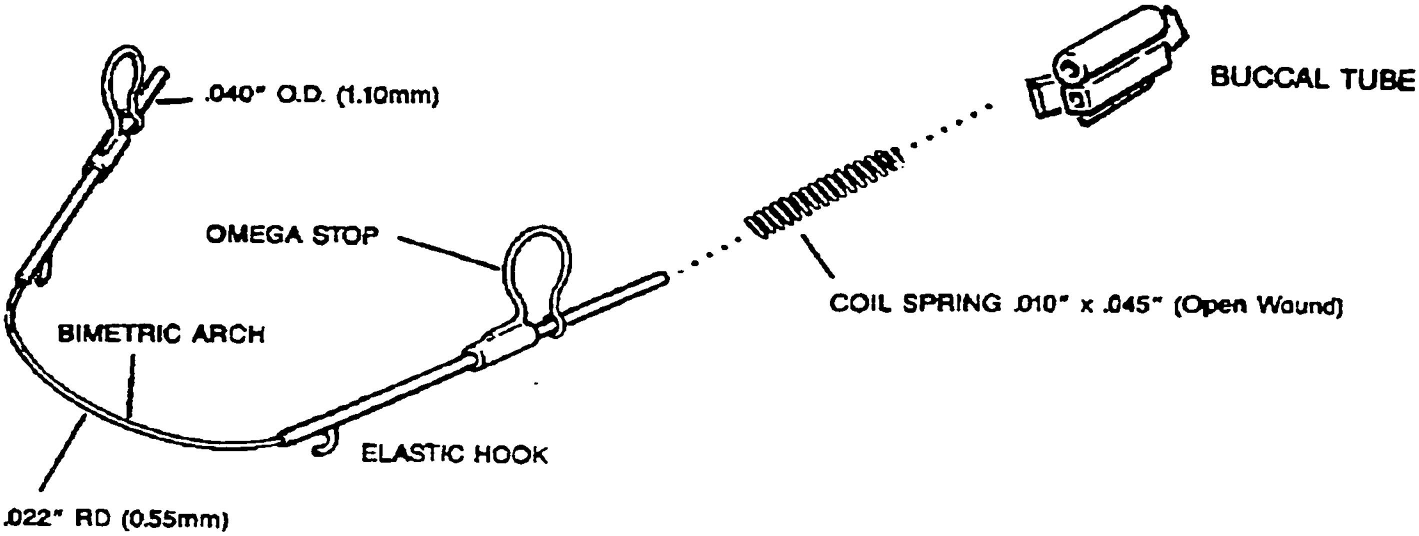
Two 3 oz. elastics used during the first 10 days. Then, one 3 oz. elastic is worn until next adjustment. Fresh elastics are applied each 12 hours and are worn 24 hours daily, including during meals.

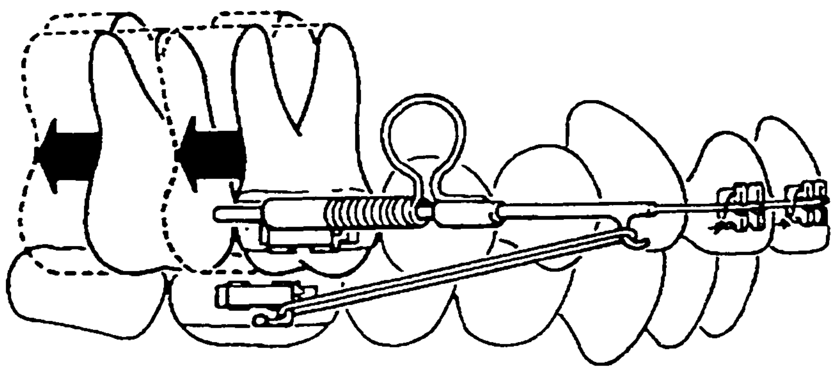
Use 5/16" 3 oz. elastics for non-extraction cases.

Use 1/4" 3 oz. elastics for extraction cases.

* Adapted from Enhanced Orthodontics, Book 2: Force Systems Mechanotherapy Manual with 3D® Modular ... 1st Phase Fixed/Removables™ by R.C. Wilson and W.L. Wilson, RMO Inc., 1988.

Figure 1 – 1 Wilson Bimetric Distalizing Arch™ Diagrams*





* Adapted from Enhanced Orthodontics, Book 2: Force Systems Mechanotherapy Manual with 3D® Modular … 1st Phase Fixed/Removables™ by R.C. Wilson and W.L. Wilson, RMO Inc., 1988.

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Chapter Two

Paper #1

Pilot Project for the Comparison of Orthopedic and Orthodontic Treatment Outcomes Utilizing Cervical Headgear or Wilson Bimetric Distalizing Arch™ – A Cephalometric Study

2.1 Introduction

"Since the introduction of cephalometrics by Broadbent in 1931, a number of different analyses have been devised".[1] This is exemplified by the range of analyses used by authors in their investigation of different methods of class II correction and by the immense number of analyses available in general.[1,4-17] However, it is the reliability and reproducibility of the lateral cephalometric analysis technique that is more critical than the technique itself.[2]

Reliability of the cephalometric analysis used depends on the ease and reproducibility of the landmarks on which the analysis is based.[2] Baumrind and Frantz investigated the reliability of head film measurement.[2,3] They identified two classes of landmark identification error which occur in the estimation of cranial dimensions from head films (lateral cephalometric radiographs): errors of projection and errors of identification.[2] The former error (projection error) results from the fact that the lateral cephalometric radiograph is a two dimensional representation of a three dimensional object. Therefore, "head films are always distorted enlargements" because the radiation produced from an x-ray tube head is nonparallel.[1] In addition, this error is confounded by further distortion from foreshortening of distances between points lying in different planes and by radial displacement of all points and structures not on the principle axis.[2] The latter error (identification error) results from the apparently straightforward process of identifying specific anatomic landmarks on head films.[2] With repeated identification of numerous landmarks and analysis of the resulting scattergrams Baumrind and Frantz found that reliability of many landmarks varied greatly but systematically. They concluded that errors in landmark identification are too great to be ignored, that the magnitude of error varies greatly between landmarks, and that the distribution of the errors is systematic and noncircular for each landmark.[2] Baumrind and Frantz also investigated the impact these errors have on conventional angular and linear measurements.[3] In addition to errors in projection and identification discussed in the previous article, a third type of error is added – mechanical error.[3] Mechanical errors occur from inaccurate tracing lines and measurement devices. As with landmark identification, great variation can be seen in the values produced for the different angular and linear measurements. In fact, Baumrind and Frantz conclude that the "most noteworthy observation, mirroring our landmark study, is the fact that angular and linear measurements from head films contain considerable errors – errors which are far too great to be overlooked or disregarded".[3]

More recently, Houston analyzed the errors of orthodontic measurements.[18] He stresses that consideration must be given to the differentiation between validity and reproducibility. Validity is the extent to which the value obtained represents the object of interest in the absence of measurement replication error whereas reproducibility is the closeness of successive measurements of the same object.[18] Validity depends on both what is being measured and the method used to measure that particular object.[18] Reproducibility will vary depending on the quality of the records, the condition under which they are measured and the care and skill of the measurer.[18] Therefore, Houston concludes, that "every study should include an assessment of reproducibility, even if standard measurements are being utilized".[18] He also makes several suggestions regarding how error can be controlled. These include: standardized radiographic technique, appropriate conditions for landmark identification, replication of measurement to reduce random errors, randomization of records to reduce systematic error, and not using duplicate radiographs.[18]

Therefore the purpose of this study was to determine the measurement replication error for the lateral cephalometric analysis and the superimposition techniques developed for this investigation. This would allow for an assessment of their reproducibility. In addition, the resulting data was utilized to conduct a Power analysis. This analysis provided a guideline for the appropriate sample size required for each group being evaluated.

2.2 Materials and Methods

A computer – aided search of the patient data base from the private practice of a single, experienced orthodontist was completed using the diagnosis of a class II division 1 malocclusion as the search term. The search was narrowed to patients that were between seven and sixteen years of age at the onset of treatment, had completed treatment, and were presently in retention. The initial age range was large to ensure that as many Wilson Arch patients as possible were to be included in the search. The chart of each of these patients was examined to determine the type of treatment modality used and the number of patients that had been treated with a Wilson Bimetric Distalizing Arch™ in conjunction with fixed appliances. Once it was determined that there appeared to be a sufficiently sized sample of patients, four patients were selected at random from class II division 1 patients.

These patients were used in a pilot study to determine the measurement replication error and a sample size guideline.

Each of the four randomly selected patient's pre – and immediate post – treatment lateral cephalometric radiograph was viewed under standardized conditions (darkened room, same light source). Three tracings were completed for each radiograph onto matte acetate using a 0.5 mm diameter HB lead pencil. A full lateral cephalometric radiograph tracing was produced, in addition to separate maxillary and mandibular tracings. Each of these tracings were repeated five times. Subsequent tracings of the same radiograph were separated by a minimum of twenty-four hours.

The following landmarks were then identified on each lateral cephalometric radiograph tracing (see Figure 2 – 1, page 81):

1. Sella (S) – the centre of the hypophyseal fossa (sella turcica)
2. Nasion (N) – the junction of the nasal and frontal bones at the most posterior point on the curvature of the bridge of the nose
3. A point (A) – the innermost point on the curvature from the maxillary anterior nasal spine to the crest of the maxillary alveolar process
4. B point (B) – the innermost point on the curvature from the chin to the alveolar junction
5. Pogonion (Pg) – the anterior most point on the contour of the chin
6. Menton (M) – the most inferior point on the curve of the symphysis of the mandible as determined by using a line tangential to the lower border of the mandible

7. Gonion (Go) – the point midway between the points representing the middle of the curvature at the left and right angles of the mandible
8. Porion (Po) – the most superior point on the curvature of the shadow of the auditory canal
9. Orbitale (Or) – the point midway between the lowest point on the inferior bony margin of the left and right orbital rims
10. Maxillary Left first molar mesial cusp tip (Mx6L) – the most inferior point of the curve of the cusp tip of the left maxillary first molar*
11. Maxillary right first molar mesial cusp tip (Mx6R) – the most inferior point of the curve of the cusp tip of the right maxillary first molar*
12. Mandibular left first molar mesial cusp tip (Mn6L) - the most superior point on the curve of the mesial cusp tip of the left mandibular first molar*
13. Mandibular right first molar mesial cusp tip (Mn6R) - the most superior point on the curve of the mesial cusp tip of the right mandibular first molar*

(* The most distal image of each molar type (maxillary or mandibular) on the lateral cephalometric radiograph was assumed to be the left molar (if two images were present))

14. Maxillary incisor tip (Mx1T) - the mid-point of the most inferior edge of the most inferior and anterior maxillary incisor
15. Maxillary incisor root apex (Mx1A) - the mid-point of the most superior tip of the root of the incisor in 14 (above)

16. Mandibular incisor tip (Mn1T) - the mid-point of the most superior edge of the most superior and anterior maxillary incisor
17. Mandibular incisor root apex (Mx1A) - the mid-point of the most inferior tip of the root of the incisor in 16 (above)
18. Pterygomaxillary fissure (Ptm) – the most posterior point on the curvature of the posterior wall of the pterygomaxillary fissure

Measurement replication errors for non – superimposed angular measurements were determined by measuring the tracings of the eight radiographs (four pre – treatment and four post – treatment) five times in random order, as noted above. The following angular measurements were made on each full lateral cephalometric radiograph tracing (see Figure 2 – 2, page 82):

1. SNA – the angle in degrees made from the intersection of lines SN and NA
2. SNB – the angle in degrees made from the intersection of lines SN and NB
3. SNPg – the angle in degrees made from the intersection of lines SN and NPg
4. ANB – the difference in degrees calculated by subtracting the value of SNB from the value of SNA
5. FH – MnPl – the angle in degrees made from the intersection of lines PoOr and GoM
6. SN – MnPl – the angle in degrees made from the intersection of lines SN and GoM

7. SN – Mx1 – the angle in degrees made from the intersection of lines SN and Mx1T-Mx1A
8. FH – Mx1 – the angle in degrees made from the intersection of lines PoOr and Mx1T-Mx1A
9. FMIA – the angle in degrees made from the intersection of lines PoOr and Mn1T-Mn1A
10. MnPl – Mn1 – the angle in degrees made from the intersection of lines GoM and Mn1T-Mn1A

Measurement replication errors for non – superimposed linear measurements were determined by tracing the eight radiographs (four pre – treatment and four post – treatment) five times in random order. Subsequent tracings of the same radiograph were separated by a minimum of twenty-four hours. The following linear measurements were then made on each full lateral cephalometric radiograph tracing (see Figure 2 – 3, page 83):

1. N perpendicular to A point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to A point*
2. N perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to Pg*

3. S perpendicular to A point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to A point
4. S perpendicular to B point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to B point
5. S perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to Pg

   (* A negative value was assigned if the landmark was to the left of the vertical perpendicular and a positive value was assigned if the landmark was to the right of the vertical perpendicular)

The measurement replication errors were calculated using the standard deviation of each measurement over the five tracings of each radiograph, and then calculating the mean of the standard deviation over the eight radiographs (four pre – treatment and four post – treatment).

Measurement replication errors for superimposed measurements were determined as follows: a coordinate system was constructed for each pre – treatment cephalometric tracing. The coordinate system for the full lateral cephalometric radiograph tracing was the PoOr line (Frankfort horizontal) in the horizontal direction and a line perpendicular to PoOr registered at S (see Figure 2 – 4, page 84). The coordinate axis for the maxillary tracing was the PoOr line with vertical being a perpendicular registered, this time, at the pterygomaxillary fissure (Ptm) (see Figure 2 – 5, page 85). For the mandibular tracing, the horizontal reference line was the mandibular plane (GoM) with the vertical axis line being perpendicular to this line registered at Go (see Figure 2 – 6, page 86).

Each of the four sets of five tracings (a set consisted of one pre – treatment and one post – treatment radiograph tracing) was then superimposed three times – once for each tracing type (anterior cranial base, maxillary, and mandibular). To complete the anterior cranial base superimposition the pre – treatment tracing was placed over the post – treatment tracing and the best fit of anterior cranial base structures were obtained. The following points were transposed from the post – treatment tracing onto the pre – treatment tracing: Mx6L, Mx6R, Mn6L, Mn6R, Mx1T, Mn1T, A point, B point, and Pg. To complete the mandibular superimposition, the pre – treatment mandibular tracing was placed over the post – treatment mandibular tracing using the best fit of the symphysis, mandibular canal, and third molar crypt (if present). Post – treatment Mn6L and Mn6R were then transposed onto the pre – treatment acetate. The maxillary superimposition was conducted in a similar manner, using the best fit of the maxilla, pterygomaxillary fissure, and the key ridges. Post – treatment Mx6L and Mx6R were then transposed.

The following linear measurements were completed on the pre – treatment tracing using the previously described constructed axes for the full lateral cephalometric radiograph tracing (see Figure 2 – 4, page 84):

1. Mx6L vertical before - the perpendicular distance in millimeters from the horizontal axis (PoOr) to the pre – treatment Mx6L

2. Mx6R vertical before - the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mx6R
3. Mx6L vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx6L
4. Mx6R vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx6R
5. Mx6L horizontal before – the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx6L
6. Mx6R horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx6R
7. Mx6L horizontal after - the perpendicular distance in millimeters from the vertical axis to transposed the post – treatment Mx6L
8. Mx6R horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mx6R
9. Mn6L vertical before – the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mn6L
10. Mn6R vertical before - the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mn6R
11. Mn6L vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn6L
12. Mn6R vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn6R

13. Mn6L horizontal before – the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn6L

14. Mn6R horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn6R

15. Mn6L horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mn6L

16. Mn6R horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mn6R

17. Mx1T vertical before - the perpendicular distance in millimeters from the horizontal axis (PoOr) to the pre – treatment Mx1T

18. Mx1T vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx1T

19. Mn1T vertical before - the perpendicular distance in millimeters from the horizontal axis (PoOr) to the pre – treatment Mn1T

20. Mn1T vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn1T

21. Mx1T horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx1T

22. Mx1T horizontal after - the perpendicular distance in millimeters from the vertical axis to transposed the post – treatment Mx1T

23. Mn1T horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn1T

24. Mn1T horizontal after - the perpendicular distance in millimeters from the vertical axis to transposed the post – treatment Mn1T
25. Overbite before - the difference in degrees calculated by subtracting the value of Mn1T vertical before from the value of Mx1T vertical before
26. Overbite after - the difference in degrees calculated by subtracting the value of Mn1T vertical after from the value of Mx1T vertical after
27. Overjet before - the difference in degrees calculated by subtracting the value of Mn1T horizontal before from the value of Mx1T horizontal before
28. Overjet after - the difference in degrees calculated by subtracting the value of Mn1T horizontal after from the value of Mx1T horizontal after
29. S perpendicular to A point - the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to A point that has been transferred from the post – treatment tracing
30. S perpendicular to B point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to B point that has been transferred from the post – treatment tracing
31. S perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to Pg that has been transferred from the post – treatment tracing

The following linear measurements were then completed on the maxillary pre – treatment tracing using the constructed axes for the maxillary tracing (see Figure 2 – 5, page 85):

1. Mx6L vertical before – the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mx6L
2. Mx6R vertical before - the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mx6R
3. Mx6L vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx6L
4. Mx6R vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx6R
5. Mx6L horizontal before – the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx6L
6. Mx6R horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx6R
7. Mx6L horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mx6L
8. Mx6R horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mx6R
9. Mx1T vertical before - the perpendicular distance in millimeters from the horizontal axis (PoOr) to the pre – treatment Mx1T
10. Mx1T vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mx1T

11. Mx1T horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mx1T
12. Mx1T horizontal after - the perpendicular distance in millimeters from the vertical axis to transposed the post – treatment Mx1T

The following linear measurements were completed on the mandibular pre – treatment tracing using the constructed axes for the mandibular tracing (see Figure 2 – 6, page 86):

1. Mn6L vertical before – the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mn6L
2. Mn6R vertical before - the perpendicular distance in millimeters from the horizontal axis to the pre – treatment Mn6R
3. Mn6L vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn6L
4. Mn6R vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn6R
5. Mn6L horizontal before – the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn6L
6. Mn6R horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn6R
7. Mn6L horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mn6L

8. Mn6R horizontal after - the perpendicular distance in millimeters from the vertical axis to the transposed post – treatment Mn6R
9. Mn1T vertical before - the perpendicular distance in millimeters from the horizontal axis (PoOr) to the pre – treatment Mn1T
10. Mn1T vertical after - the perpendicular distance in millimeters from the horizontal axis to the transposed post – treatment Mn1T
11. Mn1T horizontal before - the perpendicular distance in millimeters from the vertical axis to the pre – treatment Mn1T
12. Mn1T horizontal after - the perpendicular distance in millimeters from the vertical axis to transposed the post – treatment Mn1T

In addition to the above noted measurements, the molar differential was calculated. The pre – treatment molar differential was calculated as the perpendicular distance in millimeters from the vertical constructed axis to the mesial cusp tip of the mandibular molar subtracted from the perpendicular distance in millimeters from the vertical constructed axis to the mesial cusp tip of the corresponding maxillary molar (i.e. pre – treatment left molar differential was equal to pre – treatment Mx6L minus pre – treatment Mn6L or pre – treatment right molar differential was equal to pre – treatment Mx6R minus pre – treatment Mn6R). The post – treatment molar differential were calculated similarly using post – treatment molar positions in place of pre – treatment molar positions. The purpose of this calculation was to indicate the horizontal relationship of the maxillary molar to the mandibular molar. A negative value indicated that the maxillary molar was located distally relative to the corresponding mandibular molar (tending towards class I); a positive value indicated that the maxillary molar was located mesially relative to the corresponding mandibular molar (tending towards class II). A value of 0.0 millimeters indicated an end to end molar relationship.

