# Effects of the Xbow™ Appliance on Class II Malocclusion in Different Facial Patterns

by

Maron Higson

A Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
of The University of Manitoba
in partial fulfilment of the requirements for the degree of

MASTER OF DENTISTRY
IN ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS

Department of Preventive Dental Science

Faculty of Dentistry Division of Orthodontics
University of Manitoba
Winnipeg

# Abstract

**Objective:** To determine skeletal and dental post-treatment changes in a sample of growing patients treated with the Xbow$^{TM}$ appliance and to compare the values obtained for patients from a private practice database treated with the Xbow$^{TM}$ appliance to previous literature.

**Materials and Methods:** A retrospective sample of 38 subjects from a private orthodontic practice with Class II malocclusions were studied. The subject's growth patterns were divided into mesocephalic, dolichocephalic and brachycephalic based on Y-axis and MPA pre-treatment values. Intra- and inter-examiner reliability of the cephalometric measurements were assessed using an intraclass correlation coefficient (ICC) test. An analysis of variance (ANOVA) statistic was performed on the cephalometric variables being assessed to analyze skeletal and dental changes following treatment with the Xbow$^{TM}$ appliance between the different facial patterns.

**Results:** The results demonstrated correction of Class II malocclusions with the Xbow$^{TM}$ appliance owing to a reduction of the Class II skeletal relationship represented by a decrease in Wits appraisal (-2.88±2.88mm to -2.60±1.77mm, $p<0.05$) and ANB values (-1.86°±2.11° to -1.56°±2.10°, $p<0.05$), reduction in the SNA value for mesocephalic patients indicating a restrictive headgear effect (-2.01°±3.56°, $p<0.05$), moderate amounts of proclination represented by IMPA in the mesocephalic group (+3.54°±6.29°, $p<0.05$) and major amounts of protrusion of the lower incisors represented by L1 to A-Po (+3.06±4.01mm to +5.78±5.31mm, $p<0.05$). Insignificant

changes to the angulation and position of the maxillary incisors were found which also supported Class II dental correction.

**Conclusions:** Conclusion drawn from this study are that most Class II correction in growing patients that are treated with the Xbow$^{TM}$ appliance is owing to dental changes with minor amounts from skeletal changes. Clinicians should be aware that different growth patterns can produce variations in the presence and magnitude of skeletal and dental changes when treated with the Xbow$^{TM}$ appliance.

# Acknowledgements

I would like to express gratitude to the members of my thesis committee for supporting me during this process, Dr. William Wiltshire, Dr. James Mah, and Dr. Randeep Chana. Each member took time from their busy schedule to review and support my thesis project.

To my husband, Evan, and two dogs, Bruno and Louis. Thank you for coming along this journey with me and for continuously picking up and moving cities to watch me fulfill my dreams. I'm forever grateful I did not have to do this alone.

And lastly to my loving parents, Dean and Mandy, for making this all possible. Without them, I would not have accomplished this feat.

# Dedication

For my dad, the original Dr. Higson. Without your support and guidance, none of this would have happened.

# Contents

# List of Figures and Tables

# Chapter 1
# Introduction

## 1.1 Preface

The field of orthodontics is a complex and ever-changing part of dentistry. Numerous advances in technology and orthodontic appliances have occurred over the years which has prompted changes in how clinicians practice the specialty of orthodontics. With new and innovative approaches towards patient care, orthodontists must keep up with evidence-based data to understand how to treat their patients effectively and efficiently while also meeting the growing demands presented by their patients in terms of function and esthetics. To determine which enhancements in the orthodontic field are worth implementing clinically, professionals should turn to evidence-based research as a guiding tool to treat their patients.

The Xbow™ appliance is designed to correct skeletal and dental Class II malocclusions, although debate is still present in terms of the validity of skeletal correction. Dental Class II malocclusion occurs when the mesiobuccal groove of the mandibular first molar is distal to the mesiobuccal cusp of the maxillary first molar. Additionally, the mesial incline of the maxillary canine is anterior to the distal incline of the mandibular canine in occlusion. The line of occlusion is irregular and dependent on facial pattern, crowding and space requirements (Proffit, 2019). Skeletally, Class II malocclusion refers to a misalignment of the jaws in which the upper jaw is significantly forward in comparison to the lower jaw. Around 32% of individuals with a malocclusion present as having a Class II malocclusion, making this type of malocclusion relatively common in the general population (Ghosasra & Brizuela, 2023). Notably, retrognathism of the mandible is the most common cause of skeletal Class II development and has been proposed to account for 75% of Class II malocclusion cases (Baccetti et al., 1997). The Xbow™ appliance serves as a Class II corrector by applying gentle pressure to gradually position the lower jaw forward to promote mandibular growth while also proclining the lower incisors and slightly retroclining the upper incisors (Chana et al., 2013). These movements are achieved by utilizing a spring mechanism connected between the upper and lower jaws which applies pressure to position the lower jaw forward while a rod on the lower teeth slides along a track to control the movement of the mandible. Gurin locks (3M Unitek) are used as a special locking mechanism on the lower arch to control the amount of movement and ensure proper alignment (Flores-Mir et al. 2009).

Clinicians generally agree that the primary goal of the Forsus appliance (3M Unitek) in orthodontics is to correct Cl II dental malocclusions. The Xbow™ appliance is a fixed Cl II corrector that combines bilateral Forsus Fatigue Resistance Device springs (Unitek, Monrovia, Calif) with a maxillary expansion appliance and a mandibular triple arch (lingual and labial arches) to support the correction of excessive overjet due to mandibular retrognathism in growing children (Flores-Mir et al. 2009). Exploring a thorough understanding of the effects of the Xbow™ appliance as it relates to skeletal and dental variables is crucial for clinicians that use this appliance on their patients. Accordingly, this study will focus on using lateral cephalograms to evaluate skeletal and dental treatment changes between and within different facial types (mesocephalic, dolichocephalic and brachycephalic) in a retrospective sample of patients treated with the Xbow™ appliance.

*Xbow$^{TM}$ Design*

The Forsus appliance is a rigid, fixed appliance that is used to correct Class II malocclusions in growing individuals that present with skeletal mandibular retrognathism and a Cl II occlusal relationship. The Xbow$^{TM}$ appliance is a fixed Class II corrector that consists of a maxillary Hyrax expander, a mandibular labial and lingual bow and Forsus Fatigue Resistance Device springs (3M Unitek, Monrovia, Calif). The Forsus spring is inserted into the headgear tube of the band around the maxillary first molars and gets hooked around the labial bow, which is stopped by a Gurin lock (3M Unitek) around the mandibular canine area (Flores-Mir et al. 2009). The labial and lingual mandibular bows passively contact the mandibular incisors (Figure 1.1). The patient is still able to function in centric occlusion as the Forsus Fatigue Resistance Device springs do not act in a rigid manner to hold the mandible forward.

Figure 1.1. Xbow$^{TM}$ appliance consisting of maxillary expansion appliance and a mandibular triple arch (lingual and labial arches) and bilateral Forsus Fatigue Resistance Device Springs

Some of the reasons for utilizing a Forsus appliance, a major component of the Xbow$^{TM}$, include the device's durability, the posterior position in the mouth that allows the device to be virtually undetectable and therefore ideal from an esthetic standpoint, the ability to still allow normal jaw functioning and movement during treatment and that compliance is not an issue given the fixed nature of the appliance (Bhavani & Navaneethan, 2017). Dentally, studies have identified that the appliance demonstrates the ability to increase the proclination and intrude lower incisors, retrude and extrude maxillary incisors, decrease overjet, and decrease overbite. A 2009 study conducted by Flores-Mir et al. concluded that Cl II correction with the Xbow$^{TM}$ appliance was the combined result of skeletal and dental changes with the main skeletal influence being a restrictive headgear effect on the maxilla (Flores-Mir et. al, 2009). It was also noted that the Xbow$^{TM}$ appliance had the tendency to procline lower incisors, however, vertical facial types did not appear to affect the amount of lower incisor inclination (Chana, 2013). The multitude of functions the Xbow$^{TM}$ device demonstrates along with its growing popularity encourages further research on the comprehensive effects of treatment with this device.

## 1.2 Literature Review

### 1.2.1 Xbow$^{TM}$ Appliance Key Features

The Xbow$^{TM}$ appliance is a fixed functional appliance patented by Dr. Duncan W. Higgins that utilizes inter-arch springs and maxillary arch expansion to correct Class II malocclusions (Flores-Mir et al., 2009). Higgins initially began experimenting with the spring-loaded Herbst system used for Class II correction. He investigated the mechanics and side effects of this appliance and used this insight to later develop the Xbow$^{TM}$ appliance. The Xbow$^{TM}$ appliance focuses on completing phase one treatment targets to encourage a simpler orthodontic approach in phase two. Dr. Higgins describes the critical components of the Xbow$^{TM}$ appliance as follows (Higgins, 2006):

1. Initiation of the appliance after eruption of the maxillary first bicuspids to make space for the erupting canines.
2. Use of a rapid maxillary expander because nearly all Class II malocclusion patients require some degree of maxillary expansion.
3. The Triple "L" Arch allows the use of Class II springs with the rapid maxillary expander to correct overjet and provide space for maxillary canines.
4. Side effects resulting from the Class II springs such as posterior openbite development will settle between phases rather than utilizing elastics to counter side effects late in single phase treatment.

Dr. Higgins described four basic features of the Xbow$^{TM}$ appliance which include accomplishing Cl I buccal occlusion through over-correction of the maxillary first bicuspid and allowing physiologic rebound, reduced treatment time due to the non-compliance nature of the Forsus$^{TM}$ Fatigue Resistance Devices, space maintenance because of the rapid maxillary expansion and preservation of the leeway space and decreased risk of root resorption and decalcification that results from extensive orthodontic treatment due to the overall decreased treatment time with edgewise appliances as a result of having two phases of treatment (Higgins, 2006).

### 1.2.2 Xbow™ Comparison to other Removable Functional Appliances

The effectiveness of the Xbow™ appliance with regards to short-term skeletal and dental effects has been compared to that of a Twin-block. Ehsani et al (2015) conducted a retrospective clinical trial on 50 consecutive Class II cases treated in a private practice where 25 subjects were treated using a Twin-block and the other 25 subjects were treated using a Xbow™ followed by full fixed orthodontic treatment. A control group of 25 subjects with untreated Class II malocclusions was included to factor out growth. The results demonstrated that the maxilla grew forward less in the treatment groups than in the control groups. For mandibular changes, the corpus length increase was larger in the Twin-block group by around 3.9mm compared to the Xbow™ (Ehsani et al., 2015). The Xbow™ demonstrated an increased mandibular incisor proclination compared to the Twin-block by 3.3°. Dentally, mesial movement of the mandibular molars was increased in both treatment groups. The Wits value was decreased by 1.6mm more in the Twin-block group. There was no difference in treatment length between the Xbow™ and Twin-block. This study suggests that the Twin-block may produce slightly superior results in terms of dental and skeletal effects produced for Class II correction, however, the Twin-block effects would be highly subject to compliance.

A 2016 study conducted by Atik et al. compared the Xbow™, Frankel-2 and Trainer appliance to assess dentoskeletal and airway effects produced in prepubertal Class II division 1 patients via cephalograms (Atik et al., 2016). The sample consisted of 54 patients presenting with a Class II malocclusion due to mandibular retrognathia. Subjects were divided into four groups based on the appliance they would be treated with: Frankel-2, T4-K Trainer, Xbow™, and an untreated control group. The results indicated that the Frankel-2 and Xbow™ appliances were effective in restricting the forward growth of the maxilla and that the Frankel-2 and Trainer appliances demonstrated a more pronounced increase in mandibular length compared to the Xbow™ appliance. Further, lower incisor proclination was most pronounced in the group that was treated with the Xbow™ appliance (Atik et al., 2016). This study suggests that the Frankel-2 and Trainer appliances may be superior for producing mandibular changes, however, the Xbow™ is an effective means for limiting forward growth of the maxilla.

### 1.2.3 Xbow™ Appliance Skeletal and Dental Effects from Previous Literature

Flores-Mir et al (2009) investigated the short-term skeletal and dental effects that the Xbow™ appliance had compared with an untreated, equal control group using lateral cephalograms. The study considered 69 consecutive Class II patients that were treated with the Xbow™, with only two subjects not completing treatment. The mean treatment time was 4.5 months and controls from the Burlington growth study were used to account for growth factors. The following key conclusions were drawn (Flores-Mir et al., 2009):

i. Dental and skeletal changes played a role in the correction of the original Class II malocclusion. The ANB angle was reduced due to the reduction in maxillary protrusion (A point) without mandibular advancement.

ii. SNA, ANB, L1-MP, L1 minus Pg, overjet, U6 minus A, L6 minus Pg and A-OLp demonstrated statistically significant differences following Xbow™ treatment.

iii. SNB, U1-SN, U1 minus A, Pg-OLp and Ar-OLp did not demonstrate statistically significant differences following Xbow$^{TM}$ treatment.

iv. Improvement in overjet occurred with a net decrease of 3mm.

  i. 0.9mm from maxillary incisor posterior movement (U1 minus A)

  ii. 0.9mm from mandibular incisor anterior movement (L1 minus Pg)

  iii. 1.2mm from the mandible's outgrowth of maxilla (Pg-OLp and A-OLp)

v. Maxillary molars were significantly distalized while the mandibular molars were significantly mesialized.

Chana et al (2013) investigated skeletal and dental movements in subjects with different facial patterns following Class II correction with the Xbow$^{TM}$ appliance. A retrospective sample consisting of 134 subjects presenting for orthodontic correction of Class II malocclusion were grouped into three growth types according to pre-treatment MPA and Y-axis cephalometric measures. Dental and skeletal changes concluded from this study include (Chana et al., 2013):

i. Proclination of the lower incisors from 7.3-12.3° ± 1° (L1-MP)

ii. Protrusion of the lower incisors from 2.1-3.8mm ± 0.3mm (L1-APo)

iii. Mesial movement of the mandibular first molars from 5.5-6.9mm ± 0.7mm

iv. Retrusion of the maxillary incisor from 2.4-3.1mm ± 0.4mm

v. Decrease in Wits appraisal from 2.4-4.5mm ± 0.5mm for all facial growth types

The previous literature demonstrates that the Xbow$^{TM}$ appliance corrects Class II malocclusion through a combination of dental and skeletal effects. Skeletally, the correction is mostly acquired through the restrictive headgear effect on the maxilla to limit growth while the remaining correction occurs though dental changes in the maxilla and mandible.

## 1.3 Purpose

The purpose of this study was to determine skeletal and dental post-treatment changes in a sample of patients treated with the Xbow$^{TM}$ appliance and compare the values obtained from patients that underwent orthodontic treatment with the Xbow$^{TM}$ appliance in a private practice database to other previous literature.

## 1.4 Null Hypothesis

1. There is no significant difference in cephalometric values attained for dental changes in subjects with different facial patterns (i.e. mesocephalic, brachycephalic, dolichocephalic) treated with the Xbow$^{TM}$ appliance for Class II correction.

2. There is no significant difference in cephalometric values attained for skeletal changes in subjects with different facial patterns (i.e. mesocephalic, brachycephalic, dolichocephalic) treated with the Xbow$^{TM}$ appliance for Class II correction.

# Chapter 2

# Materials and Methods

## 2.1 Sample Selection

Pre-treatment (T1) and post-treatment (T2) cephalograms were obtained from a private orthodontic practice operating in Park City, Utah. Radiographic data sets (pre-treatment and post-treatment lateral cephalograms) were selected by searching the private practice's database for an item code denoting Xbow$^{TM}$ appliance insertion for correction of Cl II malocclusion in growing children. The sample obtained consisted of a total of 76 radiographs, of which 38 are pre-treatment cephalograms and 38 are post-treatment cephalograms. To select patients, the following inclusion criteria was utilized:

1. A complete permanent dentition.
2. Molar relationship of at least Cl II half cusp or greater bilaterally.
3. Subjects treated with the Xbow$^{TM}$ appliance.
4. Subjects with pre-treatment and post-treatment lateral cephalograms of an acceptable quality, where all required landmarks were easily identifiable.

Subjects were excluded from the study based on:

1. Subjects missing either a pre- or post-treatment cephalometric radiograph.
2. Subjects with cephalometric radiographs that are poor quality.
3. Mutilated dentitions.
4. Previous orthodontic treatment.

## 2.2 Data Collection

### 2.2.1 Calibration

The lateral cephalometric radiographs collected for this study exclude patient identifiers such as age, gender or if the radiograph was pre-treatment or post-treatment with the Xbow$^{TM}$ appliance. Each subject had a T1 lateral cephalometric radiograph taken during initial presentation at the orthodontic practice before being treated with the Xbow$^{TM}$ appliance and a T2 lateral cephalometric radiograph that was captured immediately following treatment with Xbow$^{TM}$ appliance. Each radiograph was denoted with a unique code for blinding purposes to the principal investigator. All lateral cephalometric radiographs were traced digitally using Dolphin (version, 11.95) in random order by a single operator to reduce bias. Magnification was accounted for through the digital calibration tool within the Dolphin Software. A code sheet was also transferred in the private Dropbox indicating matching pre- and post-treatment radiographs of all 38 patients that underwent Xbow$^{TM}$ appliance treatment in this study and was used following radiographic tracings to compare subject's pre- and post-treatment lateral cephalometric radiographs using statistical analyses.

Intra-examiner and inter-examiner reliability of the cephalometric measurements were assessed using an interclass correlation coefficient (ICC) test. To check intra-operator reliability, 30% of the studied samples were randomly selected using Excel's random number generator and re-traced 12 weeks after the original tracings were completed. For inter-operator reliability, the same 30% of the studied sample were re-traced by another operator (A.A., first year orthodontic resident) to account for differences in landmark errors. ANOVA statistical analysis was used to compare differences between the three growth types prior to treatment with the Xbow$^{TM}$

appliance, differences between the three growth types after treatment with the Xbow™ appliance and differences that occurred within each growth type from initial to final treatment with the Xbow™ appliance.

### 2.2.2 Defining Facial Types

Subjects were categorized into three growth types (mesocephalic, brachycephalic and dolichocephalic) according to two pre-treatment cephalometric variables:

- Mandibular plane angle (MPA, avg: 32° ± SD 2°)
- Growth axis (Y-axis, avg: 66° ± SD 2°)

Subjects were categorized as mesocephalic if they fell within the average standard deviation, dolichocephalic if their cephalometric measurements were above the standard deviation and brachycephalic if their cephalometric measurements were below the standard deviation. This yielded 15 mesocephalic, 13 brachycephalic and 10 dolichocephalic patients.

## 2.3 Statistical Analysis

Q-Q Plots were used to check the distribution of the residuals for each ANOVA. The observed quantiles of the residuals were compared to that of a standard normal curve (see example below of Q-Q Plot for occlusal plane to SN difference). When the data falls on the identify line, the distributional assumption is satisfied. This was the case of all outcomes in this study, representing that the sample was of normal distribution.