To calculate the measurement replication errors seen in Tables 2 – 1 through 2 – 9 (pages 74 to 79) the following procedures were conducted:

1. For non – superimposed data the standard deviations for each of the four patient's five tracings (pre – and post – treatment) were calculated for each measurement (n = 40). The means and standard deviations of these values were then calculated (n = 8).
2. A similar procedure was followed for the superimposed values except that there were half as many superimposed values. Therefore, the sample size for the original standard deviation calculations was twenty (n = 20) and the means of the standard deviations and standard deviations of standard deviations had a sample size of four (n = 4).

2.3 Results

A. Measurement replication error

The measurement replication error for the non – superimposed angular and linear measurements are shown in Table 2 –1 (page 74). The mean standard deviations of the angular measurements were low. All values were less than one degree for the skeletal measurements and less than 2 degrees for the incisor measurements. In addition, the standard deviations of the standard deviations were small. The mean standard deviations for the non – superimposed linear measurements were 0.753 mm and 1.586 mm. For both the angular and linear measurements, the mean standard deviations varied between specific measurements for each radiograph.

The linear skeletal measurement replication errors, as indicated by their mean standard deviation, for the full lateral cephalometric radiograph tracings and superimpositions are shown in Table 2 – 2 (page 75) and Table 2 – 3 (page 75). The pre – treatment values could have been included in Table 2 – 1 since they were measured directly. They are included in these tables (Table 2 – 2, page 75 and Table 2 – 3, page 75) to facilitate comparison with post – treatment values. The mean standard deviation ranged from 0.78 mm to 1.281 mm. It should be noted that the mean standard deviation for the superimposed (post – treatment) point in each pairing was slightly larger than the corresponding non – transposed (pre – treatment) point. The mean standard deviation increases as the distance from the constructed axis intersection increases. For these skeletal measurements, the mean standard deviations varied between specific measurements for each radiograph.

Table 2 – 4 (page 76) and Table 2 – 5 (page 77) show the measurement replication error for the dental measurements that are present in the full lateral cephalometric radiograph superimposition. Again, the values are small. Many of the mean standard deviations are less than or equal to 1.00 mm. Those values that are greater than one millimeter are only slightly larger. The horizontal measurement of the lower right first molar demonstrated the greatest variation (mean standard

deviation of 1.320 mm). In general, the mean standard deviations were smaller for vertical measure than for the corresponding horizontal measure. Also, the mean standard deviations varied between specific measurements for each radiograph.

Maxillary superimposition measurement replication error was small (Table 2 – 6, page 78 and Table 2 – 7, page 78). Only two of the eight measurements had a mean standard deviation of greater than 1.00 mm. As was noted with the full lateral cephalometric radiograph superimposition values, there was less error associated with the vertical than the horizontal measurements and the error of the superimposed (post – treatment) points was generally slightly larger than the error of the non – superimposed (pre – treatment) points.

The error associated with the mandibular superimposition measurements demonstrated the greatest error (Table 2 – 8, page 79 and Table 2 – 9, page 79). While six of the twelve measurements had mean standard deviations less than 1.00 mm, the other six measurements had mean standard deviations greater than 1.00 with 1.566 mm being the maximum variability. Consistent with the error found in the maxillary and full lateral cephalometric radiograph superimposition measurements, the vertical values demonstrated smaller error values than the corresponding horizontal errors. However, unlike the error found in the maxillary and full lateral cephalometric radiograph superimposition measurements, the superimposed values were not consistently larger than the non – superimposed values.

B. Power Analysis

The following formula was used to calculate the sample size required to produce statistically significant data[24]:

$$n = 4 \bullet \frac{[t_{df}(1 - a/2)]^2 \, S_e^2}{(\text{practically significant difference})^2} \bullet (C_1^2 + C_2^2 + \ldots + C_K^2)$$

where

$t_{df}(1 - a/2)$ = Student's t – distribution with $n - 1$ degrees of freedom (df) at a 5 % level of significance (a) = 1.96 ($a = 0.05$)

S_e^2 = standard error squared

Practically significant difference = a clinically significant value

C_1 = coefficient for the linear combination = ½

C_2 = coefficient for the linear combination = - ½

Using this formula the following Power calculations were computed for different angular and linear practically significant differences (see Table 2 – 10, page 80).

Therefore, at a practically significant difference of 1 degree or 1 millimetre would require a minimal sample size of eleven patients or greater per group.

2.4 Discussion

Angular measurement replication error, as indicated by the mean standard deviation, was less than one degree for all skeletal non – superimposed measurements and slightly greater than one degree for incisor measurements (see Table 2 – 1, page 74). The variability found in this investigation is comparable to the variability found by Baumrind and Frantz for similar measurements.[3] The resulting error was probably a function of the magnitudes of estimating error for the landmarks it interrelates with, the separation distances among the landmarks used for each angular measure, and the directions from which the line segments connecting the landmarks intercept their respective envelopes of error.[3] Trpkova *et al* conducted a meta analysis of landmark identification and reproducibility.[19] Comparison of error magnitude is difficult because their study evaluated landmarks in the horizontal and vertical planes separately using linear (millimetric) measures. However, their contention that A point, B point, pterygomaxillary fissure (inferior), sella, and gonion were reliable cephalometric landmarks appears to be supported by the variability found in this investigation since measurements using these landmarks have relatively small error values.[19]

Relative to the angular measurements, it appears that the non – superimposed linear measurements demonstrated a greater amount of variability (see Table 2 –1, page 74, Table 2 – 2, page 75 and Table 2 – 3, page 75). Again, the error probably resulted from the interaction of landmark identification error, separation distance, and the relationship of the landmark's envelope of error to the line segement.[3] It is not surprising then, that the variability would be greater for the linear measurement of nasion perpendicular to pogonion than for the variability of the linear measurement of nasion perpendicular to A point. This would occur because of the increased distance of pogonion from the other landmarks used. This increased distance would exacerbate any error in the production of horizontal reference FH or in the production of the perpendicular to it. The increased magnitude in the variability of the measurement of pogonion coincides with the meta analysis of landmark reliability.[19] This landmark (Pg) demonstrated increased variability as compared with other landmarks, especially in the vertical direction.[19]

Table 2 – 4 (page 76) and Table 2- 5 (page 77) depict the linear measurement replication error of the maxillary and mandibular molars and incisors for the full lateral cephalometric radiograph tracing with the superimposed molar and incisor positions from the post – treatment tracing. One would expect that the variability of the superimposed (post – treatment) molar position linear measurements would be consistently larger because of the additional source of error created by the process of superimposition. However, this is not the general pattern found in the calculated error data. Although in some cases this supposition holds (26, 16, and 36 vertical and 46 horizontal), the reverse can be demonstrated for the remaining measurements. This may indicate that the error introduced by the superimposition is not significant. It has been noted that, in general, the vertical measurements demonstrated less variability than the horizontal measurements for each molar type (i.e. maxillary and mandibular). This can be attributed to the increased difficulty in locating the horizontal position of the mesiobuccal cusp tip. Vertically, the most inferior (maxillary molar) or most superior (mandibular molar) portion of the cusp becomes apparent during the measurement process because the maximum (maxillary molar) or minimum (mandibular molar) distance can be easily distinguished. In the horizontal direction the cusp tip has width from which the tip must be estimated. This is analogous to determining pogonion. In the horizontal direction, the most prominent

point can be found more reliably relative to a constructed axis because of a definitive termination of the bony chin. In the vertical direction however, the chin point has width and no definite termination. Therefore, as is demonstrated in the meta analysis by Trpkova *et al*,[19] the error in determination of pogonion in a vertical direction was much greater than the corresponding error in the horizontal direction.

The increased measurement replication error seen in the horizontal linear measurements may also be related to the number of perpendicular lines required to produce a measurement. Only one perpendicular is required to complete a measurement in the vertical direction whereas completion of a horizontal measurement requires two perpendiculars. It was also noted that the error in determining the position of the mandibular cusp tip was greater than the error in determining the position of the maxillary cusp tip. This can be attributed to the dental anatomy of the corresponding cusp tips. According to Fuller and Denehy, the mesiobuccal cusp of the maxillary first molar is quite sharp in comparison to the rather blunt and rounded mesiobuccal cusp of the mandibular first molar.[20] This relative increased sharpness of the maxillary molar mesiobuccal cusp would make identification easier, thus reducing error. Regardless of the probable causes of the measurement replication errors, the absolute value of the error is comparable to other landmarks with respect to reliability.[19]

The linear skeletal measurements from the full lateral cephalometric radiograph tracing and the associated superimpositions of post – treatment landmarks demonstrate increasing error as the distance from the constructed axis increases and increased error of the superimposed points (see Table 2 – 2, page 75 and Table 2 – 3, page 75). The first observation can be attributed to an increase in the deviation of the perpendicular line as the distance from the axis increases and in the reduced reliability of locating pogonion compared with A point and B point as per Trpkova *et al.*[19] The second observation can be attributed to the additional error created by the process of superimposition.

The maxillary tracing and the associated superimposition linear dental measurements demonstrate increased error of the superimposed (post – treatment) measurements as compared to the non – superimposed (pre – treatment) measurements (see Table 2 – 6, page 78 and Table 2 – 7, page 78). This increased error can be attributed to the additional error introduced during the transposition of the post – treatment molar position onto the pre – treatment tracing. It should be noted that the relative increase in the magnitude of error between pre – and post – treatment measurements is greater for the maxillary tracing than for the full lateral cephalometric radiograph tracing. This may be the result of increased difficulty in establishing a consistent superimposition for the maxillary tracing. This concurs with the findings of Baumrind *et al* who contend that the maxillary superimposition is less reliable than the anterior cranial base (full lateral cephalometric radiograph) superimposition.[14] As with the full lateral cephalometric radiograph tracing, larger variability was noted in the horizontal measurements. This increased error can be attributed to the shape of the cusp, as was noted previously. This error may also be compounded by the additional perpendicular required to complete the measurement.

The mandibular tracings and the associated superimpositions produced errors that had similar patterns to the maxillary tracings (see Table 2 – 8, page 79 and

Table 2 – 9, page 79). Non – superimposed (pre – treatment) measurements demonstrated less variability than the superimposed (post – treatment) measurements. This increase in the magnitude of error most likely can be attributed to the additional caused by the process of superimposition. It is interesting to note that, unlike the maxillary tracing errors, the increase in error was greater for the vertical measurements than for the horizontal measurements. The type of error that occurs when conducting mandibular superimpositions using the symphysis may account for this difference. According to Baumrind *et al*, the primary error occurs through rotation.[14] Rotational error would have a greater impact on the vertical position of the superimposed molar than the horizontal position. In general, the error was greater for the mandibular molar measurements. As noted above, this may be attributed to the difference in anatomy between maxillary and mandibular molar cusps.

2.5 Conclusions

Angular and linear measurement replication error of non – superimposed and superimposed cephalometric measurements that were relevant to this investigation have been presented. In general, these measurements demonstrated error that is comparable to measurement replication error reported in the literature,[19] and thus the measurement technique used appears to be reasonably reliable and reproducible. However, it should be noted that, as the distance from the constructed axis to the measured landmark increases, so does the error.

Table 2 –1 **Non – superimposed Angular and Linear Measurement Replication Error (Skeletal Measurements)**

Measurement	Measurement Mean	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
Angular Measurements (degrees)				
SNA	80.78	0.539	0.00667	0.287
SNB	76.75	0.4725	0.00616	0.1648
SNPg	78.03	0.4855	0.00622	0.2028
ANB	4.03	0.4089	0.101	0.1629
Mandibular Plane to FH	21.44	0.988	0.0461	0.591
Mandibular Plane to SN	31.25	0.773	0.0247	0.344
SN to Mx1	100.33	1.186	0.0118	0.569
FH to Mx1	106.84	1.703	0.0159	1.083
FMIA	55.28	1.344	0.0243	0.559
Mandibular Plane to Mn1	99.56	1.071	0.0108	0.384
Linear Measurements (mm)				
Nasion perp. to A	2.89	0.753	0.261	0.445
Nasion perp. to Pg	-10.30	1.586	0.154	1.187

* SD taken over 5 tracings of each radiograph, mean of SD taken over 8 radiographs

Table 2 – 2 **Pre – treatment Linear Measurement Replication Error (Skeletal Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
S perp. to A point	69.60	0.781	0.0112	0.248
S perp. to B point	61.20	1.037	0.0169	1.068
S perp. to Pg	62.33	1.041	0.0167	0.745

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 3 **Post – treatment Linear Measurement Replication Error (Skeletal Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
S perp. to A point	69.28	0.797	0.0115	0.248
S perp. to B point	60.83	1.241	0.0204	0.528
S perp. to Pg	61.88	1.281	0.0207	0.816

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 4 **Pre – treatment Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
26 Vertical	42.98	0.3905	0.00909	0.1453
16 Vertical	43.70	0.4485	0.0103	0.1783
26 Horizontal	40.83	1.193	0.0292	0.594
16 Horizontal	41.93	1.082	0.0258	0.552
36 Vertical	42.40	0.773	0.0182	0.380
46 Vertical	42.98	1.003	0.0233	0.303
36 Horizontal	39.40	1.124	0.0285	0.619
46 Horizontal	40.90	1.290	0.0315	0.445
Mx1 Vertical	49.83	0.305	0.00612	0.335
Mx1 Horizontal	73.75	0.854	0.0116	0.542
Mn1 Vertical	44.73	0.499	0.0112	0.186
Mn1 Horizontal	68.28	0.839	0.0123	0.494
Overbite	5.10	0.318	0.0624	0.086
Overjet	5.48	0.401	0.0731	0.054

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 5 **Post – treatment Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
26 Vertical	47.53	0.599	0.0126	0.338
16 Vertical	48.13	0.535	0.0111	0.262
26 Horizontal	40.60	1.175	0.0289	0.410
16 Horizontal	41.93	1.004	0.0239	0.405
36 Vertical	47.60	0.814	0.0171	0.328
46 Vertical	48.46	0.777	0.0160	0.234
36 Horizontal	41.90	1.020	0.0243	0.700
46 Horizontal	43.53	1.320	0.0303	0.468
Mx1 Vertical	53.65	0.580	0.0108	0.390
Mx1 Horizontal	71.80	0.994	0.0138	0.532
Mn1 Vertical	51.40	0.479	0.00932	0.262
Mn1 Horizontal	69.58	1.182	0.0170	0.622
Overbite	2.25	0.385	0.171	0.412
Overjet	2.23	0.400	0.179	0.212

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 6 **Pre – treatment Maxillary Tracing Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
26 Vertical	42.88	0.488	0.0114	0.464
16 Vertical	43.48	0.437	0.0101	0.323
26 Horizontal	24.63	0.739	0.0300	0.350
16 Horizontal	26.13	0.723	0.0277	0.335
Mx1 Vertical	49.93	0.830	0.0166	0.490
Mx1 Horizontal	57.48	0.747	0.0130	0.398

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 7 **Post – treatment Maxillary Tracing Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
26 Vertical	45.50	0.660	0.0145	0.307
16 Vertical	46.40	0.733	0.0158	0.398
26 Horizontal	26.05	1.223	0.0469	0.462
16 Horizontal	27.68	1.250	0.0452	0.591
Mx1 Vertical	50.93	0.811	0.0159	0.270
Mx1 Horizontal	56.63	0.871	0.0154	0.650