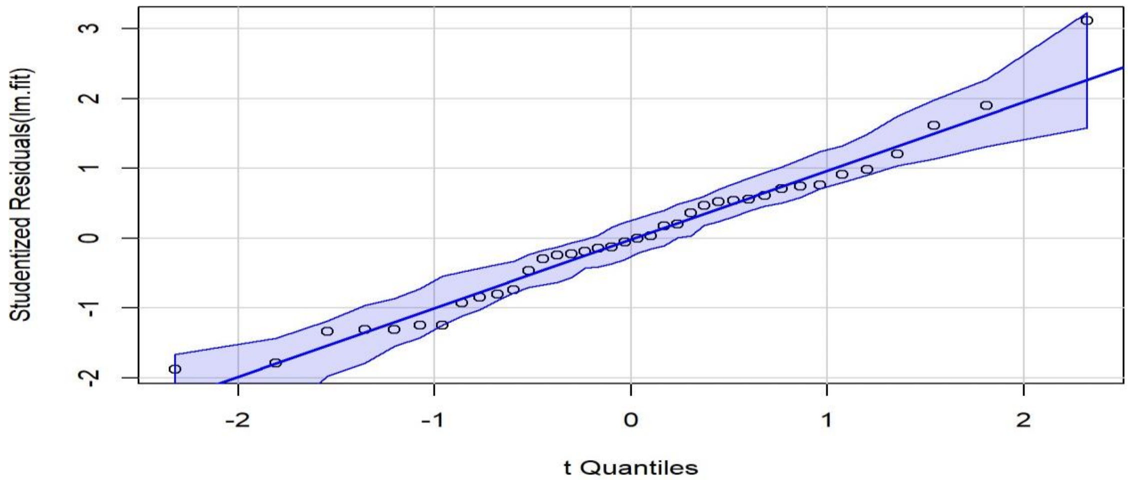


Figure 2.1. Q-Q Plot for Occlusal Plane to SN Difference

After confirmation of normal distribution, an analysis of variance (ANOVA) statistic was performed on the variables being assessed to analyze skeletal and dental effects of treatment with the Xbow$^{TM}$ appliance over time between the mesocephalic, dolichocephalic and brachycephalic groups. Distribution and type of analysis for this study is summarized in Table 2.1 below.

| **Variable** | **Distribution** | **Statistical Analysis** |
|---|---|---|
| Occ_Plane_SN | Normal | ANOVA |
| SNA | Normal | ANOVA |
| SNB | Normal | ANOVA |
| ANB | Normal | ANOVA |
| MP – SN (°) | Normal | ANOVA |
| Wits Appraisal (mm) | Normal | ANOVA |
| U1 – SN (°) | Normal | ANOVA |
| U1 – Palatal Plane (°) | Normal | ANOVA |

| | | |
|---|---|---|
| U1 – NA (°) | Normal | ANOVA |
| U1 – NA (mm) | Normal | ANOVA |
| Interincisal Angle (U1-L1) (°) | Normal | ANOVA |
| IMPA (L1 – MP) (°) | Normal | ANOVA |
| L1 Protrusion (L1-APo) (mm) | Normal | ANOVA |
| L1 – NB (°) | Normal | ANOVA |
| L1 – NB (mm) | Normal | ANOVA |
| L1 to A-Po (mm) | Normal | ANOVA |
| Y-axis (°) | Normal | ANOVA |
| Overjet (mm) | Normal | ANOVA |
| Overbite (mm) | Normal | ANOVA |
| Mandibular Incisor Extrusion (mm) | Log transformed for normal distribution | ANOVA |
| Molar Relation (mm) | Log transformed for normal distribution | ANOVA |

Table 2.1 Summary of Distribution and Type of Analysis for Examined Variables

## 2.4 Cephalometric Analysis

### 2.4.1 Natural Head Position

For the purpose of this study, it was assumed that all subjects were positioned in a stable and repeatable position when taking the pre-treatment and post-treatment lateral cephalometric radiographs. Natural head position refers to a standardized position of the head that orthodontists use when capturing cephalometric radiographs (Bansal et al., 2012). In this position the head is in an upright posture with the eyes focused on a point in the distance at eye level leading to the visual axis being horizontal. It is confirmed, based on the quality of the radiographs in this study, that all radiographs were taken in the natural head position. When the radiograph was captured, the beam of the x-ray would be perpendicular to the patient's sagittal plane with it entering the left side of the patient while the film cassette is positioned on the right side of the patient. All radiographs were taken with the patient's head positioned to the right.

### 2.4.1 Computerized Cephalometrics

The cephalometric radiographs were uploaded to a private shared Dropbox and then the data was downloaded in the JPEG digital format. The radiographs were uploaded into Dolphin Imaging (version 11.95) for cephalometric tracings and analysis. Tracing the cephalometric radiographs allows for digitization meaning the conversion of landmarks selected on the radiographs into a numerical value on a two-dimensional coordinate system (Jacobson, 2006). With this, numerical values are generated from the measurements of the landmarks allowing for analysis of skeletal and dental variables.

### 2.4.2 Cephalometric Landmarks

The field of Orthodontics utilizes cephalometric measurements for diagnosis, treatment planning and evaluation of dentofacial changes. This is accomplished by using specific landmarks on the skull, from both hard and soft tissue anatomical structures, from which linear and angular measurements are made (Phulari, et al., 2013). For this study, Rickett's and Steiner's analyses were used to analyze the skeletal and dental changes before and after Xbow™ appliance therapy.

Cephalometric landmarks for the modified Steiner's analysis and Rickett's analysis, adapted from Jacobson, 1995, are seen in figure 2.3 and 2.4 respectively.

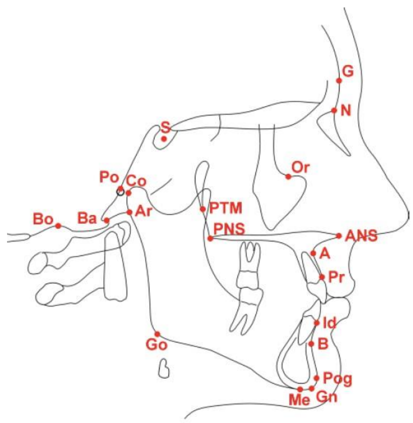


Figure 2.3 Representation of Modified Steiner's Analysis Landmarks

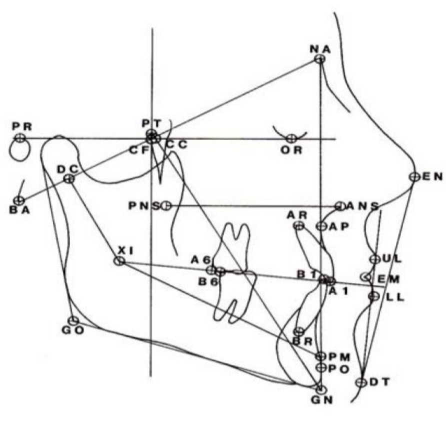


Figure 2.4 Representation of Modified Ricketts Analysis Landmarks

A complete summary for descriptions of each landmark from the modified Steiner's and Rickett's analysis can be found in Table 2.2 (Broadbent, 1975 and Jacobson, 1995). Some overlap of variables can be found between these two analyses but, regardless, have the same description. Measurements can be divided into midsagittal, unilateral, or bilateral. Midsagittal refers to landmarks that fall on the midsagittal plane and hence is a unilateral landmark. Unilateral landmarks refer to measurements that can only be identified on one side of the face while bilateral landmarks refer to measurements that can be identified on both sides of the face (Jacobson, 2006).

| Landmark | Analysis | Description | Midsagittal/Bilateral |
|---|---|---|---|
| A-point (subspinale, ss) | Steiner Ricketts | Most posterior, deep point on the midline in the curvature between ANS and prosthion. | Midsagittal |
| Anterior nasal spine (ANS) | Steiner Ricketts | Tip of the bony anterior nasal spine, on the midsagittal plane, at the inferior margin of the piriform aperture. Defines the anterior end of the palatal plane of the nasal floor. | Midsagittal |
| Articulare (Ar) | Steiner Ricketts | Constructed point that marks the intersection between the inferior surface of the cranial base, the posterior outlines of the ascending rami or mandibular condyle. | Bilateral |
| B-point (Point B, supramentale, sm) | Steiner Ricketts | Most posterior, deep point on the midline in the curvature of the anterior mandible between infradentale and pogonion. | Midsagittal |
| Basion (Ba) | Steiner Ricketts | Most anterior, inferior point located on the foramen magnum margin. Found on the | Midsagittal |

| | | | |
|---|---|---|---|
| | | inferior border of the basilar portion of the occipital bone. | |
| Bolton (Bo) | Steiner Ricketts | Highest point on the outlines of the retrocondylar fossae of the occipital bone which approximates the center of the foramen magnum. | Bilateral |
| CC point (CC) | Ricketts | Point at which the facial axis crosses with the BaN plane, known as the Cranial Center. | Midsagittal |
| Condylion (Co) | Steiner Ricketts | Most superior posterior point on the head of the mandibular condyle. | Bilateral |
| DC Point | Ricketts | Point on the condylar neck located on the Basion-Nasion line. | Bilateral |
| Glabella (G) | Steiner Ricketts | Most prominent point located on the anterior contour of the frontal bone in the midsagittal plane. | Midsagittal |
| Gnathion (Gn) | Steiner Ricketts | Most anterior, inferior point located on the bony chin. | Midsagittal |

Table 2.2 Modified Ricketts and Modified Steiner's Cephalometric Landmark Descriptions

### 2.4.3 Cephalometric Planes

Table 2.3 represents descriptions of the planes used in this study. The majority of the analyses utilize one or more cephalometric lines. These lines can either join two landmarks, be tangent to an outline from a landmark, or be perpendicular to another line from a landmark. The following planes are described by Broadbent and Jacobson (Broadbent, 1975 and Jacobson, 1995).

| Plane | Analysis | Description |
|---|---|---|
| Basion-Nasion line (Ba-N) | Ricketts | Line connecting the basion and nasion landmarks which represents the cranial base. |
| E-line (E-plane, Esthetic line of Ricketts) | Ricketts | Line tangent to the chin and nose to assess lip fullness. |
| Facial axis of Ricketts | Ricketts | Line connecting gnathion to cranial point (Pt) which is the lower border of the foramen rotundum and the most posterosuperior point of the outline of the pterygomaxillary fissure. |
| Facial plane (FP, Facial line) | Steiner<br>Ricketts | Line connecting nasion to pogonion. |
| Frankfort horizontal plane (FH) | Steiner<br>Ricketts | Line connecting the lower point of the floor of the orbit to the highest point on the external auditory meatus ridge (porion). |
| H-line (Harmony line of Holdaway) | Ricketts | Line tangent to the soft tissue of the chin and the upper lip. Used for assessing soft tissue profile. |
| Mandibular Plane (MP) | Steiner<br>Ricketts | Line extending from gonion to gnathion which passes through the mandibular border. |

| | | |
|---|---|---|
| Occlusal Plane (OP) | Steiner<br>Ricketts | Line passing through the occlusal surfaces of the maxillary and mandibular first permanent molars and the first and second premolars. |
| Palatal Plane (ANS-PNS, PP, Nasal floor) | Steiner<br>Ricketts | Line extending from PNS to ANS. |
| S-line (Esthetic plane of Steiner) | Steiner | Line connecting midpoint of columella of the nose to soft tissue pogonion. |
| Sella-Nasion line (SN) | Steiner | Line extending from sella to nasion which represents the anterior cranial base. |
| Y-axis (Growth axis) | Steiner<br>Ricketts | Line connecting sella and gnathion which serves to indicate growth pattern of mandible. |
| Angle of convexity (NAPog) | Steiner<br>Ricketts | Angle formed from NA and A-Pog lines which indicates degree of convexity of skeletal profile. |
| ANB angle | Steiner<br>Ricketts | Difference between SNA and SNB angles which indicated the anteroposterior relationship between the maxilla and mandible. |
| SNA angle | Steiner<br>Ricketts | Angle formed from intersection of SN and NA lines which assesses the anteroposterior position of the maxilla with regards to the cranial base |
| SNB angle | Steiner<br>Ricketts | Angle formed intersection of NA and NB lines which assesses the anteroposterior position of the mandible in relation to the cranial base. |

| | | |
|---|---|---|
| Facial angle (FH-NPog) | Steiner Ricketts | Angle formed from the intersection between the Frankfort horizontal plane and the facial plane (N-Pog). |
| Facial axis angle of Ricketts (Ba-Pt-Gn) | Ricketts | Angle formed from the intersection of the facial axis of Ricketts and the Ba-N line which indicates growth pattern. |
| Facial height, Anterior; Posterior; and Total | Steiner Ricketts | Vertical dimension indicator of the face. Anterior lower facial height is indicated by linear distance between ANS and menton. Percent ratio of previous linear measurement (ANS-Me) over total anterior facial height (N-Me) assesses relative proportionality of anterior face in the vertical dimension. Posterior facial height is assessed using linear measurement from S to Go. |
| Gonial angle (angle of the mandible, Condylar angle) | Steiner | Angle formed from the intersection of a line tangent to the posterior border of the ramus and the mandibular plane. Can serve as a mandibular growth indicator. |
| Holdaway ratio (LI-NB/Pg-NB) | Steiner | The linear distance from the labial surface of the mandibular central incisor to the NB line over the linear distance of the chin to the same line, represented as a ratio. |

| | | |
|---|---|---|
| Interincisal angle | Steiner<br>Ricketts | Angle formed from intersection between the long axis of the maxillary and mandibular central incisors. |
| LI-to-APo distance | Steiner | Perpendicular distance from the incisal edge of the mandibular central incisors to the A-Pog line. |
| Mandibular plane angle | Steiner<br>Ricketts | Angle formed from intersection point of SN and GoGn which assesses mandibular plane steepness as it relates to the cranial base. |
| Nasolabial angle (NLA) | Steiner<br>Ricketts | Anterior inferior angle formed from intersection of line tangent to columella of the nose and line extending from subnasale to mucocutaneous border or upper lip. |
| Wits appraisal | Steiner | Assesses jaw disharmony using perpendicular lines extending from the functional occlusal plane from points A and B, and then measuring the distance between the two points of intersection of the two perpendicular lines. |
| Molar Relation | Rickets | Assesses the position of the maxillary first molar in relation to the pteroid vertical and canine cusp. A molar is considered to be in normal position along its long axis when the line joining the distobuccal and mesiopalatal cusps of the maxillary first permanent molars passes 4mm distal to the canine cusp tip in the opposite site. |

Table 2.3 Modified Ricketts and Modified Steiner's Cephalometric Planes Descriptions

# Chapter 3

# Results

## 3.1 Reliability

To determine the reliability of the measurements being assessed, an intraclass correlation coefficient (ICC) test was completed on 30% of the sample used in this study. The intraclass correlation coefficient quantifies absolute agreement, not mere correlation among values. All values were assessed using the Shrout-Fleiss ICC (2,1) method, in which both raters and subjects were considered sources of random variability.  Cephalometric radiographs from 30% of the sample were randomly selected using Excel's random number generator and re-measured by two separate examiners 12 weeks following the original measurements. The measures captured from the re-tracing of the 30% of cephalometric radiographs were used to identify landmark identification errors. Based on the intraclass correlation coefficient (ICC), the level of reliability can be assessed. Values range from 0 (representing no agreement) to 1 (representing perfect agreement). The results from the intra-examiner test demonstrate very high consistency in the repeated measurements. Specifically, there was no ICC value that was less than 0.94 (Molar Relation) as well as none of the 95% confidence intervals for the ICC population values showed a lower limit less than 0.863 (Molar Relation) (Table 3.1) The following data combine both T1 (pre-treatment) and T2 (posttreatment) measurements for intra-operator reliability.

| Variables Examine T1 to T2 | Intraclass Correlation | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower limit | Upper Limit |
| Occ_Plane_SN | 0.995 | 0.989 | 0.998 |
| SNA | 0.996 | 0.991 | 0.998 |

| | | | |
|---|---|---|---|
| SNB | 0.995 | 0.988 | 0.998 |
| ANB | 0.973 | 0.937 | 0.989 |
| MP – SN (°) | 0.996 | 0.991 | 0.998 |
| Wits Appraisal (mm) | 0.982 | 0.959 | 0.993 |
| U1 – SN (°) | 0.999 | 0.997 | 1 |
| U1 – Palatal Plane (°) | 0.999 | 0.998 | 1 |
| U1 – NA (°) | 0.999 | 0.996 | 0.999 |
| U1 – NA (mm) | 0.989 | 0.975 | 0.996 |
| Interincisal Angle (U1-L1) (°) | 0.998 | 0.996 | 0.999 |
| IMPA (L1 – MP) (°) | 0.998 | 0.995 | 0.999 |
| L1 Protrusion (L1-APo) (mm) | 0.993 | 0.983 | 0.997 |
| L1 – NB (°) | 0.996 | 0.989 | 0.998 |
| L1 – NB (mm) | 0.98 | 0.953 | 0.992 |
| L1 to A-Po (mm) | 0.995 | 0.988 | 0.998 |
| Y-axis (°) | 0.994 | 0.985 | 0.997 |
| Overjet (mm) | 0.987 | 0.97 | 0.995 |
| Overbite (mm) | 0.977 | 0.947 | 0.99 |
| Mandibular Incisor Extrusion (mm) | 0.995 | 0.988 | 0.998 |
| Molar Relation (mm) | 0.94 | 0.863 | 0.947 |

Table 3.1 ICC test value for intra-rater reliability

The inter-rater ICC values showed similar variability as seen in the intra-rater results, demonstrating overall results of excellent reliability ranging from 0.928 to 0.999. Strong agreement of the remeasurement values is evident by all correlation coefficients being greater than 0.93 (Molar Relation) (Table 4.2). Based on the results captured, it is evident that reproducibility of the cephalometric variables is reliable within a 12-week period. The following data combine both T1 (pre-treatment) and T2 (post-treatment) measurements for inter-operator.

| Variables Examine T1 to T2 | Intraclass Correlation | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower limit | Upper Limit |
| Occ_Plane_SN | 0.988 | 0.972 | 0.995 |
| SNA | 0.988 | 0.971 | 0.995 |
| SNB | 0.986 | 0.968 | 0.994 |
| ANB | 0.945 | 0.874 | 0.977 |
| MP – SN (°) | 0.991 | 0.977 | 0.996 |
| Wits Appraisal (mm) | 0.968 | 0.925 | 0.986 |
| U1 – SN (°) | 0.997 | 0.992 | 0.999 |
| U1 – Palatal Plane (°) | 0.997 | 0.993 | 0.999 |
| U1 – NA (°) | 0.996 | 0.991 | 0.999 |
| U1 – NA (mm) | 0.973 | 0.928 | 0.99 |
| Interincisal Angle (U1-L1) (°) | 0.996 | 0.992 | 0.999 |
| IMPA (L1 – MP) (°) | 0.996 | 0.987 | 0.999 |
| L1 Protrusion (L1-APo) (mm) | 0.97 | 0.929 | 0.987 |
| L1 – NB (°) | 0.989 | 0.974 | 0.995 |

| | | | |
|---|---|---|---|
| L1 – NB (mm) | 0.948 | 0.877 | 0.978 |
| L1 to A-Po (mm) | 0.993 | 0.982 | 0.997 |
| Y-axis (°) | 0.981 | 0.954 | 0.992 |
| Overjet (mm) | 0.975 | 0.86 | 0.992 |
| Overbite (mm) | 0.928 | 0.838 | 0.969 |
| Mandibular Incisor Extrusion (mm) | 0.958 | 0.694 | 0.988 |
| Molar Relation (mm) | 0.93 | 0.839 | 0.97 |

Table 3.2 ICC test value for inter-rater reliability

## 3.2 Differences Between Groups Prior to Xbow™ Treatment (T1)

The retrospective study sample consisted of 38 patients presenting with Class II malocclusion to be treated with the Xbow™ appliance. Subjects were divided into three growth patterns (mesocephalic, brachycephalic and dolichocephalic) according to MPA and Y-axis pre-treatment cephalometric values. The results yielded 15 mesocephalic, 13 brachycephalic and 10 dolichocephalic subjects. We will begin by comparing the brachycephalic and dolichocephalic groups, then compare the brachycephalic and mesocephalic groups and lastly compare the mesocephalic and dolichocephalic groups to observe growth pattern, skeletal and dental changes.