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 8 **Pre – treatment Mandibular Tracing Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
36 Vertical	30.08	0.5295	0.0176	0.0977
46 Vertical	30.40	0.5830	0.0192	0.1743
36 Horizontal	35.48	1.438	0.0402	0.808
46 Horizontal	37.25	1.566	0.0420	0.807
Mn1 Vertical	38.48	0.247	0.00642	0.292
Mn1 Horizontal	62.85	1.454	0.0231	0.912

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 9 **Post – treatment Mandibular Tracing Linear Measurement Replication Error (Dental Measurements)**

Measurement (mm)	Mean of Measure	Mean of Standard Deviation*	Coefficient of Variation	Standard Deviation of Standard Deviation
36 Vertical	32.03	0.9192	0.0287	0.1219
46 Vertical	32.43	0.710	0.0219	0.231
36 Horizontal	37.10	1.502	0.0405	1.123
46 Horizontal	38.58	1.393	0.0361	1.057
Mn1 Vertical	39.25	0.586	0.0149	0.048
Mn1 Horizontal	63.53	1.428	0.0224	0.790

* SD taken over 5 tracings of each radiograph, mean of SD taken over 4 radiographs

Table 2 – 10 Power Analysis Calculation Results

Largest SD	Practically Significant Difference			
Linear (1.586 mm)	0.5 mm	1.0 mm	1.5 mm	2.0 mm
Power	38.7	9.7	4.3	2.4
Angular (1.703 degrees)	0.5 degrees	1.0 degrees	1.5 degrees	2.0 degrees
Power	44.6	11.1	5.0	2.8

Figure 2 – 1 Cephalometric Landmarks

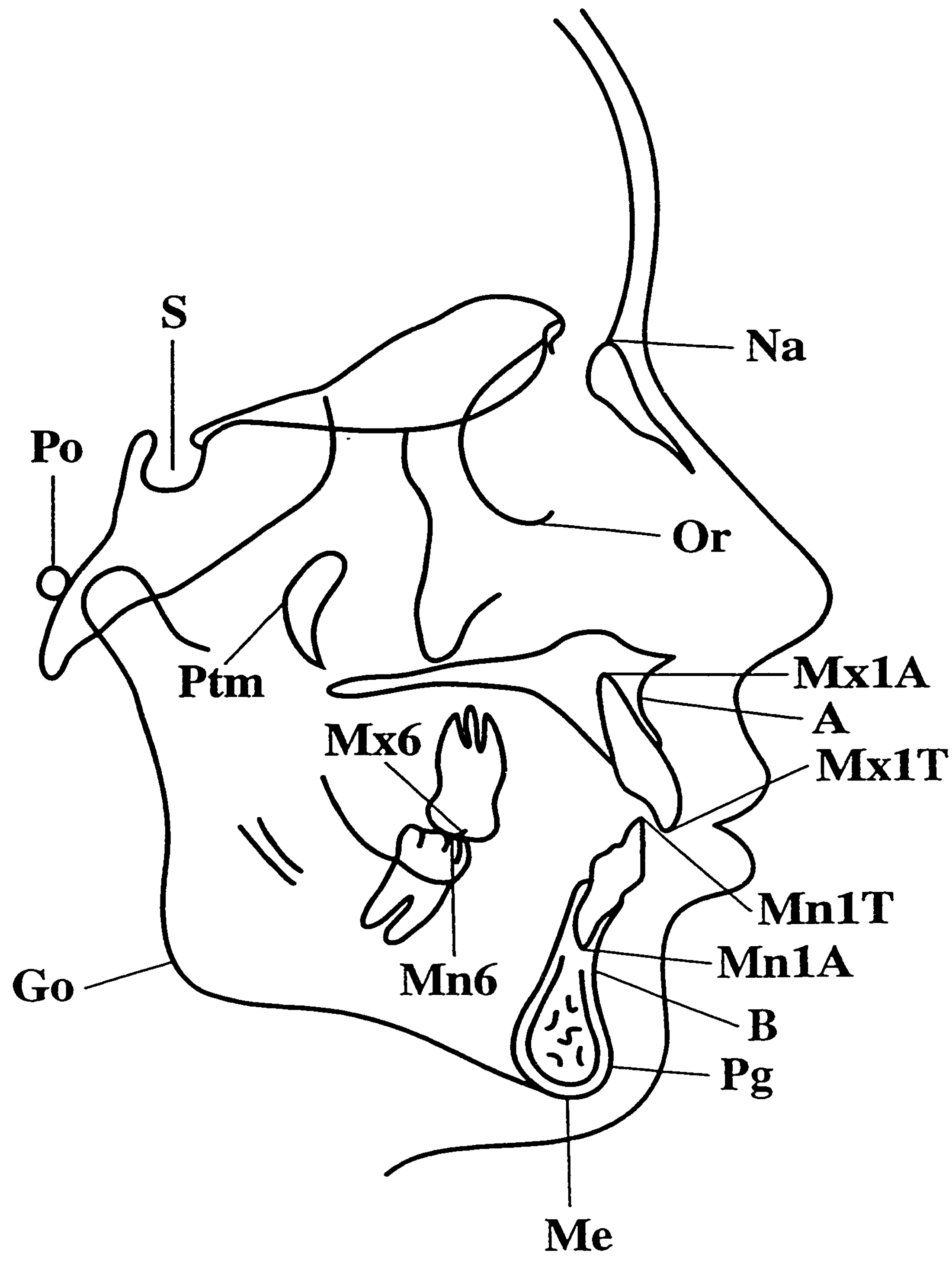


Figure 2 – 2 Non – superimposed Angular Measurements

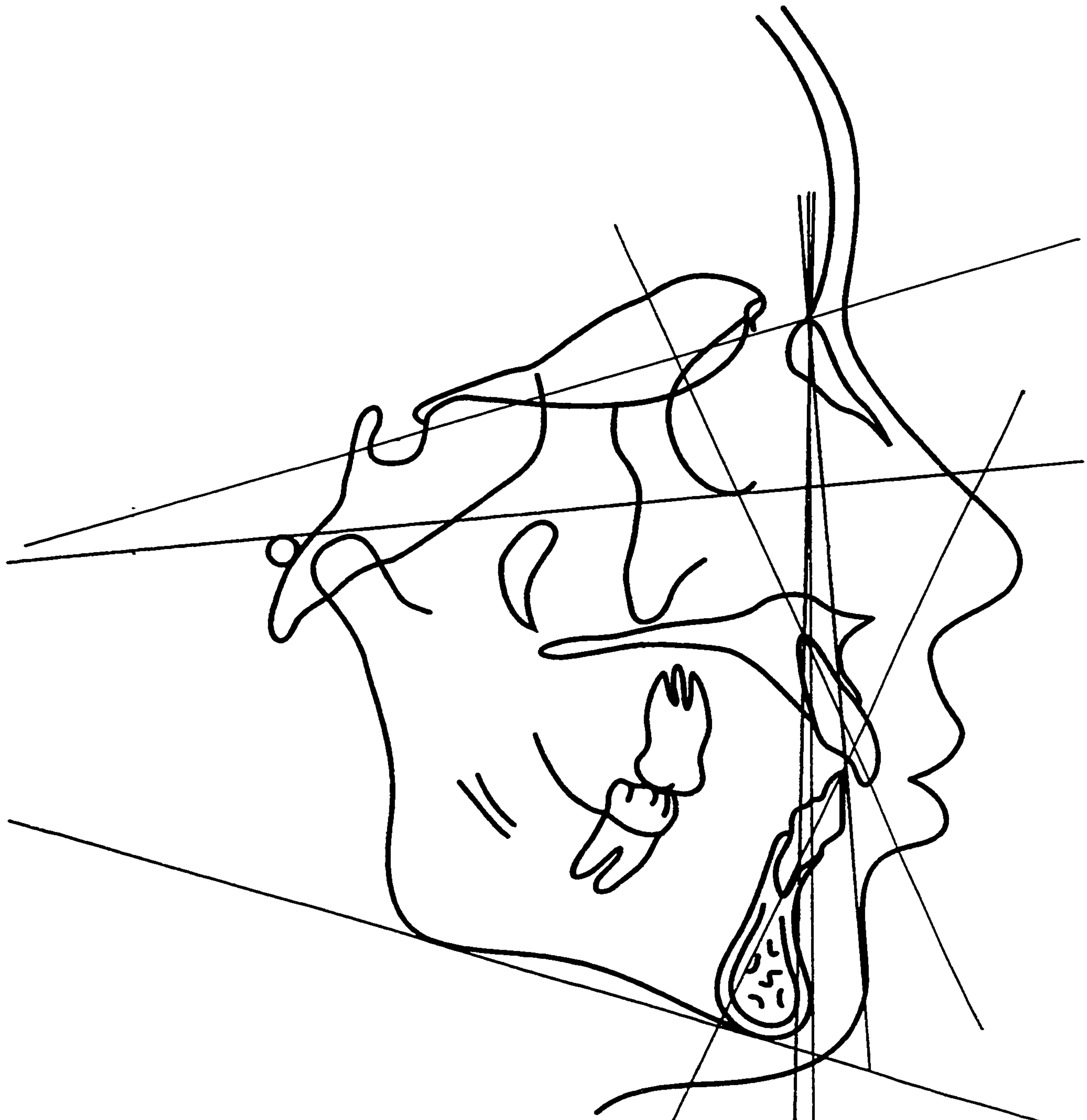


Figure 2 – 3 Non – superimposed Linear Measurements

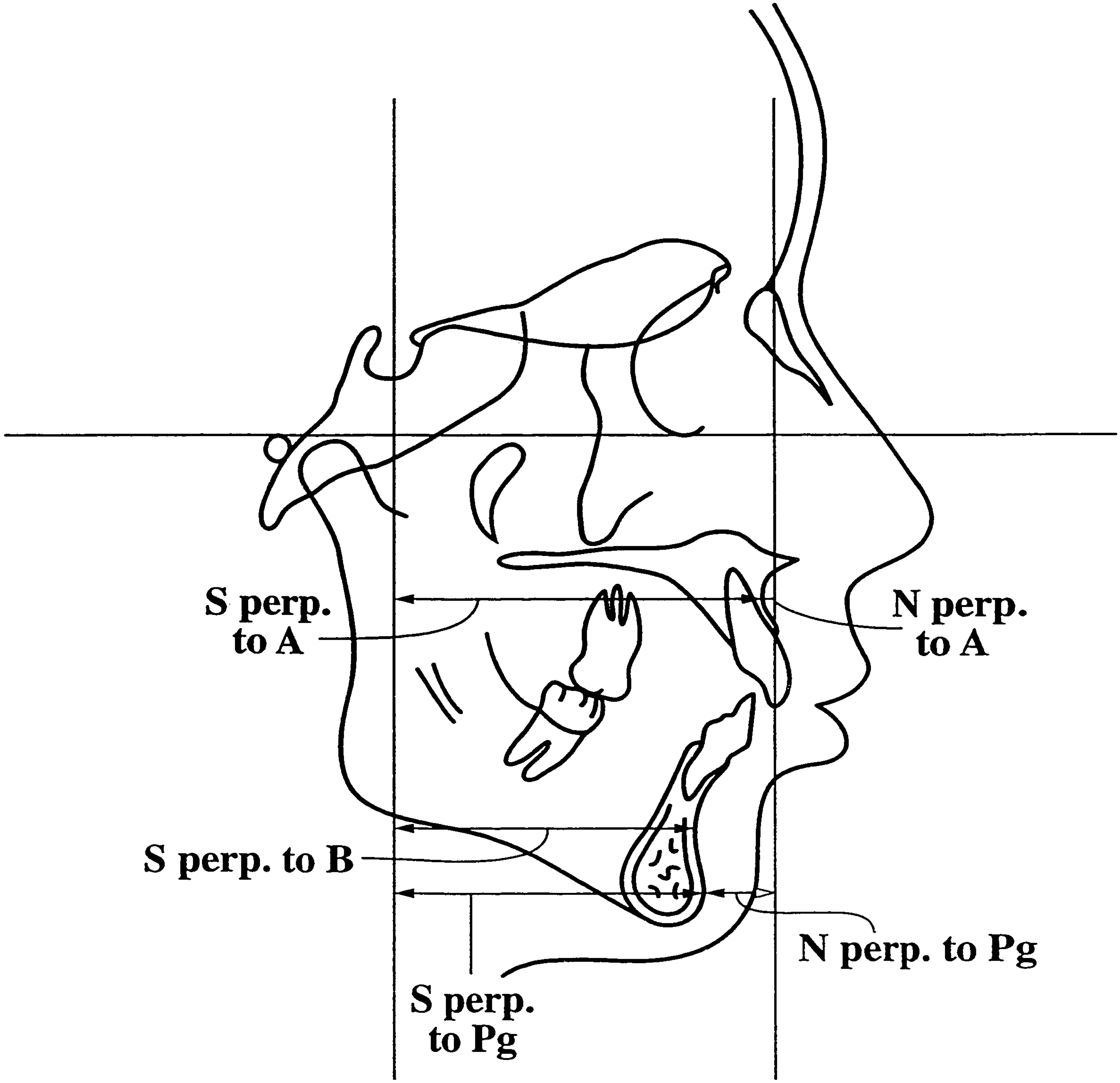


Figure 2 – 4 **Non – superimposed and Superimposed Linear Measurements**

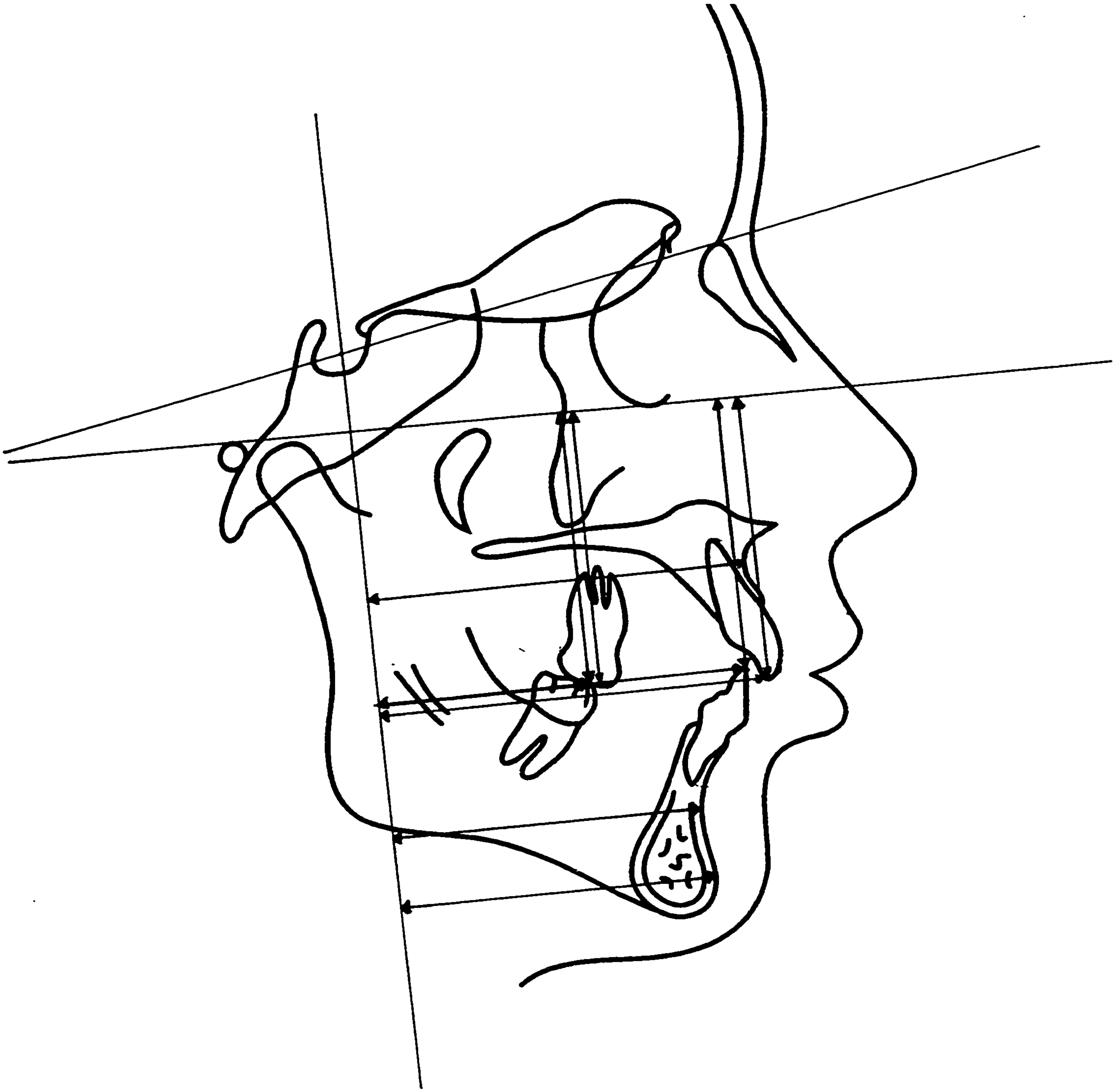


Figure 2 – 5 **Maxillary Non – superimposed and Superimposed Linear Measurements**