### 3.2.1 Difference Between Brachycephalic and Dolichocephalic Prior to Xbow™ Treatment (T1) (Table 3.3)

**a. Growth Pattern**

i. Both Y-axis and MPA displayed a statistically significant difference between brachycephalic and dolichocephalic groups ($p<0.05$). This demonstrates two distinct facial patterns present before treatment with the Xbow$^{TM}$ appliance.

**b. Skeletal Pattern**

i. ANB and Wits appraisal did not display a statistically significant difference between the brachycephalic and dolichocephalic group ($p>0.05$). This demonstrates that both pre-treatment groups had Class II skeletal patterns. SNB showed a statistically significant difference between the brachycephalic and dolichocephalic groups, representing a more retrusive position of B point in the dolichocephalic group.

**c. Dental Variables**

i. Variables representing the upper incisors (U1-SN, U1-NA, U1-Palatal Plane) did not demonstrate statistically significant values between brachycephalic and dolichocephalic facial types. However, the lower incisor variables did show some statistically significant variation (IMPA, L1 Protrusion, L1 to NB linear). This is to be expected as dental compensations often occur for different facial patterns. The position of the lower incisor relative to the mandibular plane, namely IMPA, showed a statistically significant difference in which the brachycephalic was more proclined compared to the dolichocephalic group yet, the dolichocephalic group was more protruded in comparison to the brachycephalic group. Overjet and overbite did not demonstrate statistically significant results between the two facial types ($p>0.05$).

| Variables | Brachycephalic Pre-Treatment | Dolichocephalic Pre-treatment | p-value |
|---|---|---|---|
| | Mean±SE | Mean±SE | |

| | | | |
|---|---|---|---|
| Occ Plane to SN (°) | 12.3±4.72 | 17.3±4.19 | 0.017 |
| ANB (°) | 5.80±1.38 | 5.73±1.72 | 0.909 |
| SNA | 84.9±3.86 | 81.8±3.19 | 0.051 |
| SNB | 79.9±3.67 | 76.9±3.47 | 0.041 |
| Y-Axis (°) | 62.6±1.30 | 70.1±1.57 | <0.0001 |
| MP – SN (°) | 24.7±2.42 | 36.8±1.83 | <0.0001 |
| Wits Appraisal (mm0 | 3.62±1.45 | 2.45±2.28 | 0.230 |
| U1 – SN (°) | 99.2±7.35 | 99.5±8.48 | 0.935 |
| U1 – Palatal Plane (°) | 106±7.85 | 108±8.14 | 0.612 |
| U1 – NA (°) | 15.2±8.28 | 18.6±7.02 | 0.355 |
| U1 – NA (mm) | 1.05±2.56 | 2.79±2.89 | 0.130 |
| Interincisal Angle (U1-L1) (°) | 134±6.75 | 129±9.78 | 0.195 |
| IMPA (L1-MP) (°) | 100±6.75 | 94.5±3.02 | 0.023 |
| L1 Protrusion (L1-APo) (mm) | 0.131±1.04 | 1.79±2.13 | 0.011 |
| L1 -NB (°) | 24.9±4.60 | 26.7±3.57 | 0.364 |
| L1 – NB (mm) | 3.39±0.92 | 5.21±1.79 | 0.020 |
| L1 to A-Po (mm) | 20.6±4.31 | 22.2±3.36 | 0.365 |
| Overjet (mm) | 4.35±1.39 | 4.89±1.25 | 0.454 |
| Overbite (mm) | 3.36±1.17 | 2.82±1.44 | 0.334 |

| | | | |
|---|---|---|---|
| Mandibular incisor extrusion (mm) | 2.27±1.95 | 1.41±0.694 | 0.117 |
| Molar relation | 0.869±1.11 | 0.710±0.849 | 0.691 |

Table 3.3 Difference Between Brachycephalic and Dolichocephalic Prior to Xbow$^{TM}$ appliance Treatment

### 3.2.2 Difference Between Brachycephalic and Mesocephalic Prior to Xbow$^{TM}$ Treatment (T1) (Table 3.4)

i. **Growth Pattern**

   i. Both Y-axis and MPA displayed a statistically significant difference between brachycephalic and mesocephalic groups ($p<0.05$). This demonstrates two distinct facial patterns present before treatment with the Xbow$^{TM}$ appliance.

ii. **Skeletal Pattern**

   i. ANB and Wits appraisal did not display a statistically significant difference between the brachycephalic and mesocephalic group ($p>0.05$). This demonstrates that both pre-treatment groups had Class II skeletal patterns. SNB showed a statistically significant difference between the brachycephalic and mesocephalic groups, representing a more retrusive position of B point in the mesocephalic group.

iii. **Dental Variables**

   i. Variables representing the upper incisors (U1-SN and U1-Palatal Plane) did not demonstrate statistically significant values among brachycephalic and mesocephalic facial types. U1-NA angular did show very borderline significance and thus it is not convincing to signify certain differences between the two facial patterns for this measure.

However, the incisor to mandibular plane angle did show some statistically significant variation. This is to be expected as dental compensations often occur for different facial patterns. IMPA showed a statistically significant difference in which the brachycephalic group was more proclined compared to the mesocephalic group. Overjet and overbite did not demonstrate statistically significant results between the two facial types (p>0.05).

| Variables | Brachycephalic Pre-Treatment | Mesocephalic Pre-treatment | p-value |
|---|---|---|---|
| | Mean±SE | Mean±SE | |
| Occ Plane to SN (°) | 12.3±4.72 | 15.5±5.09 | 0.088 |
| ANB (°) | 5.80±1.38 | 5.44±1.29 | 0.514 |
| SNA | 84.9±3.86 | 82.5±3.78 | 0.099 |
| SNB | 79.9±3.67 | 77.1±3.01 | 0.032 |
| Y-Axis (°) | 62.6±1.30 | 66.9±0.987 | <0.00001 |
| MP – SN (°) | 24.7±2.42 | 31.6±1.68 | <0.00001 |
| Wits Appraisal (mm0 | 3.62±1.45 | 3.21±2.80 | 0.633 |
| U1 – SN (°) | 99.2±7.35 | 103±10.3 | 0.312 |
| U1 – Palatal Plane (°) | 106±7.85 | 112±9.88 | 0.103 |
| U1 – NA (°) | 15.2±8.28 | 21.2±9.88 | 0.077 |
| U1 – NA (mm) | 1.05±2.56 | 3.11±2.62 | 0.049 |
| Interincisal Angle (U1-L1) (°) | 134±6.75 | 129±10.3 | 0.173 |
| IMPA (L1-MP) (°) | 100±6.75 | 95.6±6.67 | 0.039 |

| | | | |
|---|---|---|---|
| L1 Protrusion (L1-APo) (mm) | 0.131±1.04 | 0.487±1.84 | 0.344 |
| L1 -NB (°) | 24.9±4.60 | 24.1±5.05 | 0.636 |
| L1 – NB (mm) | 3.39±0.92 | 3.99±2.26 | 0.383 |
| L1 to A-Po (mm) | 20.6±4.31 | 21±4.26 | 0.799 |
| Overjet (mm) | 4.35±1.39 | 5.64±2.15 | 0.053 |
| Overbite (mm) | 3.36±1.17 | 3.27±1.34 | 0.850 |
| Mandibular incisor extrusion (mm) | 2.27±1.95 | 1.63±0.677 | 0.190 |
| Molar relation | 0.869±1.11 | 0.633±0.84 | 0.514 |

Table 3.4 Difference Between Brachycephalic and Mesocephalic Prior to Xbow$^{TM}$ appliance Treatment

### 3.2.2 Difference Between Dolichocephalic and Mesocephalic Prior to Xbow$^{TM}$ Treatment (T1) (Table 3.4)

i. **Growth Pattern**

   a. Y-axis and MPA both showed a statistically significant difference between mesocephalic and dolichocephalic groups ($p<0.05$), indicating that two distinct facial patterns were present prior to Xbow$^{TM}$ treatment.

ii. **Skeletal Pattern**

   a. Both ANB and Wits appraisal were not statistically significant between the mesocephalic and dolichocephalic groups ($p>0.05$), indicating that both groups demonstrate Class II skeletal patterns prior to Xbow$^{TM}$ treatment.

### iii. Dental Variables

a. The facial patterns in mesocephalic and dolichocephalic groups were similar enough to not produce statistically significant differences about molar and incisor position as well as overjet and overbite ($p>0.05$). This suggests that the dental compensations for the mesocephalic and dolichocephalic groups were similar prior to Xbow$^{TM}$ treatment for this group of subjects.

| Variables | Mesocephalic Pre-Treatment | Dolichocephalic Pre-treatment | p-value |
|---|---|---|---|
| | Mean±SE | Mean±SE | |
| Occ Plane to SN (°) | 15.5±5.09 | 17.3±4.19 | 0.345 |
| ANB (°) | 5.44±1.29 | 5.73±1.72 | 0.625 |
| SNA | 82.5±3.78 | 81.8±3.19 | 0.615 |
| SNB | 77.1±3.01 | 76.9±3.47 | 0.918 |
| Y-Axis (°) | 66.9±0.987 | 70.1±1.57 | <0.00001 |
| MP – SN (°) | 31.6±1.68 | 36.8±1.83 | <0.00001 |
| Wits Appraisal (mm0 | 3.21±2.80 | 2.45±2.28 | 0.422 |
| U1 – SN (°) | 103±10.3 | 99.5±8.48 | 0.392 |
| U1 – Palatal Plane (°) | 112±9.88 | 108±8.14 | 0.312 |
| U1 – NA (°) | 21.2±9.88 | 18.6±7.02 | 0.473 |
| U1 – NA (mm) | 3.11±2.62 | 2.79±2.89 | 0.769 |
| Interincisal Angle (U1-L1) (°) | 129±10.3 | 129±9.78 | 0.945 |
| IMPA (L1-MP) (°) | 95.6±6.67 | 94.5±3.02 | 0.653 |

| | | | |
|---|---|---|---|
| L1 Protrusion (L1-APo) (mm) | 0.487±1.84 | 1.79±2.13 | 0.069 |
| L1 -NB (°) | 24.1±5.05 | 26.7±3.57 | 0.173 |
| L1 – NB (mm) | 3.99±2.26 | 5.21±1.79 | 0.101 |
| L1 to A-Po (mm) | 21±4.26 | 22.2±3.36 | 0.483 |
| Overjet (mm) | 5.64±2.15 | 4.89±1.25 | 0.289 |
| Overbite (mm) | 3.27±1.34 | 2.82±1.44 | 0.411 |
| Mandibular incisor extrusion (mm) | 1.63±0.677 | 1.41±0.694 | 0.678 |
| Molar relation | 0.633±0.84 | 0.710±0.849 | 0.843 |

Table 3.5 Difference Between Mesocephalic and Dolichocephalic Prior to Xbow$^{TM}$ appliance Treatment

## 3.3 Change Score Differences Between Groups Following Xbow$^{TM}$ Treatment (T2-T1)

To assess whether the three facial type groups experienced different magnitudes of changes in their various measurements, the average change scores (the difference values from T1 and T2 for each variable) were compared using an ANOVA to determine if statistically significant differences were found.

### 3.3.1 Difference Between Brachycephalic and Dolichocephalic Change Scores of Xbow$^{TM}$ Treatment (T1-T2)

i. **Growth Pattern**

a. Y-axis was significantly different between the brachycephalic and dolichocephalic change score values ($p<0.05$) following Xbow$^{TM}$ appliance treatment. Since Y-axis measures Sella to gnathion and indicates the growth pattern of the mandible these differences could reflect the different growth patterns seen in the mandible by brachycephalic and dolichocephalic patients. However, MPA did not display significantly different change values ($p>0.05$) indicating that there was not a change in the pre-existing facial patterns following treatment with the Xbow$^{TM}$ appliance.

**ii. Skeletal Pattern**

a. ANB and Wits appraisal did not demonstrate statistically significant differences in change scores following Xbow$^{TM}$ appliance treatment. There was a reduction in both Wits appraisal and ANB values demonstrated by the change scores for brachycephalic and dolichocephalic groups demonstrating correction of the original Class II skeletal pattern.

**iii. Dental Variables**

a. The facial pattern did not influence the movement of the upper incisor and molars; hence, the change scores did not produce statistically significant differences between the two groups ($p>0.05$) after Xbow$^{TM}$ treatment. No statistically significant difference was present for lower incisor variables ($p>0.05$), however, both brachycephalic and dolichocephalic groups demonstrated an increase in IMPA values (2.67±5.55° and 1.89±4.18°, respectively). This increase in IMPA is consistent with the proclination of the lower incisors that is expected to occur following Xbow$^{TM}$ appliance therapy. Both overjet and overbite were reduced following Xbow$^{TM}$ treatment in both groups

(-1.37±1.59 mm and -1.98±1.19 mm) but were not found to be statistically different in their change scores (p>0.05).

| Variables | Brachycephalic Pre-Treatment | Dolichocephalic Pre-treatment | p-value |
|---|---|---|---|
| | Mean Change Score ± SE | Mean Change Score ± SE | |
| Occ Plane to SN (°) | 2.90±5.72 | 2.54±5.49 | 0.882 |
| ANB (°) | -1.70±1.20 | -1.56±2.10 | 0.858 |
| SNA | -1.77±4.31 | -1.12±3.02 | 0.680 |
| SNB | -0.738±4.03 | -0.75-±3.60 | 0.994 |
| Y-Axis (°) | 2.47±2.53 | 0.220±2.20 | 0.016 |
| MP – SN (°) | 0.231±6.54 | -1.67±5.15 | 0.385 |
| Wits Appraisal (mm0 | -2.60±1.77 | -2.88±2.88 | 0.804 |
| U1 – SN (°) | 1.99±7.73 | 0.810±9.50 | 0.759 |
| U1 – Palatal Plane (°) | 2.66±8.77 | 2.22±10.5 | 0.913 |
| U1 – NA (°) | 3.42±7.82 | 2.10±10.8 | 0.746 |
| U1 – NA (mm) | 0.623±2.63 | 0.220±3.51 | 0.762 |
| Interincisal Angle (U1-L1) (°) | -4.55±6.63 | -1.85±11 | 0.497 |
| IMPA (L1-MP) (°) | 2.67±5.55 | 1.89±4.18 | 0.741 |
| L1 Protrusion (L1-APo) (mm) | 1.02±1.79 | 1.05±1.61 | 0.962 |

| | | | |
|---|---|---|---|
| L1 -NB (°) | 2.92±5.21 | 1.28±2.79 | 0.455 |
| L1 – NB (mm) | 0.277±1.40 | 0.370±1.01 | 0.895 |
| L1 to A-Po (mm) | 5.15±4.86 | 3.06±4.01 | 0.312 |
| Overjet (mm) | -1.37±1.59 | -1.98±1.19 | 0.408 |
| Overbite (mm) | -1.51±1.38 | -1.80±0.794 | 0.583 |
| Mandibular incisor extrusion (mm) | -1.35±2.14 | -0.910±0.384 | 0.450 |
| Molar relation | -1.23±1.10 | -1.10±0.86 | 0.777 |

Table 3.6 Difference Between Brachycephalic and Dolichocephalic Change Scores with Xbow$^{TM}$ Appliance Treatment

### 3.3.2 Difference Between Brachycephalic and Mesocephalic Change Scores of Xbow$^{TM}$ Treatment (T1-T2)

i. **Growth Pattern**

   a. Y-axis and MPA did not display significantly different change values (p>0.05) showing that there was not a change in the pre-existing facial patterns following treatment with the Xbow$^{TM}$ appliance.

ii. **Skeletal Pattern**

   a. ANB and Wits appraisal did not demonstrate statistically significant differences in brachycephalic and mesocephalic change scores (p>0.05) following Xbow$^{TM}$ appliance treatment.

iii. **Dental Variables**

a. The facial pattern did not influence the movement of the upper incisor and molars; hence, the change scores did not produce statistically significant differences between the two groups ($p>0.05$) after Xbow$^{TM}$ treatment. No statistically significant differences were present for lower incisor variables ($p>0.05$), however, both brachycephalic and mesocephalic groups demonstrated an increase in IMPA values (2.67±5.55° and 3.54±6.29°, respectively). This increase in IMPA is consistent with the proclination of the lower incisors that is expected to occur following Xbow$^{TM}$ appliance therapy. Overbite was reduced following Xbow$^{TM}$ treatment in both groups (-1.51±1.38 and -1.79±1.54 mm, respectively) but was not found to have statistically significant differences in change scores between the brachycephalic and mesocephalic groups. Overjet was found to show statistically significant change scores in the brachycephalic and mesocephalic groups ($p<0.05$) in which the mesocephalic facial type showed increased reduction, -2.95±2.11 mm, compared to the brachycephalic facial type, -1.37±1.59 mm.

| Variables | Brachycephalic Pre-Treatment | Mesocephalic Pre-treatment | p-value |
|---|---|---|---|
| | Mean Change Score ± SE | Mean Change Score ± SE | |
| Occ Plane to SN (°) | 2.90±5.72 | 1.57±5.85 | 0.544 |
| ANB (°) | -1.70±1.20 | -1.86±2.11 | 0.820 |
| SNA | -1.77±4.31 | -2.01±3.56 | 0.863 |
| SNB | -0.738±4.03 | -0.10±3.28 | 0.646 |
| Y-Axis (°) | 2.47±2.53 | 1.25±0.70 | 0.137 |

| | | | |
|---|---|---|---|
| MP – SN (°) | 0.231±6.54 | -0.153±3.51 | 0.845 |
| Wits Appraisal (mm) | -2.60±1.77 | -2.68±3.11 | 0.937 |
| U1 – SN (°) | 1.99±7.73 | -1.38±9.88 | 0.335 |
| U1 – Palatal Plane (°) | 2.66±8.77 | -1.01±9.65 | 0.319 |
| U1 – NA (°) | 3.42±7.82 | -0.06±10.2 | 0.346 |
| U1 – NA (mm) | 0.623±2.63 | -0.02±3.39 | 0.592 |
| Interincisal Angle (U1-L1) (°) | -4.55±6.63 | -1.83±10.2 | 0.449 |
| IMPA (L1-MP) (°) | 2.67±5.55 | 3.54±6.29 | 0.682 |
| L1 Protrusion (L1-APo) (mm) | 1.02±1.79 | 1.63±1.66 | 0.337 |
| L1 -NB | 2.92±5.21 | 4.40±5.80 | 0.451 |
| L1 – NB (mm) | 0.277±1.40 | 1.13±2.13 | 0.185 |
| L1 to A-Po (mm) | 5.15±4.86 | 5.78±5.31 | 0.735 |
| Overjet (mm) | -1.37±1.59 | -2.95±2.11 | 0.021 |
| Overbite (mm) | -1.51±1.38 | -1.79±1.54 | 0.583 |
| Mandibular incisor extrusion (mm) | -1.35±2.14 | -0.893±0.759 | 0.385 |
| Molar relation | -1.23±1.10 | -1.07±1.20 | 0.705 |