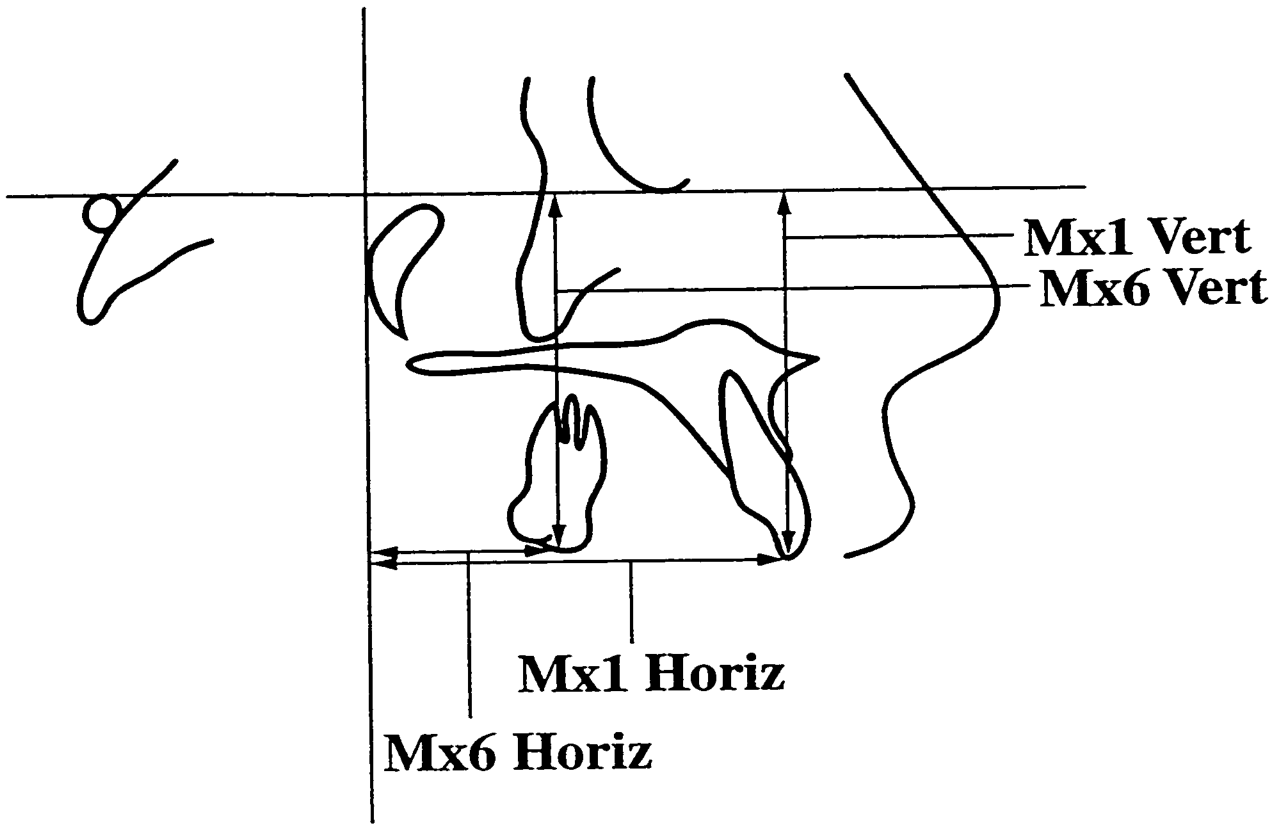
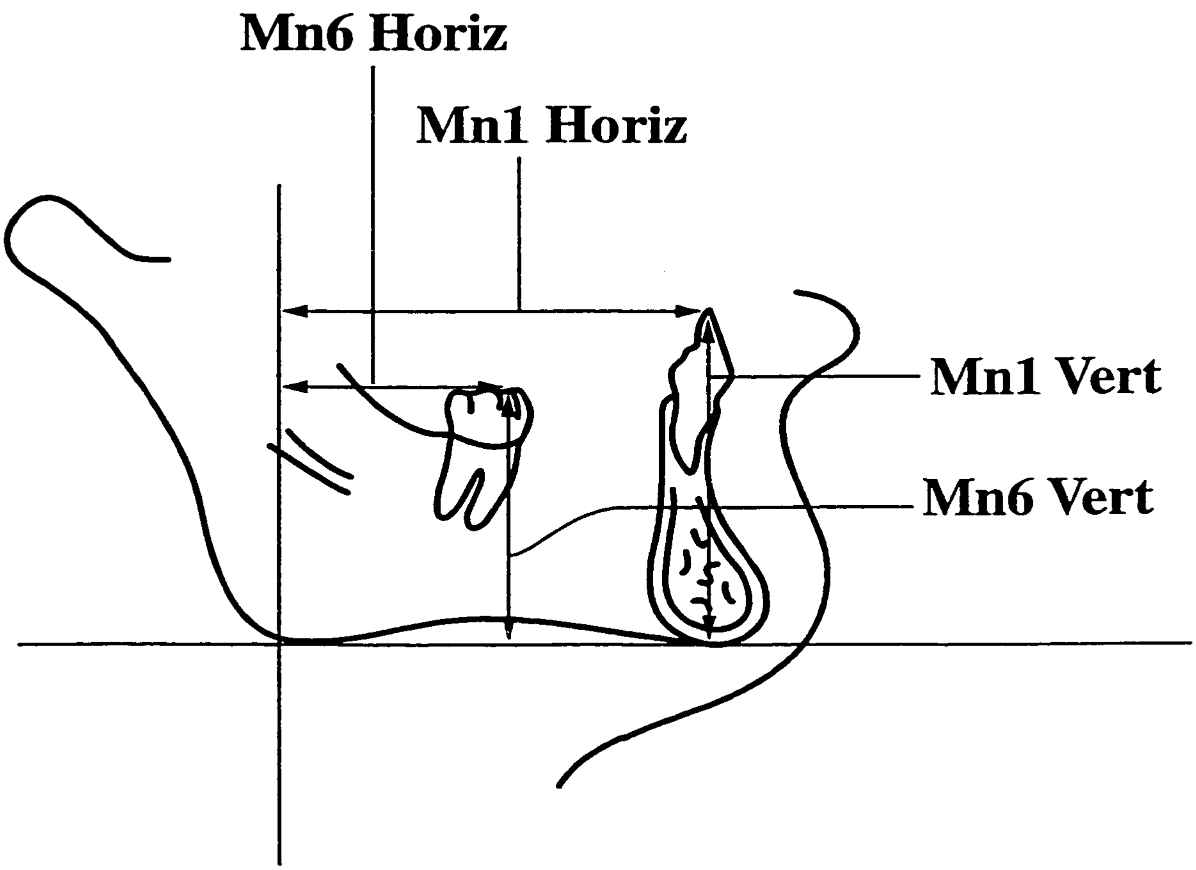


Figure 2 – 6 **Mandibular Non – superimposed and Superimposed Linear Measurements**



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Chapter Three

Paper #2

Comparison of Orthopedic Treatment Outcomes Utilizing Cervical Headgear or Wilson Bimetric Distalizing Arch™ – A Cephalometric Study

3.1 Introduction

Patients with class II malocclusions commonly present to the orthodontist for treatment.[1] The type of treatment that the orthodontist chooses will depend on the nature and severity of the presenting malocclusion and the philosophy, experience and educational background of the practitioner. A myriad of other factors such as, but not limited to, the patient's age, level of physical and dental development, and predicted level of cooperation will also influence the treatment modality selected and utilized.

Non-surgical correction of class II malocclusions can be achieved through growth modification, dental camouflage, or compensation of the skeletal discrepancy.[2,3] In North America, extraoral force has been the most frequent approach to growth modification, whereas the Europeans favored the use of functional appliances.[3,4] Numerous studies have demonstrated the efficacy of extraoral traction in achieving a class I molar relationship.[3,5-10] However, a consensus has not been reached as to the cervical headgear's mechanism of class II correction or long term affects.[3] One researcher has concluded that extraoral traction alters the apical base relationship by influencing maxillary alveolar growth.[5] Another has concluded that class II correction is achieved through orthodontic distalization of maxillary molars.[6] Additional investigators have demonstrated other mechanisms of class II correction such as inhibition of mesial migration of the maxillary molar with the downward and forward growth of the maxillary complex,[7] alteration in the direction of growth of the maxilla,[8,9] and mandibular growth accentuation.[9-11] More recently, the efficacy of cervical headgear treatment has been questioned. The results of a long term, randomized clinical trial have demonstrated that the difference in the full lateral cephalometric radiograph change in the anteroposterior jaw relationship was very similar between the headgear treated group and the control group.[12]

Dental compensation as a method of class II correction can be accomplished by distalization of the maxillary dentition, mesialization of the mandibular dentition or a combination of both. Many methods have been proposed for the distalization of maxillary molars as a form of dental compensation for class II malocclusions.[14-23] Class II elastics, rare earth repelling magnets, super elastic nickel-titanium arch wires and coils, the Jones Jig™ and its modifications, the pendulum appliance and the Wilson Bimetric Distalizing Arch™ have all been proposed for class II correction.[14,15,17,19-23,32]

Although the Wilson Bimetric Distalizing Arch™ (see Figure 3 – 1, page 109 for diagrams) was introduced in 1978,[33,34] there appears to be a paucity of data regarding the efficacy of this appliance. The purpose of this study was to investigate the orthopedic treatment effects of the Wilson Bimetric Distalizing Arch™ in conjunction with full fixed appliance therapy. These orthopedic effects were compared to a matched sample of patients treated with cervical headgear, bite plate and full fixed appliance therapy.

3.2 Materials and Methods

The sample of convenience for this study consisted of pre – treatment and immediate post – treatment lateral cephalometric radiographs of 33 patients obtained from the private practice of a single, experienced orthodontist. The criteria for patient selection were as follows:

1. Class II skeletal pattern as indicated by an ANB angle of greater than or equal to 4.0 degrees.
2. Class II dental relationship as indicated by a molar relationship of end to end or greater on the lateral cephalometric radiograph..
3. Age range for the patients was between 9.0 years and 12.5 years at the outset of treatment.
4. Facial growth pattern in a 'neutral' direction as determined by satisfying that the mandibular plane to FH angle be within the published range of norms.
5. All patients had to have undergone non – extraction treatment consisting of either Wilson Bimetric Distalizing Arch therapy or cervical headgear/anterior biteplate therapy in conjunction with full fixed appliance therapy.

In addition, the availability of pre – treatment and post- treatment lateral cephalometric radiographs exhibiting sufficient contrast and definition were required. An attempt was made to match the samples based on age at the outset of treatment, gender, skeletal relationship, dental relationship, and a 'neutral' growth pattern.

The ages and gender distributions of the two groups are displayed in Table 3 – 1 (page 104). All patients were successfully treated to a class I molar relationship (as indicated by the lateral cephalometric radiograph) with mean overjet relationships of 2.18 mm to 2.57 mm and mean overbite relationships of 1.43 mm to 2.16 mm.

All pre – and post – treatment lateral cephalometric radiographs were obtained by a private imaging facility using a Seimens Orthoceph 10S radiograph machine using a standardized radiographic technique. This technique used an exposure setting of 0.32 to 0.40 milliseconds at 12 mA and 75 kVp. The film to source distance is 75 inches and the patient to source distance is 60 inches.

Measurement replication error was calculated as mean standard deviation for angular and linear measurements. Angular measurements demonstrated mean standard deviations of less than 1.0 degree with very low coefficients of variation. Linear measurements demonstrated mean standard deviations of 1.5 millimeters or less. The coefficient of variation was larger than for the angular measurements. This information enabled the calculation of sample size using a Power analysis. The calculated sample size for a 1.0 mm and 1.0 degree practically significant difference was twelve patients per group.

Fourteen consecutive patients treated with the Wilson Bimetric Distalizing Arch™ were selected from the patient base of a single practitioner whose records were all produced by a private imaging facility. A corresponding sample of headgear/bite plate treated patients matched for age, skeletal pattern, and dental relationship was selected for the comparison. This second group of patients was also selected from the previously mentioned patient base.

Treatment mechanics for each sample was consistent. The Wilson Bimetric Distalizing Arch™ group had their molars distalized into a 'super' class I relationship followed by the placement of a Nance holding arch. Once the remaining premolar and cuspid teeth erupted, they were also distalized after full fixed bonding using sliding mechanics. A closing loop was then utilized to retract the anterior teeth. The cervical headgear/bite plate group were also treated to a class I molar relationship. The headgear was maintained at night until dental maturation. A similar procedure for space closure with full fixed bonding was utilized.

All pairs of lateral cephalometric radiographs were then blinded, randomized and assigned an identification number. The principal examiner traced the radiographic pairs. The landmarks listed in Table 3 - 2 (page 104) were identified.

The following angular measurements were made on each full lateral cephalometric radiograph tracing (see Figure 3 – 3, page 111):

1. ANB – the angle in degrees made from the intersection of lines NaA and NaB
2. FH – MnPl – the angle in degrees made from the intersection of lines PoOr and GoM

A coordinate system was then constructed for each pre – treatment cephalometric tracing. The coordinate system for the full lateral cephalometric radiograph tracing was the PoOr line (Frankfort horizontal) in the horizontal direction and a line perpendicular to PoOr registered at S (see Figure 3 – 4, page 112).

The following linear measurements were then made on each full lateral cephalometric radiograph tracing (see Figure 3 – 4, page 112):

1. N perpendicular to A point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to A point*

2. N perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to Pg*
3. S perpendicular to A point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to A point
4. S perpendicular to B point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to B point
5. S perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to Pg

(* A negative value was assigned if the landmark was to the left of the vertical perpendicular and a positive value was assigned if the landmark was to the right of the vertical perpendicular)

To complete the anterior cranial base superimposition the pre – treatment tracing was placed over the post – treatment tracing and the best fit of anterior cranial base structures was obtained. A point, B point, and Pg were transposed from the post – treatment tracing onto the pre – treatment tracing.

The following linear measurements were completed on the superimposed tracing:

1. N perpendicular to A point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to A point that has been transferred from the post – treatment tracing *
2. N perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at N to Pg that has been transferred from the post – treatment tracing *
3. S perpendicular to A point - the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to A point that has been transferred from the post – treatment tracing
4. S perpendicular to B point – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to B point that has been transferred from the post – treatment tracing
5. S perpendicular to Pg – the linear measurement in millimeters made perpendicular from a line perpendicular to the line PoOr registered at S to Pg that has been transferred from the post – treatment tracing

(* A negative value was assigned if the landmark was to the left of the vertical perpendicular and a positive value was assigned if the landmark was to the right of the vertical perpendicular)

Treatment charts of the patients from both groups were consulted to determine the number of months in phase I treatment (active, retention, and total) and the number of months in phase II treatment (active). The total number of appointments in each phase was also determined.

Paired Student t – tests were then completed to examine the appropriateness of the matched samples and to detect differences in orthopedic treatment effects between the two samples.

3.3 Results

The pre – treatment age and skeletal cephalometric values for the two sample groups is presented in Table 3 – 3 (page 105). There was a statistically significant difference in age between the two groups. The patients being treated with the Wilson Bimetric Distalizing Arch™ were approximately nine months older than the patients being treated with headgear at the outset of treatment.

The headgear group and the Wilson Arch group had mandibles that were retruded with respect to the maxilla as measured by the ANB angle. The ANB angles were 4.50 degrees (for the Wilson Arch group) and 4.84 degrees (the headgear group). This slight difference in the ANB angle between the two groups was not statistically significant. This measurement, in addition to the mandibular measurements, indicated that both groups could be classified as retrognathic (i.e. mild class II).

Another skeletal measurement is the mandibular plane angle. The FH to mandibular plane angle demonstrated a statistically significant difference between the two groups. The headgear group had mandibular plane angles relative to FH that were larger than in the corresponding Wilson Arch group. Both of these values were within published norms (mean 24 degrees, range 18 to 30 degrees)[32].

The vertical constructed axis enabled further comparison of the skeletal components of each group. No statistically significant differences were noted of the initial horizontal position of A point or B point relative to the vertical constructed axis. The initial horizontal position of Pg relative to the constructed axis was statistically greater for the Wilson Arch group.

Table 3 – 5 (page 107) portrays the post – treatment age and skeletal cephalometric measurements from the full lateral cephalometric radiograph tracing. At the completion of treatment the age of the two groups was not statistically different. There was however, almost a nine month age difference between the two groups. The Wilson Arch group, on average, was still older.

The measurements that indicate the position of the maxilla demonstrate equality between the two groups. That is, there were no statistically significant differences between the Wilson Arch group and the headgear group with respect to N perpendicular to A point or the perpendicular distance of A point from the vertical constructed axis. Similarly, the positional indicator measurement of B point (the perpendicular distance of B point from the vertical constructed axis) shows no statistically significant difference between the two groups.

No statistically significant differences were noted for the two measurements of Pg (N perpendicular to Pg and the perpendicular distance of Pg from the vertical constructed axis).

The inclination of the mandibular plane to the cranial base was larger in the headgear group than the Wilson Arch group. This difference was statistically significant with the headgear group being slightly steeper.

The elapsed time (from initial records to post – treatment records) and the changes in skeletal measures are presented in Table 3 – 6 (page 108).

The elapsed time, which included phase I treatment (either Wilson Arch or headgear) and full fixed appliance therapy, was just over 3 and one half years for both groups. No statistically significant difference was noted.

No statistically significant differences were noted in either the number of appointments or number months in treatment for either phase (phase I or phase II) (see Table 3 – 3, page 105).

There were no statistically significant differences between the two groups with respect to change in skeletal measurements. The N perpendicular to A point measurement reduced in both groups. A point, as measured from the vertical constructed axis, increased slightly in the Wilson Arch group and in the headgear group (see Table 3 – 6, page 108). There were corresponding increases in the linear measurements of Pg and B point. Both groups experienced a reduction in the ANB angle. The decrease was greater in the Wilson Arch group but the difference was not statistically significant.

3.4 Discussion

The age difference between the two groups was approximately nine months, with the Wilson Arch group being significantly older. This difference may represent a sampling error or it may represent a bias on the part of the practitioner for treating older class II patients with the Wilson Arch. Regardless of the cause, the age difference must be considered in the interpretation of the data. However, the age range for both groups was within the pubertal growth phase and it is unlikely growth potential was a significant factor. In addition, maxillary second molars were not erupted in either group and therefore it is unlikely that the second molar position influenced the results.

The statistically significant differences noted between the two groups with respect to pre – treatment cephalometric measurements may also demonstrate a bias of the orthodontic practitioner. The skeletal measurements indicate that the Wilson Arch group had more prominent pogonion positions. In skeletal class II cases, increased pogonion prominence would tend to camouflage the skeletal disharmony. The possibility exists that treatment selection may have been influenced by facial appearance. Therefore, those patients that appeared to be facially more class II due to a weak pogonion may have been treated with headgear therapy based on the assumption that greater skeletal affects would ensue.

The sample size for the Wilson Arch group is slightly smaller than the headgear group. Gender difference between groups could impact the results if there was a difference in the amount of growth, the direction of growth, or the response to treatment between the two genders. In our study, there was a difference in the number of patients of each gender in the two groups. This is not a concern because the ratios of males to females in each sample are equal. The impact of each gender will be proportionately equal to the sample as a whole. Unfortunately, it was not possible to separate the two samples by gender because the sample sizes were not large enough to permit this. Therefore, it is possible that gender specific differences in treatment outcome may have occurred that could not be evaluated due to lack of power of the sample size.

In general, there appears to be a moderation in the post – treatment skeletal measurements in both samples. After approximately three and a half years of treatment the Wilson arch group exhibited similar skeletal changes as the Headgear group. This indicates that treatment effects (or lack thereof) of the two groups were similar. One would not expect to see skeletal effects induced by Wilson Arch treatment. Thus, any skeletal effects that were produced by headgear/bite plate therapy were not maintained during the second phase of full fixed appliance therapy. Alternatively, skeletal effects may have been minimal and mainly the result of growth. Therefore, over the treatment time period, growth in both groups was similar.

The length both samples were in treatment was statistically equivalent. Although statistically the number of months in active treatment was not statistically significant it may be clinically significant because reducing active treatment time may reduce cost of treatment for the practitioner.

It is difficult to compare this study to the data presented by Muse *et al* because of differences in the timing of post – treatment evaluation and the method of superimposition.[30] Muse *et al* evaluated their treatment effects after the 16 week molar distalization phase whereas this investigation also took into account phase two treatment and approximately 3 years of development. Therefore, differences between these two studies may be related to the growth compensation that could have occurred during the longer treatment time. Different superimposition techniques may also produce differing results.[30] Differences in practitioners may have also influenced results.

3.5 Conclusions

The following conclusions can be drawn:

1. No statistically significant differences were noted regarding the length of treatment or number of required appointments between the headgear treated group and the Wilson Bimetric Distalizing Arch treated group.
2. No statistically significant differences were noted regarding the length of treatment or number of appointments for either phase of treatment.
3. No statistically significant differences were noted with respect to the change in skeletal cephalometric measurements between the headgear treated group and the Wilson Bimetric Distalizing Arch™ treated group.

The clinical implication of these conclusions is that neither of these treatment modalities is superior to the other with respect to skeletal effects. Therefore, the decision to use one of these appliances over the other should not be based on effectiveness of inducing skeletal change.

Table 3 – 1 Age and Gender Distribution

Group	Gender	Number	Mean Age (Pre – treatment) (years)	Mean Age (Post – treatment) (years)	Length of Treatment (years)
Wilson Bimetric Distalizing Arch™ Group	Female	10	10.94	14.69	3.74
	Male	4	12.17	15.27	3.10
Cervical Headgear/Bite Plate Group	Female	14	10.33	13.89	3.55
	Male	5	11.06	14.80	3.54

Table 3 – 2 Landmarks

Landmark	Abbreviation	Definition
Sella	S	The centre of the hypophyseal fossa (sella turcica)
Nasion	Na	The junction of the nasal and frontal bones at the most posterior point on the curvature of the bridge of the nose
A point	A	The innermost point on the curvature from the maxillary anterior nasal spine to the crest of the maxillary alveolar process
B point	B	The innermost point on the curvature from the chin to the alveolar junction
Pogonion	Pg	The anterior most point on the contour of the chin
Menton	Me	The most inferior point on the curve of the symphysis of the mandible as determined by using a line tangential to the lower border of the mandible
Gonion	Go	The point midway between the points representing the middle of the curvature at the left and right angles of the mandible
Porion	Po	The most superior point on the curvature of the shadow of the auditory canal
Orbitale	Or	The point midway between the lowest point on the inferior bony margin of the left and right orbital rims
Pterygo-maxillary fissure	Ptm	The most posterior point on the curvature of the posterior wall of the pterygomaxillary fissure

Table 3 – 3 Treatment Times and Number of Appointments

Measurement	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Phase I				
Total Time (months)	11.77 (7.50)	11.10 (10.6)	0.67	0.84
Active Treatment Time (months)	5.00 (1.63)	8.53 (7.20)	- 3.53	0.085
Retention Time	6.77 (6.89)	2.53 (4.93)	4.24	0.079
Number of Appointments	9.38 (4.75)	8.93 (7.79)	0.45	0.85
Phase II				
Total Time (months)	22.15 (4.93)	23.00 (6.96)	- 0.85	0.71
Number of Appointments	19.62 (5.16)	21.07 (7.59)	- 1.45	0.56

Table 3 – 4 Pre – Treatment Cephalometric Measurements (Age and Skeletal)

Measurement	Published Mean Norms	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Age (years)		11.29 (1.20)	10.53 (0.79)	0.76	0.049*
Skeletal					
ANB (degrees)	2	4.50 (0.65)	4.84 (1.40)	-0.34	0.36
MnPl to FH (degrees)	22	24.25 (2.64)	26.71 (3.70)	-2.46	0.033*
N perp. to A (mm)	F: 2.3 M: -1.7	-1.79 (1.94)	-1.16 (3.18)	-0.63	0.49
N perp. to Pg (mm)	F: -6.7 M: -7.7	-8.68 (2.71)	-9.63 (3.99)	0.92	0.42
S perp. to A point (mm)		69.32 (3.25)	68.26 (2.45)	1.06	0.33
S perp. to B point (mm)		61.25 (3.54)	59.24 (3.21)	2.01	0.10
S perp. Pg (mm)		62.75 (3.75)	59.79 (3.65)	2.96	0.032*

* significant at 5 % level of significance

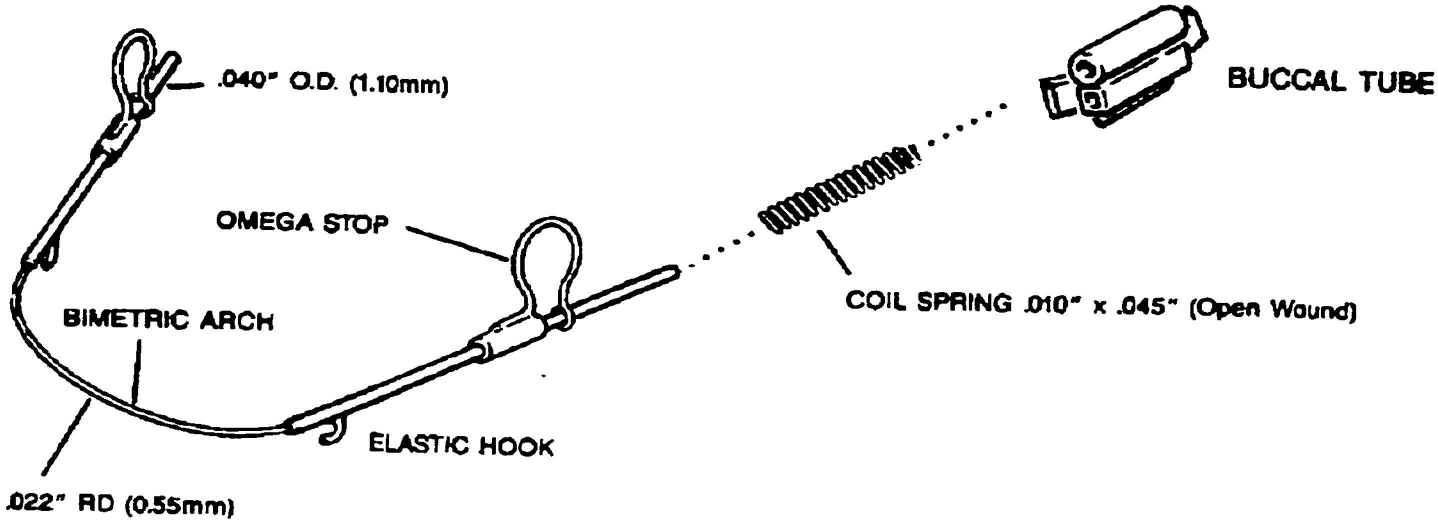
Table 3 – 5 Post – Treatment Cephalometric Measurements (Age and Skeletal)

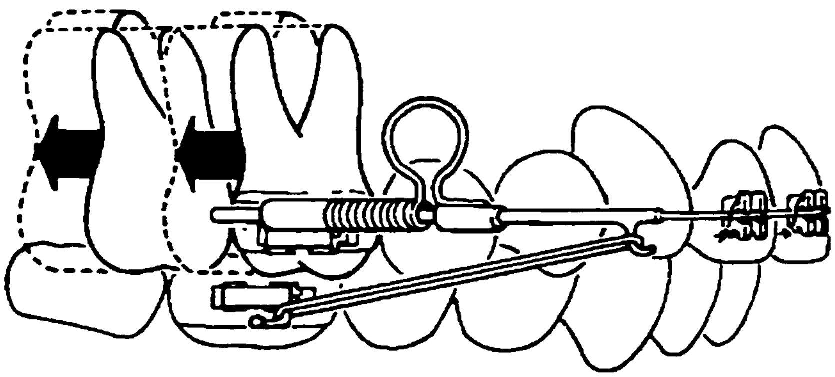
Measurement	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Age (years)	14.86 (1.46)	14.13 (1.04)	0.73	0.12
Skeletal				
ANB (degrees)	2.91 (1.30)	3.47 (1.59)	-0.56	0.28
MnPl to FH (degrees)	24.50 (3.19)	26.53 (4.32)	-2.03	0.13
N perp. to A (mm)	-3.11 (3.08)	-2.61 (3.49)	-0.50	0.67
N perp. to Pg (mm)	-7.96 (5.98)	-9.63 (5.41)	1.67	0.42
S perp. to A point (mm)	69.68 (4.19)	68.47 (2.86)	1.21	0.36
S perp. to B point (mm)	62.25 (5.63)	60.18 (4.18)	2.07	0.26
S perp. to Pg (mm)	64.29 (7.56)	60.82 (4.78)	3.47	0.15

Table 3 – 6 Difference Between Pre – and Post – Treatment Measurements (Age and Skeletal Measures)

Measures	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Elapsed Time (years)	3.558 (0.93)	3.549 (0.82)	0.009	0.98
ANB (degrees)	-1.57 (1.27)	-1.37 (1.13)	-0.20	0.64
MnPl to FH (degrees)	0.25 (2.34)	-0.18 (2.52)	0.43	0.61
N perp. to A (mm)	-1.32 (1.91)	-1.45 (2.05)	0.13	0.86
N perp. to Pg (mm)	1.57 (4.70)	0.00 (3.49)	1.57	0.30
S perp. to A point (mm)	0.36 (2.34)	0.24 (1.67)	0.12	0.87
S perp. To B point (mm)	1.00 (3.90)	0.95 (2.57)	0.05	0.97
S perp. to Pg (mm)	1.61 (5.61)	1.03 (2.67)	0.58	0.72

Figure 3 – 1 Wilson Bimetric Distalizing Arch™ Diagrams*





* Adapted from Enhanced Orthodontics, Book 2: Force Systems Mechanotherapy Manual with 3D® Modular … 1st Phase Fixed/Removables™ by R.C. Wilson and W.L. Wilson, RMO Inc., 1988.