Table 3.7 Difference Between Brachycephalic and Mesocephalic Change Scores with Xbow$^{TM}$ Appliance Treatment

### 3.3.3 Difference Between Dolichocephalic and Mesocephalic Change Scores of Xbow™ Treatment (T1-T2)

i. **Growth Pattern**

a. Y-axis and MPA did not display significantly different change values ($p>0.05$) showing that there was not a change in the pre-existing facial patterns following treatment with the Xbow™ appliance.

ii. **Skeletal Pattern**

a. ANB and Wits appraisal did not demonstrate statistically significant differences in dolichocephalic and mesocephalic change scores ($p>0.05$) from Xbow™ appliance treatment.

iii. **Dental Variables**

a. The facial pattern did not significantly influence the movement of the upper incisor and molars; hence, the change scores did not produce statistically significant differences between the two groups ($p>0.05$) after Xbow™ treatment. No statistical difference was present for lower incisor variables ($p>0.05$), however, both mesocephalic and dolichocephalic groups demonstrated an increase in IMPA values (3.54±6.29° and 1.89±4.18°, respectively). This increase in IMPA is consistent with the proclination of the lower incisors that is expected to occur following Xbow™ appliance therapy. Overbite was reduced following Xbow™ treatment in the mesocephalic and dolichocephalic groups (-1.79±1.54 mm and -1.80±0.794 mm) but was not found to have statistically significant differences in change scores ($p>0.05$) between the two groups. Overjet was reduced to a greater extent in the mesocephalic facial type

(-2.95±2.11 mm) but was not found to demonstrate statistical significance change scores ($p>0.05$) compared to the dolichocephalic facial group (1.98±1.19 mm).

| Variables | Mesocephalic Pre-Treatment Mean Change Score ± SE | Dolichocephalic Pre-treatment Mean Change Score ± SE | p-value |
|---|---|---|---|
| Occ Plane to SN (°) | 1.57±5.85 | 2.54±5.49 | 0.681 |
| ANB (°) | -1.86±2.11 | -1.56±2.10 | 0.693 |
| SNA | -2.01±3.56 | -1.12±3.02 | 0.559 |
| SNB | -0.10±3.28 | -0.75-±3.60 | 0.664 |
| Y-Axis (°) | 1.25±0.70 | 0.220±2.20 | 0.243 |
| MP – SN (°) | -0.153±3.51 | -1.67±5.15 | 0.475 |
| Wits Appraisal (mm0 | -2.68±3.11 | -2.88±2.88 | 0.855 |
| U1 – SN (°) | -1.38±9.88 | 0.810±9.50 | 0.559 |
| U1 – Palatal Plane (°) | -1.01±9.65 | 2.22±10.5 | 0.415 |
| U1 – NA (°) | -0.06±10.2 | 2.10±10.8 | 0.585 |
| U1 – NA (mm) | -0.02±3.39 | 0.220±3.51 | 0.853 |
| Interincisal Angle (U1-L1) (°) | -1.83±10.2 | -1.85±11 | 0.997 |
| IMPA (L1-MP) (°) | 3.54±6.29 | 1.89±4.18 | 0.472 |
| L1 Protrusion (L1-APo) (mm) | 1.63±1.66 | 1.05±1.61 | 0.399 |

| | | | |
|---|---|---|---|
| L1 -NB | 4.40±5.80 | 1.28±2.79 | 0.146 |
| L1 – NB (mm) | 1.13±2.13 | 0.370±1.01 | 0.271 |
| L1 to A-Po (mm) | 5.78±5.31 | 3.06±4.01 | 0.178 |
| Overjet (mm) | -2.95±2.11 | -1.98±1.19 | 0.178 |
| Overbite (mm) | -1.79±1.54 | -1.80±0.794 | 0.981 |
| Mandibular incisor extrusion (mm) | -0.893±0.759 | -0.910±0.384 | 0.976 |
| Molar relation | -1.07±1.20 | -1.10±0.86 | 0.952 |

Table 3.8 Difference Between Mesocephalic and Dolichocephalic Change Scores with Xbow™ Appliance Treatment

## 3.4 The Difference Within Each Group Before and After Xbow™ Treatment (T2-T1)

### 3.4.1 Difference Between Initial and Final Treatment for Brachycephalic Group (n=13) (T2-T1)

i. **Growth Pattern**

   a. Y-axis was statistically significant ($p<0.05$) with a mean change score of 2.47±2.53° in the brachycephalic group following Xbow™ treatment, indicating changes in the pattern of mandibular growth as represented by gnathion. However, MPA was not found to have changed in a statistically significant manner ($p>0.05$) following XBow™ appliance therapy. This may be attributed to the brachycephalic nature of the patients producing less significant mandibular plane angle changes as these patients often show a horizontal pattern of growth.

**ii. Skeletal Pattern**

a. ANB and Wits both produced statistically significant changes ($p<0.05$) following Xbow$^{TM}$ appliance treatment. ANB was significantly reduced by an average of 1.7±1.20° with Xbow$^{TM}$ treatment. Wits appraisal demonstrated a statistically significant average reduction of 2.60±1.77 mm. This demonstrates correction of the original Class II skeletal malocclusion.

**iii. Dental Variables**

a. The overall dental movements achieved with Xbow$^{TM}$ treatment were in favor of Class II dentoalveolar correction. The upper incisors did not demonstrate significant angular changes ($p>0.05$). The lower incisors also did not demonstrate significant angular changes between initial and final values with Xbow$^{TM}$ treatment ($p>0.05$). However, there was an increase in IMPA of 2.67±5.55° from initial to final treatment within the brachycephalic subject group. Changes in the interincisal angle were significant and demonstrated an average reduction of 4.55±6.63° suggesting a change towards proclination of the incisors following Xbow$^{TM}$ treatment ($p<0.05$). Mandibular incisor extrusion was significant ($p<0.05$)with an average reduction of 1.35±2.14 mm which would contribute to a decrease in overbite seen following Xbow$^{TM}$ treatment. Molar relation was also significant with an average reduction of -1.23±1.10 mm ($p<0.05$) indicating a corrective dental movement of the original Class II maxillary molar position towards a Class I maxillary molar position. Both overjet and overbite were significantly reduced (-1.37±1.59mm and -1.51±1.38 mm) towards normal with Xbow™ treatment ($p<0.05$).

| Variables | Brachycephalic Mean Change Score ± SE | p-value |
|---|---|---|
| Occ Plane to SN (°) | 2.90±5.72 | 0.0926 |
| ANB (°) | -1.70±1.20 | 0.0003 |
| SNA | -1.77±4.31 | 0.1646 |
| SNB | -0.738±4.03 | 0.5216 |
| Y-Axis (°) | 2.47±2.53 | 0.0043 |
| MP – SN (°) | 0.231±6.54 | 0.9009 |
| Wits Appraisal (mm) | -2.60±1.77 | 0.0002 |
| U1 – SN (°) | 1.99±7.73 | 0.3710 |
| U1 – Palatal Plane (°) | 2.66±8.77 | 0.2951 |
| U1 – NA (°) | 3.42±7.82 | 0.1412 |
| U1 – NA (mm) | 0.623±2.63 | 0.4098 |
| Interincisal Angle (U1-L1) (°) | -4.55±6.63 | 0.0292 |
| IMPA (L1-MP) (°) | 2.67±5.55 | 0.1084 |
| L1 Protrusion (L1-APo) (mm) | 1.02±1.79 | 0.0638 |
| L1 -NB | 2.92±5.21 | 0.0667 |
| L1 – NB (mm) | 0.277±1.40 | 0.4881 |
| L1 to A-Po (mm) | 5.15±4.86 | 0.0024 |

| | | |
|---|---|---|
| Overjet (mm) | -1.37±1.59 | 0.0090 |
| Overbite (mm) | -1.51±1.38 | 0.0020 |
| Mandibular incisor extrusion (mm) | -1.35±2.14 | 0.0429 |
| Molar relation | -1.23±1.10 | 0.0017 |

Table 3.9 Difference Between Initial and Final Treatment for the Brachycephalic Group (n=13) (T2-T1)

### 3.4.2 Difference Between Initial and Final Treatment for Dolichocephalic Group (n=10) (T2-T1)

i. **Growth Pattern**

a. Both Y-axis and MPA were not statistically significant from before and after treatment with the Xbow™ appliance ($p>0.05$), indicating the appliance did not change the pre-existing facial pattern in the dolichocephalic group.

ii. **Skeletal Pattern**

a. ANB and Wits appraisal were both statistically significant following Xbow™ treatment ($p<0.05$), with a mean reduction of 1.56±2.10° and 2.88±2.88 mm, respectively. This demonstrates correction of the original Class II skeletal malocclusion.