Figure 3 – 2 Cephalometric Landmarks

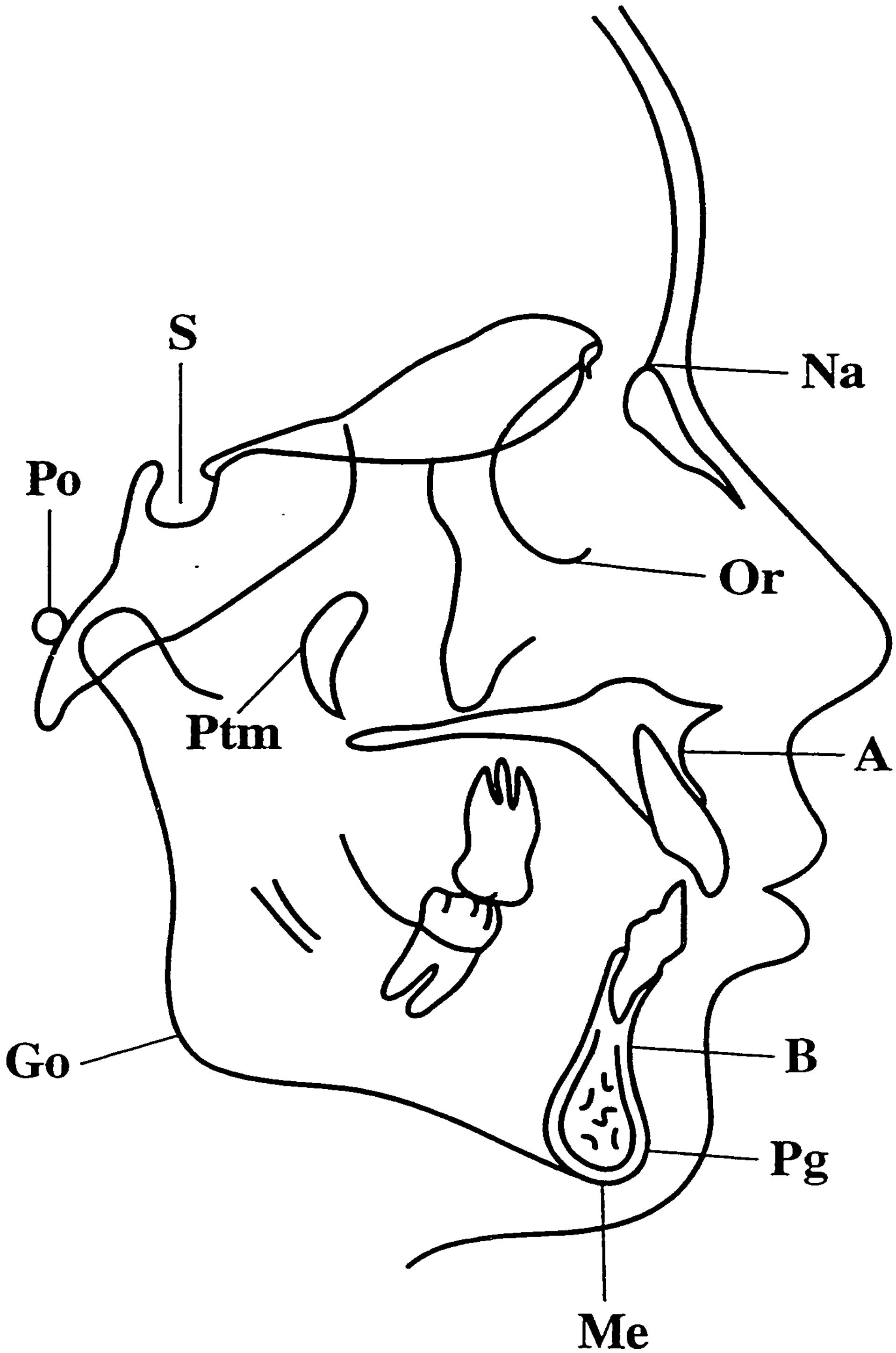


Figure 3 – 3 Angular Measurements

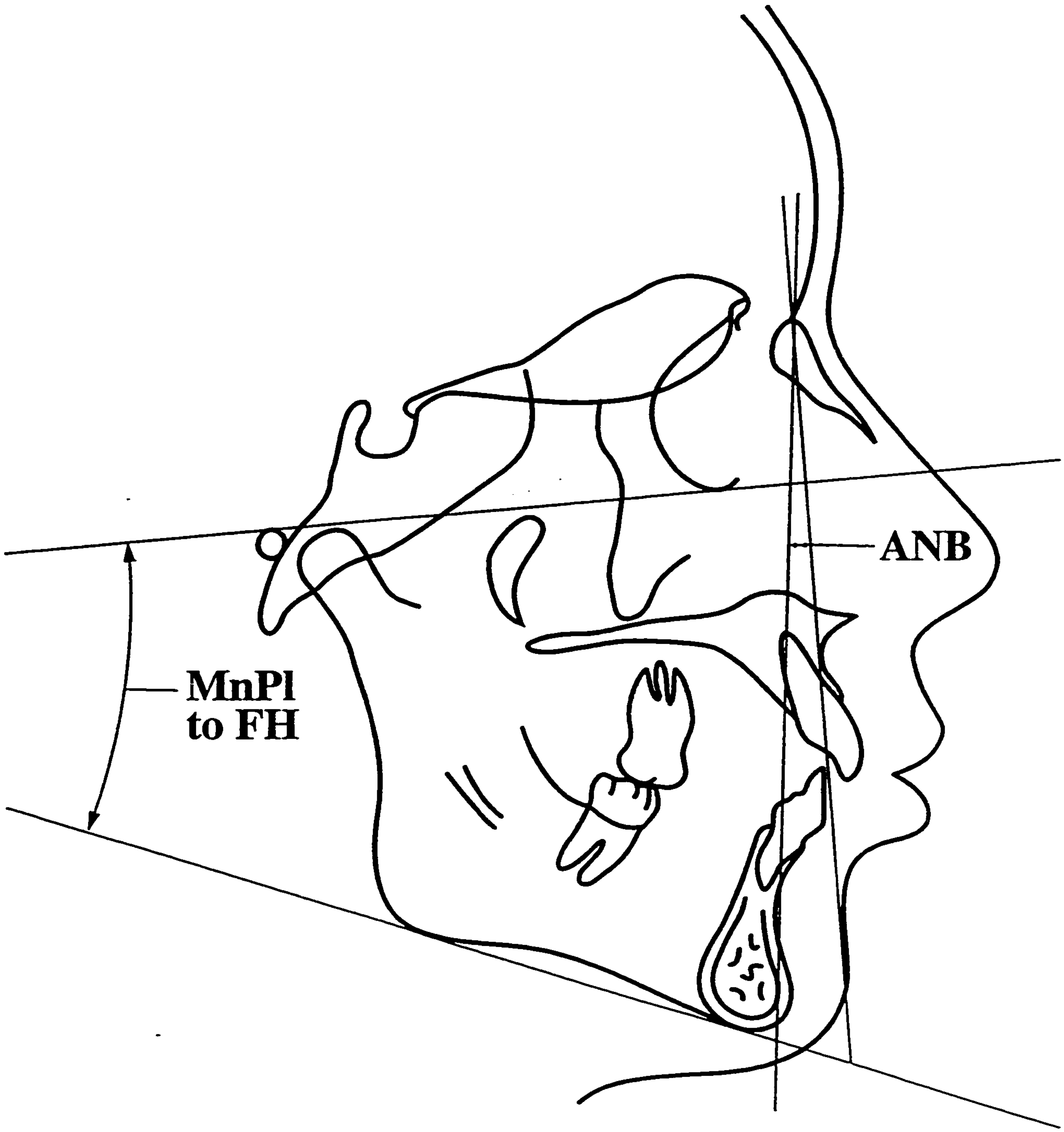
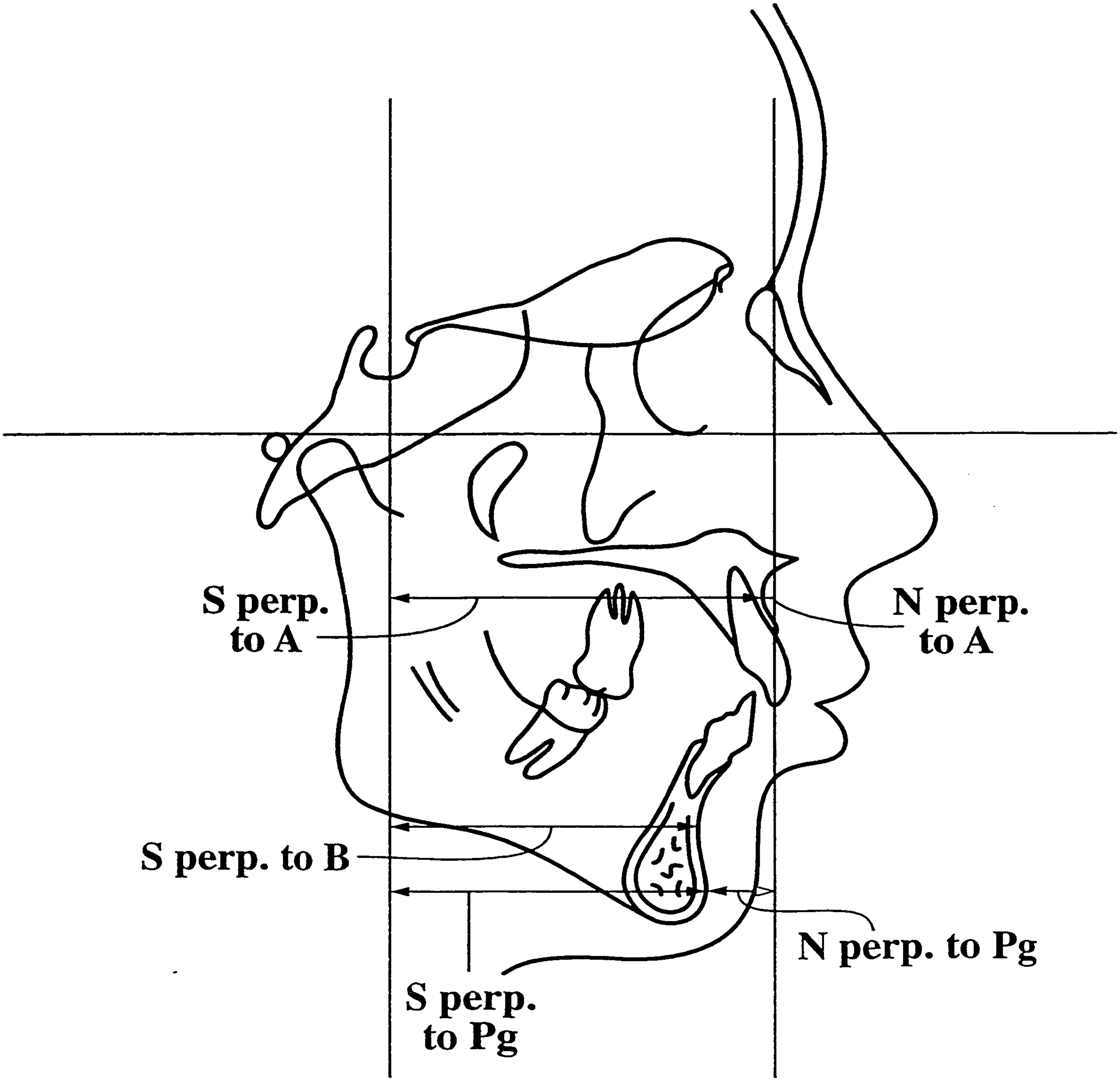


Figure 3 – 4 Linear Measurements



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Chapter Four

Paper #3

Comparison of Orthodontic Treatment Outcomes Utilizing

Cervical Headgear or Wilson Bimetric Distalizing Arch™

– A Cephalometric Study

4.1 Introduction

Correction of class II molar relationships is a very common orthodontic treatment goal. Many methods have been proposed and subsequently evaluated.[1-33] Orthodontic class II correction is commonly focused on maxillary molar distalization.[4-12,15,18-28] However, those that criticize these techniques suggest that molar correction is achieved, in part, by mesialization of the mandibular molars.[10]

A second component to the correction of class II malocclusion is reduction of the excess overjet. This reduction is attempted orthopedically through growth modification or through distalization of the entire maxillary dentition. Overjet reduction may also be the result of mesialization of the mandibular dentition which is associated with proclination of mandibular incisors.

The purpose of this investigation was to examine the orthodontic (dental) treatment effects of the Wilson Bimetric Distalizing Arch™ in conjunction with full fixed appliance therapy. Horizontal and vertical change in first molar position as well as vertical, horizontal and angular change in incisor position was analyzed. These orthodontic effects were compared to a matched sample of patients that were treated with cervical headgear, bite plate, and full fixed appliance therapy.

4.2 Materials and Methods

The data that was obtained for this portion of the investigation was produced using the samples described previously.[33]

All pairs of lateral cephalometric radiographic tracings were blinded, randomized and assigned an identification number. The pairs were analyzed using the landmarks described previously.[33] The additional landmarks listed and defined in Table 4 - 1 (page 130) were identified (see Figure 4 – 1, page 135).

The coordinate system that was constructed previously was used in this part of the investigation.[33]

The following angular measurements were made on each full lateral cephalometric radiograph tracing (see Figure 4 – 2, page 136):

1. FH – Mx1 – the angle in degrees made from the intersection of lines PoOr and Mx1T-Mx1A
2. FMIA – the angle in degrees made from the intersection of lines PoOr and Mn1T-Mn1A
3. MnPl – Mn1 – the angle in degrees made from the intersection of lines GoM and Mn1T-Mn1A

The following linear measurements were made on each full lateral cephalometric radiograph tracing. To obtain the transposed landmarks for these measurements an anterior cranial base superimposition was used. Placing the pre – treatment tracing over the post – treatment tracing and obtaining the visual best fit of the anterior cranial base structures enabled registration of the post – treatment dental landmarks onto the pre – treatment tracing. The following measurements were then made utilizing both the pre – and post – treatment dental landmarks:

1. Mx6L and R vertical - the perpendicular distance in millimeters from the horizontal axis (PoOr) to Mx6L and Mx6R
2. Mx6L and R horizontal - the perpendicular distance in millimeters from the vertical axis to Mx6L and Mx6R

3. Mn6L and R vertical - the perpendicular distance in millimeters from the horizontal axis to Mn6L and Mn6R
4. Mn6L and R horizontal - the perpendicular distance in millimeters from the vertical axis to Mn6L and Mn6R
5. Mx1T vertical - the perpendicular distance in millimeters from the horizontal axis (PoOr) to Mx1T
6. Mn1T vertical - the perpendicular distance in millimeters from the horizontal axis (PoOr) to Mn1T
7. Mx1T horizontal - the perpendicular distance in millimeters from the vertical axis to Mx1T
8. Mn1T horizontal - the perpendicular distance in millimeters from the vertical axis to Mn1T
9. Overbite - the difference in millimeters calculated by subtracting the value of Mn1T vertical from the value of Mx1T vertical
10. Overjet - the difference in millimeters calculated by subtracting the value of Mn1T horizontal from the value of Mx1T horizontal

In addition to the above noted measurements, the molar differential was calculated. The pre – treatment molar differential was calculated as the perpendicular distance in millimeters from the vertical constructed axis to the mesial cusp tip of the mandibular first molar subtracted from the perpendicular distance in millimeters from the vertical constructed axis to the mesial cusp tip of the corresponding maxillary first molar. The post – treatment molar differential were calculated similarly using post – treatment molar positions in place of pre – treatment molar positions. The purpose of this calculation was to indicate the horizontal relationship of the maxillary first molar to the mandibular first molar. A negative value indicated that the maxillary molar was located distally relative to the corresponding mandibular molar (tending towards class I); a positive value indicated that the maxillary molar was located mesially relative to the corresponding mandibular molar (tending towards class II). A value of 0.0 millimeters indicated an end to end molar relationship.

The following linear measurements were then completed on the maxillary pre – treatment tracing using the constructed axis. This constructed axis was the PoOr line with the vertical being a perpendicular line registered at pterygomaxillary fissure (Ptm). To obtain the superimposition the best fit of the maxilla, pterygomaxillary fissure and the key ridges was used. The post – treatment landmarks were transposed onto the pre – treatment tracing using this best fit (see Figure 4 – 3, page 137). The following measurements were then made utilizing both the pre – and post – treatment dental landmarks:

1. Mx6L and R vertical - the perpendicular distance in millimeters from the horizontal axis to Mx6L and Mx6R
2. Mx6L and R horizontal - the perpendicular distance in millimeters from the vertical axis to Mx6L and Mx6R
3. Mx1T vertical - the perpendicular distance in millimeters from the horizontal axis (PoOr) to Mx1T
4. Mx1T horizontal - the perpendicular distance in millimeters from the vertical axis to Mx1T

The following linear measurements were completed on the mandibular pre – treatment tracing using the constructed axes for the mandibular tracing. To complete the mandibular superimposition, the pre – treatment mandibular tracing was placed over the post – treatment mandibular tracing using the best fit of the symphysis, mandibular canal, and third molar crypt (if present). Post – treatment Mn6L and Mn6R were then transposed onto the pre – treatment acetate that enabled registration of the post – treatment dental landmarks onto the pre – treatment tracing (see Figure 4 – 4, page 138). The following measurements were then made utilizing both the pre – and post – treatment dental landmarks:

1. Mn6L and R vertical - the perpendicular distance in millimeters from the horizontal axis to Mn6L and Mn6R
2. Mn6L and R horizontal - the perpendicular distance in millimeters from the vertical axis to Mn6L and Mn6R
3. Mn1T vertical - the perpendicular distance in millimeters from the horizontal axis (PoOr) to Mn1T
4. Mn1T horizontal - the perpendicular distance in millimeters from the vertical axis to Mn1T

Paired Student t – tests were completed to detect differences in orthodontic treatment effects between the two samples.

4.3 Results

Comparison of the pre – treatment cephalometric dental measurements indicated that there was no statistically significant difference between the horizontal or vertical position of the maxillary or mandibular molars between the two groups (see Table 4 – 2, page 131). This comparison also demonstrated no difference between the two groups with respect to pre – treatment linear or angular position of the maxillary or mandibular incisors (see Table 4 – 2, page 131).

The post – treatment horizontal and vertical positions of the maxillary and mandibular molars and incisors also demonstrated no statistically significant differences (see Table 4 – 3, page 132).

Statistically significant differences were noted for the change in the dental measurements between the two groups on the anterior cranial base tracings and superimpositions (see Table 4 – 4, page 133). The change in the molar differential (calculated as the post – treatment molar differential subtracted from the pre – treatment molar differential) ranged between 1.00 mm and 2.29 mm (see Table 4 – 4, page 133). A statistically significant difference was noted for the right molar differential change. The change was greater in the headgear group than in the Wilson Arch group. The difference in the vertical position of the maxillary molars between the headgear sample and the Wilson Arch sample was approximately 1.5 mm. This difference was statistically significant for the maxillary left molar only. The headgear group had the larger vertical change in molar position. Change in the horizontal position of the maxillary molars was noted for both groups. There were no statistically significant differences between the two groups. It appears the magnitude of change was greater for the right molar than the left molar in both groups. Statistically, however, the difference was not significant for either group. Similar results can be noted for the mandibular molars. Vertically, the headgear group had a greater change in position compared to the Wilson Arch group. This difference was statistically significant for the mandibular right molar. The change in the horizontal position of the mandibular molars was just greater than 3 mm which was statistically equivalent for both groups.

Incisor position change between the two groups was very similar (see Table 4 – 4, page 133). A statistically significant difference was only noted for the overjet difference (see Table 4 – 4, page 133). The headgear group demonstrated a larger reduction in overjet by approximately 1.5 mm.

Comparisons of the changes in the maxillary molar position relative to the maxillary superimposition are presented in Table 4 – 5 (page 134). The magnitude of change in vertical direction was much greater for the headgear group than the Wilson Arch group. Statistically, the vertical measurement values were significantly different between the two groups with the noted larger vertical change in the headgear group. The horizontal change in position of the maxillary molars was statistically equivalent between the two groups.

Changes in position of the mandibular molars relative to the mandibular superimposition are presented in Table 4 – 6 (page 134). In stark contrast to the maxillary molar position change, the magnitude of mandibular molar position change in the vertical direction was equivalent between both groups. No statistically significant differences were noted in the horizontal direction either.

4.4 Discussion

Table 4 - 4 (page 133) depicts the change in molar positions from the full lateral cephalometric radiograph tracing and associated superimpositions. Statistically significant differences were noted for the vertical position change of the left maxillary and right mandibular molars as well as for the change in the right molar differential. The headgear group demonstrated a larger downward movement of the maxillary molar. From this tracing it is not possible to determine if this vertical change was due to extrusion of the maxillary molar, downward growth of the maxilla carrying the molar with it or a combination of the two. The vertical position change of the mandibular molar was also in a downward direction. This may seem to contradict the data because the values of the vertical change for both molars are of the same sign (i.e. positive). However, this positive value only indicates that the molars (both maxillary and mandibular) moved away from the horizontal constructed horizontal axis. Therefore, the mandibular molar may have been intruded, or carried away from the horizontal constructed axis with the downward growth of the mandible, or a combination of the two. It is also possible that the molar may have extruded relative to the mandible, but this movement was camouflaged by greater downward growth of the mandible away from the horizontal axis.

No difference was noted between the two groups with respect to the change in the horizontal position of the maxillary or mandibular molars on the full lateral cephalometric radiograph tracing and superimposition. In both groups, the post – treatment horizontal position of the molars was slightly advanced compared with their corresponding pre – treatment position.

The maxillary superimposition was completed to aid in the differentiation between maxillary molar movement caused by skeletal and dental changes (full lateral cephalometric radiograph tracing) and dental maxillary molar movement (maxillary tracing). The headgear group had greater molar position change in the vertical direction that was statistically significant on the maxillary tracings and superimpositions (see Table 4 – 5, page 134). The difference in magnitude of change between the two groups indicates that the maxillary molar in the headgear group extruded dentally more than the maxillary molar in the Wilson Arch treated group. This correlates well with the observations made regarding the full lateral cephalometric radiograph tracing which also demonstrated greater downward movement of the maxillary molar in the headgear treated group as compared to the Wilson Bimetric Distalizing Arch™ group. However, the magnitude of change does not coincide between the full lateral cephalometric radiograph tracing and the maxillary tracing. If growth remained constant between the two groups and only dental extrusion occurred, one would expect the magnitude of the difference between the two groups to remain the same. This does not occur. The magnitude of the difference between the two groups is greater for the maxillary superimposition than for the full lateral cephalometric radiograph superimposition. This can be attributed to differences in growth between the two groups (either as a result of sampling or due to the effects of the treatment provided).

It appears that the amount of vertical skeletal growth is less in the headgear group since the difference is less in the full lateral cephalometric radiograph superimposition than in the maxillary superimposition. However, the opposite may actually be true because as the maxilla develops there may be a greater amount of alveolar development than apposition of bone on the oral (as opposed to nasal) side of the palate.[30] This produces an apparent deepening of the palatal vault.[30] This would result in the apparent extrusion of the molar when superimposition is conducted because when the deeper palatal vault of the post – treatment maxilla is superimposed on the shallower pre – treatment palatal vault, the result is a relative downward movement of the post – treatment maxillary molar. Therefore, vertical maxillary development may not be greater in the Wilson Bimetric Distalizing Arch™ group as the data indicates because increased extrusive movement of the maxillary molars in the cervical headgear group may camouflage the vertical maxillary growth that occurred.

In the horizontal direction it has been noted that there was greater dental movement of the maxillary molar in the headgear group in the maxillary tracing. This indicates that less dental mesial movement of the maxillary molar occurred with the Wilson Arch treated group. This does not correlate with the full lateral cephalometric radiograph tracing where there was no statistically significant difference in the horizontal molar position change. This lack of correlation may be attributed to an increased restriction of forward growth of the maxilla by the cervical headgear therapy that has been proposed by a number of investigators.[1-3,11,31,32] This would result in equivalent molar position changes between the two groups. However, the data appears to indicate that the final position was achieved with greater dental movement in the Wilson Bimetric Distalizing Arch™ group.

The mandibular tracing and associated superimposition was completed to aid in the differentiation of the dental movement of the mandibular molar from change in molar position due to combined tooth movement and skeletal changes. Equal amounts of molar extrusion were experienced in both groups. It should be emphasized that the direction of change of the vertical molar position that was demonstrated in the mandibular tracing was in a direction opposite to the vertical molar position change that was seen in the full lateral cephalometric radiograph tracing. This indicates that downward vertical growth of the mandible was significantly greater than the amount of extrusion that occurred in either samples because the full lateral cephalometric radiograph magnitude and direction of mandibular molar displacement was downward. Since the vertical change, in a downward direction, was greater in the full lateral cephalometric radiograph tracing for the headgear treated group, it appears that this group experienced greater vertical growth of the mandible. This may be attributed to the use of an anterior bite plate in this group.

Minimal dental change of the horizontal position of the mandibular molars was experienced in each sample. Therefore, the movement seen in the full lateral cephalometric radiograph superimposition appears to be mainly due to the forward growth of the mandible carrying the mandibular molars forward. That is, there does not appear to be any greater mesial movement of the mandibular molar in either group.

With respect to incisor position change, it has been noted that the only statistically significant difference between the two groups was in the overjet measurement (see Table 4 – 4, page 133). This difference does not seem to correspond to the pre – and post – treatment equivalence demonstrated by this measurement (see Table 4 – 2, page 131 and Table 4 – 3, page 132). The discrepancy may be explained by the initial difference in magnitude of overjet which was larger for the headgear group. In order to correct excess overjet, more change was required in the headgear group. This does not imply that headgear is more effective than the Wilson Arch is, but rather both systems resulted in a successful outcome. It is difficult to compare this data to the data presented by Muse *et al* because of differences in the timing of post – treatment evaluation and the method of superimposition.[10] Muse *et al* evaluated their treatment effects after the 16 week molar distalization phase whereas this investigation also took into account phase two treatment and approximately 3 years of development. Therefore, differences between these two studies may be related to the growth that could have occurred during the longer treatment time. Different superimposition techniques will produce differing results.[10] It is interesting to note, however, that Muse *et al* found greater forward horizontal movement of the mandibular molar compared to this investigation with respect to dental movement.[10]

4.5 Conclusions

The following conclusions can be drawn:

1. Statistically significant differences were noted in the change in the vertical position of the maxillary and mandibular molars using the full lateral cephalometric radiograph tracing and the associated superimposition

between the headgear treated group and the Wilson Bimetric Distalizing Arch™ treated group.

2. Statistically significant differences were noted in the change in the vertical position of the maxillary molar using the maxillary tracing and the associated superimposition.
3. No statistically significant differences were noted in the change in the vertical or horizontal positions of the mandibular molars using the mandibular tracing and the associated superimposition.
4. A statistically significant difference was noted for the change in overjet between the two groups with the headgear group having a larger overjet reduction.

The clinical implication of these conclusions is that neither of these treatment modalities is superior to the other with respect to final molar or incisor relationship.

Table 4 – 1 Additional Landmarks

Landmark	Abbreviation	Definition
Maxillary left first molar mesial cusp tip	Mx6L	The most inferior point of the curve of the cusp tip of the left maxillary first molar*
Maxillary right first molar mesial cusp tip	Mx6R	The most inferior point of the curve of the cusp tip of the right maxillary first molar*
Mandibular left first molar mesial cusp tip	Mn6L	The most superior point on the curve of the mesial cusp tip of the left mandibular first molar*
Mandibular right first molar mesial cusp tip	Mn6R	The most superior point on the curve of the mesial cusp tip of the right mandibular first molar*
Maxillary incisor tip	Mx1T	The mid-point of the most inferior edge of the most inferior and anterior maxillary incisor
Maxillary incisor root apex	Mx1A	The mid-point of the most superior tip of the root of the incisor in 5 (above)
Mandibular incisor tip	Mn1T	The mid-point of the most superior edge of the most superior and anterior maxillary incisor
Mandibular incisor root apex	Mx1A	The mid-point of the most inferior tip of the root of the incisor in 7 (above)

* The most distal image of each molar type (maxillary or mandibular) on the lateral cephalometric radiograph was assumed to be the left molar (if two images were present)

Table 4 – 2 Pre – Treatment Cephalometric Measurements (Age and Dental)

Measurement	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Age (years)	11.29 (1.20)	10.53 (0.79)	0.76	0.049*
Molar				
L molar differential (mm)	0.214 (0.99)	0.500 (0.99)	-0.286	0.42
R molar differential (mm)	0.036 (0.54)	0.61 (1.14)	-0.574	0.11
26 Vertical (mm)	43.68 (2.67)	42.11 (2.43)	1.58	0.094
16 Vertical (mm)	44.14 (2.80)	42.92 (2.57)	1.22	0.21
26 Horizontal (mm)	38.79 (2.71)	37.87 (2.53)	0.92	0.33
16 Horizontal (mm)	40.93 (3.20)	39.61 (2.73)	1.32	0.22
36 Vertical (mm)	43.32 (2.52)	41.95 (2.59)	1.37	0.14
46 Vertical (mm)	43.86 (2.91)	42.24 (2.47)	1.44	0.10
36 Horizontal (mm)	38.57 (3.19)	37.37 (2.93)	1.38	0.28
46 Horizontal (mm)	40.96 (3.00)	39.00(3.19)	1.96	0.081
Incisor				
FH to Mx1 (degrees)	107.39 (4.09)	111.26 (8.76)	- 3.87	0.10
FMIA (degrees)	59.32 (6.11)	57.76 (4.60)	1.56	0.43
Mandibular Plane to Mn1 (degrees)	96.68 (7.19)	95.47 (5.23)	1.21	0.60
Mx1 Vertical (mm)	50.25 (3.07)	49.76 (3.64)	0.49	0.68
Mx1 Horizontal (mm)	72.21 (72.21)	72.55 (3.52)	-0.34	0.81
Mn1 Vertical (mm)	45.89 (3.23)	45.42 (2.89)	0.47	0.67
Mn1 Horizontal (mm)	67.54 (4.18)	66.71 (3.02)	0.83	0.54
Overbite (mm)	4.36 (1.35)	4.34 (2.30)	0.00	0.98
Overjet (mm)	4.68 (1.75)	5.84 (2.12)	-1.16	0.10

* significant at 5 % level of significance

Table 4 – 3 Post – Treatment Cephalometric Measurements (Age and Dental)

Measurement	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Age (years)	14.86 (1.46)	14.13 (1.04)	0.73	0.12
Molar				
L molar differential (mm)	-1.73 (1.29)	-1.79 (1.07)	0.06	0.89
R molar differential (mm)	-1.04 (1.41)	-1.447 (0.815)	0.407	0.34
26 Vertical (mm)	48.79 (2.99)	48.82 (3.18)	-0.03	0.98
16 Vertical (mm)	49.43 (3.26)	49.13 (3.20)	0.30	0.80
26 Horizontal (mm)	40.49 (3.87)	38.71 (3.19)	1.78	0.17
16 Horizontal (mm)	43.50 (3.88)	41.37 (3.24)	2.13	0.11
36 Vertical (mm)	49.04 (3.14)	49.24 (3.45)	-0.20	0.86
46 Vertical (mm)	49.68 (3.35)	49.84 (3.37)	-0.16	0.89
36 Horizontal (mm)	42.21 (3.79)	40.50 (3.42)	1.17	0.19
46 Horizontal (mm)	44.54 (4.62)	42.82 (3.19)	1.72	0.24
Incisor				
FH to Mx1 (degrees)	110.25 (4.85)	110.87 (7.82)	-0.62	0.77
FMIA (degrees)	55.04 (7.46)	52.45 (4.25)	2.59	0.26
Mandibular Plane to Mn1 (degrees)	100.11 (6.25)	100.66 (5.40)	-0.55	0.79
Mx1 Vertical (mm)	54.50 (3.39)	55.05 (4.54)	-0.55	0.69
Mx1 Horizontal (mm)	73.07 (5.54)	71.71 (2.98)	1.36	0.42
Mn1 Vertical (mm)	53.07 (3.66)	52.89 (4.07)	0.18	0.90
Mn1 Horizontal (mm)	70.50 (5.75)	69.53 (3.15)	0.97	0.57
Overbite (mm)	1.43 (1.11)	2.16 (0.80)	-0.73	0.05
Overjet (mm)	2.57 (1.24)	2.18 (0.51)	0.39	0.29

Table 4 – 4 Difference Between Pre – and Post – Treatment Measures (Dental)

Measurement	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Molar				
L Molar Differential	1.94 (1.25)	2.29 (1.16)	-0.35	0.42
R Molar Differential	1.00 (1.51)	2.05 (1.22)	-1.05	0.042*
26 Vertical Difference	5.11 (1.73)	6.71 (2.42)	-1.60	0.034*
16 Vertical Difference	5.32 (1.92)	6.74 (2.37)	-1.42	0.068
26 Horizontal Difference	1.68 (3.37)	0.84 (2.13)	0.84	0.42
16 Horizontal Difference	2.57 (3.24)	1.76 (2.51)	0.81	0.44
36 Vertical Difference	5.71 (2.03)	7.26 (2.76)	-1.55	0.073
46 Vertical Difference	5.79 (1.96)	7.61 (2.29)	-1.82	0.020*
36 Horizontal Difference	3.64 (3.49)	3.13 (2.28)	0.51	0.64
46 Horizontal Difference	3.57 (3.76)	3.82 (2.17)	-0.25	0.83
Incisor				
FH to Mx1 (degrees)	2.86 (5.18)	-0.4 (12.4)	3.26	0.31
FMIA (degrees)	-4.29 (7.94)	-5.32 (5.48)	1.03	0.68
Mand Plane to Mn1 (degrees)	3.43 (7.49)	5.18 (5.23)	-1.75	0.46
Mx1 Vertical (mm)	4.25 (2.10)	5.29 (2.98)	-1.04	0.25
Mx1 Horizontal (mm)	0.86 (3.42)	-0.84 (3.54)	1.70	0.18
Mn1 Vertical (mm)	7.18 (2.65)	7.47 (2.75)	-0.29	0.76
Mn1 Horizontal (mm)	2.96 (3.68)	2.82 (2.14)	0.14	0.89
Overbite (mm)	-2.93 (1.19)	-2.18 (2.16)	-0.75	0.22
Overjet (mm)	-2.11 (1.13)	-3.66 (2.01)	1.5	0.01*

* significant at 5 % level of significance

Table 4 – 5 Difference Between Pre – and Post – Treatment Measures (Dental) – Maxillary Tracing

Measurement (mm)	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Molar				
26 Vertical	2.25 (0.73)	5.03 (2.06)	-2.78	0.0000*
16 Vertical	2.54 (1.20	4.92 (2.19)	-2.38	0.0004*
26 Horizontal	1.25 (1.76)	1.50 (1.68)	-0.25	0.68
16 Horizontal	1.79 (2.41)	2.63 (1.63)	-0.84	0.27
Incisor				
Mx1 Vertical (mm)	1.71 (1.99)	3.18 (2.55)	-1.47	0.07
Mx1 Horizontal (mm)	0.50 (1.85)	-0.05 (3.29)	0.55	0.54

* significant at 0.1 % level of significance

Table 4 – 6 Difference Between Pre – and Post – Treatment Measures (Dental) – Mandibular Tracing

Measurement (mm)	Wilson Arch Group (SD)	Headgear Group (SD)	Mean Difference	P – value
Molar				
36 Vertical	3.71 (1.59)	2.97 (1.30)	0.74	0.17
46 Vertical	3.36 (0.50)	2.97 (1.49)	0.39	0.47
36 Horizontal	0.71 (1.38)	0.34 (1.50)	0.37	0.47
46 Horizontal	1.36 (1.49)	0.97 (1.18)	0.39	0.43
Incisor				
Mn1 Vertical (mm)	1.75 (1.54)	2.76 (1.66)	-1.01	0.08
Mn1 Horizontal (mm)	0.46 (2.40)	0.37 (2.10)	0.09	0.91

Figure 4 – 1 Additional Cephalometric Landmarks

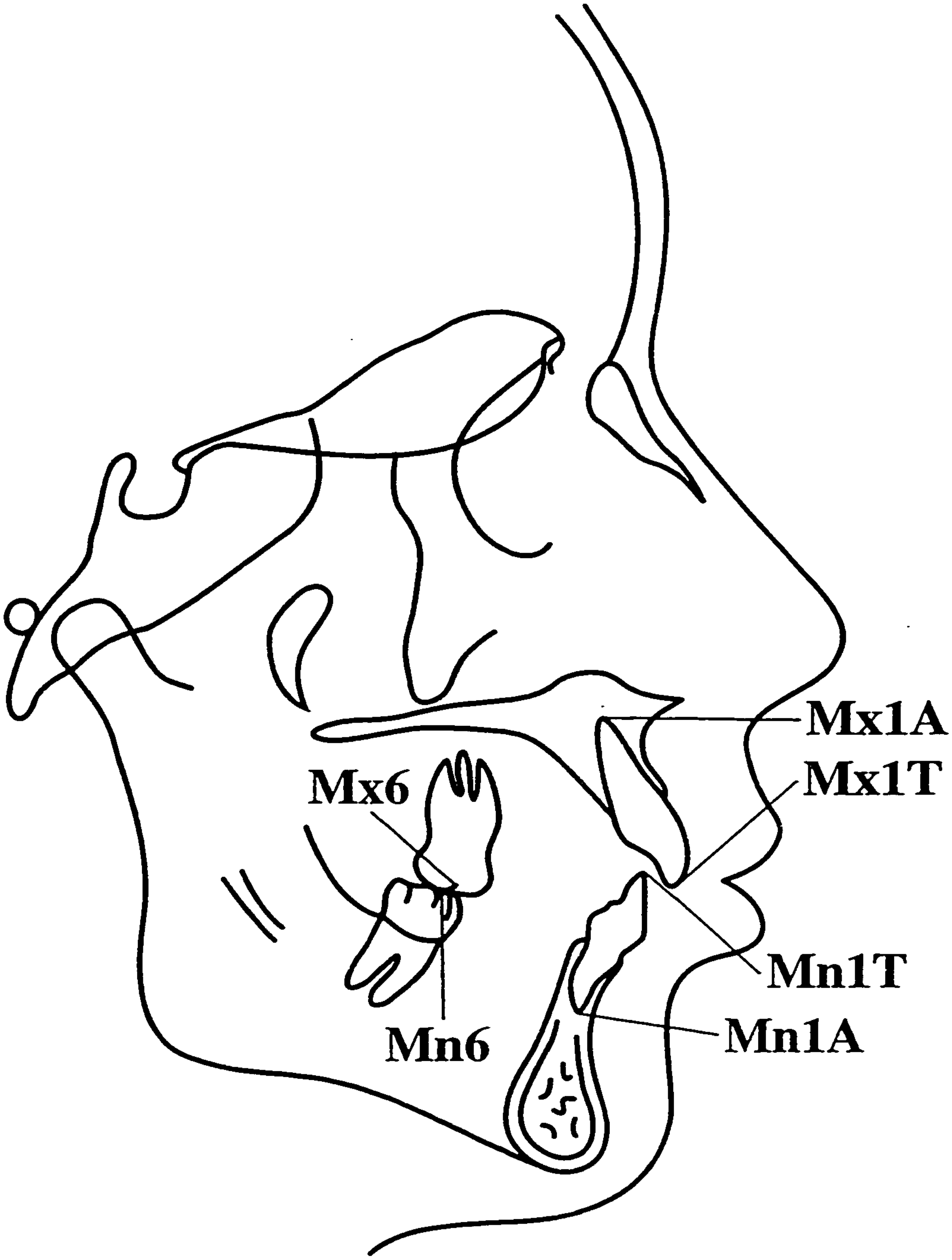


Figure 4 – 2 Angular and Linear Dental Measurements

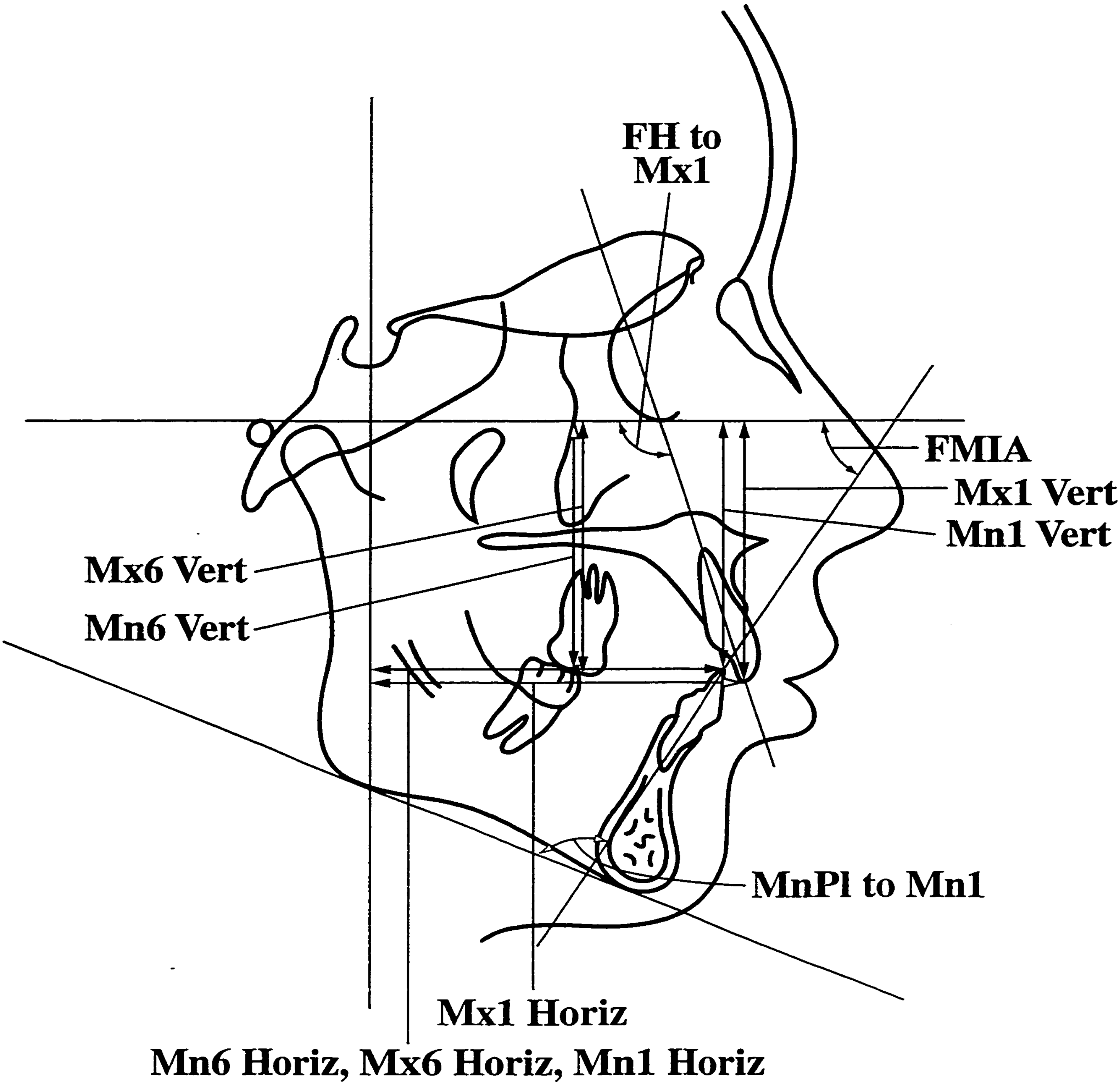


Figure 4 – 3 Maxillary Linear Measurements

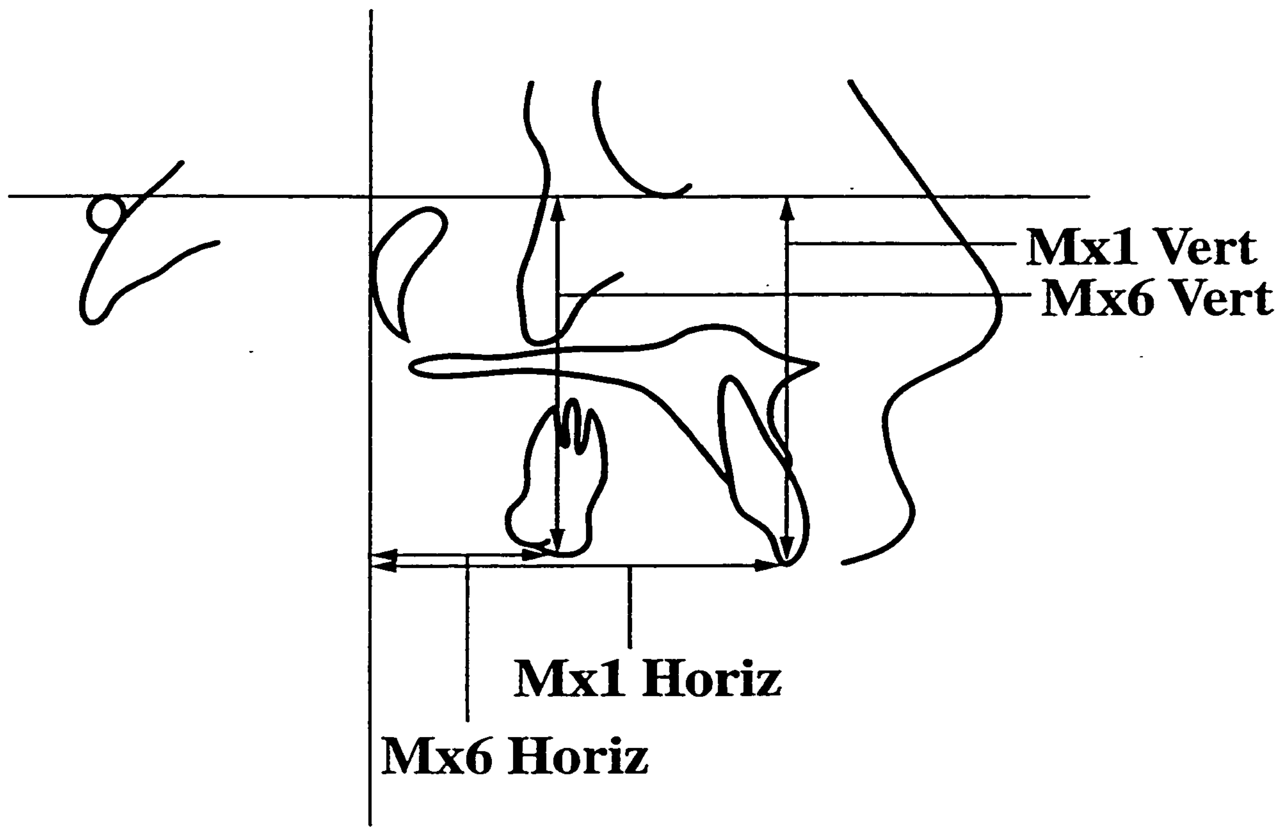
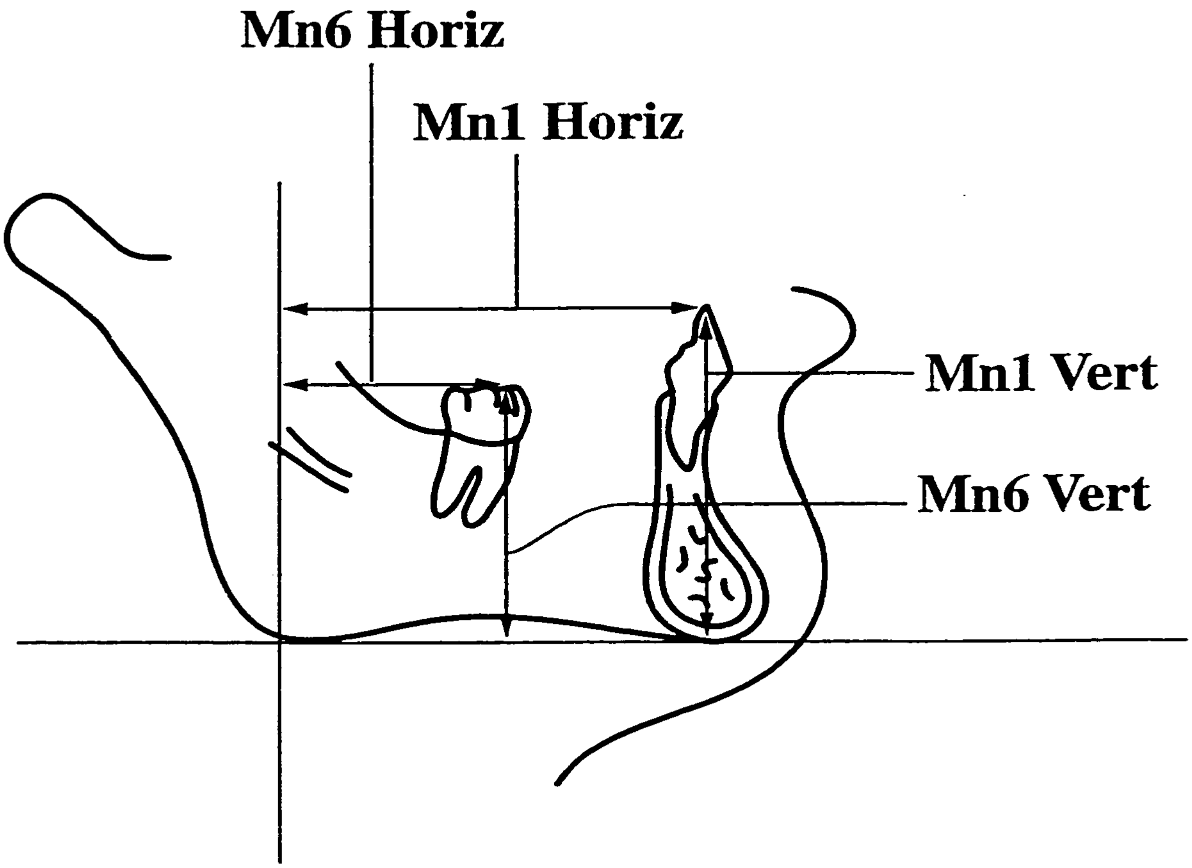


Figure 4 – 4 Mandibular Linear Measurements



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Chapter Five

Discussion

And

Recommendations

5.1 General Discussion

The identification and subsequent thorough evaluation of alternative modalities developed for the treatment of class II malocclusions would provide orthodontic practitioners with a sound basis on which to base their appliance selection and class II treatment modalities. Many 'new' treatment modalities that are presented, are done so in the form of case studies and anecdotal case presentations. This leaves the orthodontic clinician with the unenviable task of choosing to either attempt treating patients on blind faith that the 'new' therapy actually does work or disregarding the therapy altogether.

According to McNamara, headgear therapy is the most common treatment for Angle's class II malocclusions.[1] In addition, many studies have been conducted that concluded that extraoral traction was an effective method of correcting class II malocclusions.[2-5] However, a recent, long term, prospective study has provided strong evidence contrary to earlier findings.[6] In fact, they concluded that early treatment with a headgear or functional appliance followed by later comprehensive treatment, on average, does not produce major differences in jaw relationship or dental occlusion compared with later one – stage comprehensive treatment.[7] It appears that any skeletal change experienced during the early treatment phase (headgear treatment) is not maintained "so that little if any difference remains after comprehensive treatment is completed".[7]

Therefore, the purpose of this research project was to investigate the effectiveness of treating class II patients with the Wilson Bimetric Distalizing Arch™ in conjunction with full fixed appliance therapy. Orthodontic and orthopedic effects of this class II treatment modality were compared to the effects of treatment using cervical headgear, anterior biteplate, and full fixed appliance. The Wilson Bimetric Distalizing Arch™ was introduced by Wilson a part of his "modular orthodontic system" in 1978.[8,9] There does not appear to be any published literature regarding the effectiveness of this appliance until Muse *et al* presented their investigation in 1993.[10] This study only followed their sample for a maximum of 16 weeks.[10] They did conclude that molars could be distalized to a class I molar relationship during this time period.[10] However, they noted that maxillary molar tipping, maxillary and mandibular incisor proclination, and mandibular molar mesialization did occur.[10] The objective of this investigation was to attempt to determine the orthodontic and orthopedic outcomes of Wilson Bimetric Distalizing Arch™ treatment after comprehensive treatment as compared to cervical headgear, anterior biteplate, and full fixed appliance therapy.

To ensure that the measurements that were to be used for the analysis of the lateral cephalometric radiographs for this investigation were to be of value, the, as Houston states, "tedious" and "unrewarding" task of error analysis was completed as the first part of this study.[11] The non – superimposed angular measurement replication error was, in all instances, less than one degree. This magnitude of error appears to be consistent with measurement replication errors of similar angular measurements previously published.[12] The non – superimposed linear measurement replication error appeared to be greater in comparison to the angular measurements (especially for the measurement to Pg). This does correspond to the increased variability of Pg found by Trpkova *et al.*[13] The magnitude of the measurement replication error does seem comparable to the calculated errors determined by the meta analysis.[13] In most instances, it appears that the process of superimposition created additional error. For the full lateral cephalometric radiograph, the error analysis demonstrated consistent error that correlated to previously published values.

Assessment of the pre – treatment mean ages and mean cephalometric measurements of the two treatment groups demonstrated that adequately matched samples had been produced. This statement does not imply that the matching was ideal. Mean age and mean cephalometric differences were noted between the two groups. However, within the constraints and the restrictions of a retrospective investigation, the similarity of the two samples was sufficient to enable valuable and meaningful conclusions regarding the topic of study.

Much research has been conducted which demonstrated the skeletal effects of extraoral traction.[2-4,14] Although the long term skeletal effect of the headgear appliance has recently come under attack, it was the expectation of the principal investigator that the skeletal differences would be noted between the two treatment groups with the headgear treated group demonstrating greater skeletal influence.[6,7] The data produced in this investigation did not allow for this conclusion. In fact, no statistically significant difference could be shown between the two treatment groups with respect to full lateral cephalometric radiograph change in skeletal cephalometric indicators. This appears to support the conclusion of Tulloch *et al* that long term skeletal change with headgear treatment is not maintained.[7] This does not to imply that extraoral traction therapy is not an effective class II treatment modality because the data indicates that class II molar relationships are corrected and that correction may, in part, be skeletal in nature.

Analysis of the molar position change relative to the anterior cranial base superimposition indicated that that greater vertical change occurred in the headgear group. The increased downward movement of the maxillary molar can be attributed to the extrusive nature of the cervical headgear on the molar, to increased vertical growth of the maxilla that has been reported by other investigators, or to a combination of both of these effects.[2-4] The anterior biteplate may have allowed for increased molar extrusion. It is also possible that the use of the class II elastics required for the Wilson Bimetric Distalizing Arch™ may have produced intrusive forces on the maxillary molar. This would occur because of the extrusive component of force on the mandibular molar and the intrusive force on the maxillary molar cause by the downward anterior rotation of the maxillary arch. This would theoretically inhibit or, at least, retard downward molar movement. The maxillary tracing and superimposition that also demonstrate greater downward molar displacement support these postulations.

The change in the position of the maxillary molar in a horizontal direction is statistically equivalent in the anterior cranial base tracing and in the maxillary tracing. Greater mesial dental movement of the maxillary molar occurred in the headgear group (although this difference was not statistically significant) but full lateral cephalometric radiograph no difference was discovered. Therefore, in order for the full lateral cephalometric radiograph molar position between the two groups to be equal, there must have been some type of subtle skeletal influence of headgear treatment (i.e. increased maxillary skeletal growth restriction) that is not present in the Wilson Arch treated group.

The position change of the mandibular molars also demonstrated contradictory data between the full lateral cephalometric radiograph and the mandibular tracings. The data from the full lateral cephalometric radiograph tracing indicated that the mandibular molars moved downward whereas the mandibular tracing showed upward, extrusive movement. This can be accounted for by downward growth of the mandible and maxilla that was greater than the extrusive dental movement. The fact that the extrusive dental movement was equivalent between the two groups in the mandibular tracing and not equivalent in the full lateral cephalometric radiograph tracing can be attributed to increased mandibular growth in the headgear treated group. This may be caused by compensatory vertical growth of the mandible induced by the anterior biteplate or increased vertical maxillary development caused the cervical headgear.

In conclusion, the present research investigated: 1) the error associated with the cephalometric and superimposition measurement analysis and, 2) the orthodontic and orthopedic treatment effects of cervical headgear therapy and Wilson Bimetric Distalizing Arch™ therapy in conjunction with full fixed appliance therapy. This research has provided a thorough evaluation of an alternative class II treatment modality (the Wilson Bimetric Distalizing Arch™) that, to our knowledge, has not been investigated in this manner. The research has demonstrated that 'at the end of the day' both modalities correct class II malocclusions. There are indications that the correction may be achieved in slightly different manner. In addition, this investigation tends to support the contention of Tulloch *et al* that the skeletal effects of headgear treatment may not be maintained fully.[7]

The Wilson Bimetric Distalizing Arch™ is not the panacea for class II malocclusion correction. However, this investigation has shown this appliance appears to be as effective as cervical headgear for treating class II malocclusions. It cannot be recommended that this is the appliance to replace cervical headgear, but in light of recent findings regarding the questionable long term treatment effects of cervical headgear, the Wilson Bimetric Distalizing Arch™ may provide orthodontic practitioners with alternative class II treatment modality.

5.2 Recommendations for Future Studies

As with any investigation, this study demonstrated inherent weaknesses that may be addressed and improved upon in future studies:

1. As Tulloch has indicated, retrospective studies can possibly bias the sample selection.[5] Therefore, a parallel, randomized, double – blinded clinical trial could be conducted with a third, non – treated control group added. The addition of a non – treated control group may further aid in distinguishing treatment effects from normal growth and development. This type of study could reduce any bias introduced through a retrospective sampling. In addition, sample sizes could be better controlled, records could be taken at standardized intervals, and the matching of sample groups could be idealized. In addition, it would allow

for the calculation of annualized amounts of molar movements and enable control or monitoring of amount of class II elastic wear.

2. The focus of the investigation could be expanded to include measurement of molar angulation change and incisor angulation change. This would enable a comparison to the data presented by Muse *et al.*[10] The issue of incisor angulation assessment has already been initiated by the principle examiner.
3. Digitization of lateral cephalometric radiographs may reduce measurement replication error, expedite analysis, and therefore, allow for the development of a data base.
4. Addition of a sample group that was treated with a high – pull headgear in conjunction with full fixed appliances may provide further insight into the effects of different types of extra – oral force.

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