iii. **Dental Variables**

The overall dental movements of the Xbow™ appliance were in favor of Class II dentoalveolar correction for the dolichocephalic facial group. The upper incisors did not demonstrate significant angular changes ($p>0.05$). The lower incisors also did not demonstrate significant angular changes between initial and final values with Xbow™

treatment (p>0.05). Although, there was an increase in IMPA of 1.89±4.18° following Xbow™ treatment within the dolichocephalic subject group. Mandibular incisor extrusion was significant (p<0.05) with an average reduction of 0.910±0.384 mm which would contribute to a decrease in overbite seen following Xbow™ treatment. Molar relation was also significant with an average reduction of 1.10±0.86 mm (p<0.05) indicating a corrective dental movement of the original Class II maxillary molar position towards a Class I maxillary molar position. Both overjet and overbite were significantly reduced (-1.98±1.19 and -1.80±0.794, respectively) towards normal with Xbow™ treatment (p<0.05).

| Variables | Dolichocephalic<br>Mean Change Score ± SE | p-value |
|---|---|---|
| Occ Plane to SN (°) | 2.54±5.49 | 0.1774 |
| ANB (°) | -1.56±2.10 | 0.0432 |
| SNA | -1.12±3.02 | 0.2714 |
| SNB | -0.75-±3.60 | 0.5260 |
| Y-Axis (°) | 0.220±2.20 | 0.7686 |
| MP – SN (°) | -1.67±5.15 | 0.3319 |
| Wits Appraisal (mm0 | -2.88±2.88 | 0.0116 |
| U1 – SN (°) | 0.810±9.50 | 0.7936 |
| U1 – Palatal Plane (°) | 2.22±10.5 | 0.5187 |
| U1 – NA (°) | 2.10±10.8 | 0.5523 |
| U1 – NA (mm) | 0.220±3.51 | 0.8472 |
| Interincisal Angle (U1-L1) (°) | -1.85±11 | 0.6076 |

| | | |
|---|---|---|
| IMPA (L1-MP) (°) | 1.89±4.18 | 0.1869 |
| L1 Protrusion (L1-APo) (mm) | 1.05±1.61 | 0.0687 |
| L1 -NB | 1.28±2.79 | 0.3128 |
| L1 – NB (mm) | 0.370±1.01 | 0.2755 |
| L1 to A-Po (mm) | 3.06±4.01 | 0.0392 |
| Overjet (mm) | -1.98±1.19 | 0.0005 |
| Overbite (mm) | -1.80±0.794 | 0.0001 |
| Mandibular incisor extrusion (mm) | -0.910±0.384 | <0.00001 |
| Molar relation | -1.10±0.86 | 0.0029 |

Table 3.10 Difference Between Initial and Final Treatment for the Dolichocephalic Group (n=10) (T2-T1)

### 3.4.2 Difference Between Initial and Final Treatment for Mesocephalic Group (n=15) (T2-T1)

i. **Growth Pattern**

a. Y-axis was statistically significant ($p<0.05$) with a mean change score of 1.25±0.70° between initial and final treatment with the XBow$^{TM}$ indicating a change in the growth pattern in the mesocephalic group. This could be due to the ideal growth potential in mesocephalic patients which would produce changes in the gnathion position from mandibular growth leading to changes in Y-axis. MPA was not found to be statistically significant ($p>0.05$) between initial and final treatment following Xbow$^{TM}$ appliance treatment, indicating no changes in the pre-existing facial pattern.

ii. **Skeletal Pattern**

a. ANB and Wits appraisal were both statistically significant following Xbow$^{TM}$ treatment ($p<0.05$), with a mean reduction of 1.86±2.11° and 2.68±3.11 mm, respectively. This demonstrates correction of the original Class II skeletal malocclusion.

iii. **Dental Variables**

The overall dental movements of the Xbow$^{TM}$ appliance were in favor of Class II dentoalveolar correction for the mesocephalic facial group. The upper incisors did not demonstrate significant angular changes ($p>0.05$). Dental changes in the lower incisors were significant ($p<0.05$) with an increased mean proclination to MP (3.54±6.29°) and NB angular (4.40±5.80°) and increased mean protrusion to APog (1.63±1.66 mm). Mandibular incisor extrusion was significant ($p<0.05$) with an average reduction of 0.893±0.759 mm which would contribute to a decrease in overbite seen following Xbow$^{TM}$ treatment. Molar relation was also significant with an average reduction of 1.07±1.20 mm ($p<0.05$) indicating a corrective dental movement of the original Class II maxillary molar position towards a Class I maxillary molar position. Both overjet and overbite were significantly reduced (-2.95±2.11 mm and -1.79±1.54 mm) towards normal with Xbow$^{TM}$ treatment ($p<0.05$).

| Variables | Mesocephalic Mean Change Score ± SE | p-value |
|---|---|---|
| Occ Plane to SN (°) | 1.57±5.85 | 0.3155 |
| ANB (°) | -1.86±2.11 | 0.0042 |

| | | |
|---|---|---|
| SNA | -2.01±3.56 | 0.0460 |
| SNB | -0.10±3.28 | 0.9076 |
| Y-Axis (°) | 1.25±0.70 | 0.0068 |
| MP – SN (°) | -0.153±3.51 | 0.8680 |
| Wits Appraisal (mm0 | -2.68±3.11 | 0.0049 |
| U1 – SN (°) | -1.38±9.88 | 0.5970 |
| U1 – Palatal Plane (°) | -1.01±9.65 | 0.6924 |
| U1 – NA (°) | -0.06±10.2 | 0.9821 |
| U1 – NA (mm) | -0.02±3.39 | 0.9815 |
| Interincisal Angle (U1-L1) (°) | -1.83±10.2 | 0.4981 |
| IMPA (L1-MP) (°) | 3.54±6.29 | 0.0467 |
| L1 Protrusion (L1-APo) (mm) | 1.63±1.66 | 0.0018 |
| L1 -NB | 4.40±5.80 | 0.0108 |
| L1 – NB (mm) | 1.13±2.13 | 0.0600 |
| L1 to A-Po (mm) | 5.78±5.31 | 0.0009 |
| Overjet (mm) | -2.95±2.11 | 0.0001 |
| Overbite (mm) | -1.79±1.54 | 0.0005 |
| Mandibular incisor extrusion (mm) | -0.893±0.759 | 0.0004 |
| Molar relation | -1.07±1.20 | 0.0038 |

Table 3.11 Difference Between Initial and Final Treatment for the Mesocephalic Group (n=13) (T2-T1

# Chapter 4

# Discussion

Fixed Class II correctors are an alternative to solve compliance issues in young children that do not wear their removable Class II appliances long enough to make the necessary treatment changes. However, some controversy exists regarding the amount of skeletal and dental changes that fixed appliances produce. The Xbow$^{TM}$ appliance, a type of fixed class II corrector used in growing children, is known for Class II correction owing predominantly to dental changes. However, debate is present regarding the presence and possible magnitude of skeletal changes produced by the Xbow$^{TM}$. This study investigated dental and skeletal cephalometric changes in subjects with different facial patterns (i.e. mesocephalic, brachycephalic, dolichocephalic) treated with the Xbow$^{TM}$ appliance for Class II correction.

When comparing the Xbow$^{TM}$ appliance to other fixed Class II correctors, the Jasper Jumper$^{TM}$ has been considered to function in a similar manner to the Xbow$^{TM}$ appliance. The Jasper Jumper is a tooth-borne functional appliance that acts in a flexible manner attaching between the maxillary and mandibular arches to produce inter-arch changes through headgear-like forces (Cope et al., 1994). A flexible spring, which is also a component in the Xbow$^{TM}$, provides a controlled force to move the mandible forward. This appliance has been shown to produce Class II correction predominantly through dentoalveolar changes and since the mechanism is similar to that of a Xbow$^{TM}$ appliance, it would support the notion that the Xbow$^{TM}$ also works largely through dentoalveolar changes (Cope et al., 1994 & Basavaraddi et al., 2016). On the other hand, the Herbst appliance is another fixed Class II corrector, which is largely accepted as an appliance that can produce skeletal changes (Paulsen H., 1997). Skeletal changes observed from Herbst appliance therapy are owing to the ability of the appliance to distract the condyle from the glenoid fossa which in turn leads to mandibular growth. Paulsen et al (1997) investigated the orthopedic effects on the morphology of the condyles following treatment with the Herbst appliance and noted changes in the morphology and the presence of a double contour of the condyle following treatment which was interpreted as bone modelling. Tareq (2022) used CBCT imaging to evaluate three-dimensional positional changes (anteroposterior, vertical, and mediolateral) in the condyle and glenoid fossa following treatment with the Herbst and Xbow™ appliances compared to a control group. The conclusions drawn from this study were that there were no significant differences in the mean positional change in the condyle and fossa as a unit, in the condyle independently, as well as the fossa independently across all dimensions following treatment with the Herbst or Xbow™ appliance (Tareq A., 2022). In addition, the Herbst and Xbow™ both did not produce additional or restrictive positional changes in the condyle relative to the fossa when compared to the control. Hence, this study suggests that the condylar changes, which have been suggested as an important component for skeletal changes in the Herbst appliance, may not be that different from the Xbow™ appliance following treatment.

The present study supports that the Xbow™ appliance is capable of producing statistically significant skeletal and dental changes and provides insight into the type of skeletal and dental changes that may be expected in subjects with different facial growth patterns when they are treated with the Xbow™ appliance. A 2009 study by Dr. Flores-Mir et al., demonstrated that the Xbow™ appliance produced Class II correction in growing children mainly through dental changes with a less significant amount owing to skeletal changes (Flores-Mir et al., 2009). This was evident dentally through significant changes seen in L1-MP, L1 minus Pg, overjet, U6 minus A, L6 minus Pg and a-OLp from pre-treatment cephalometric measures to post-treatment cephalometric measures. Our study also demonstrated significant dental changes following treatment with Xbow™ appliance therapy. Similar to Flores-Mir et al., a statistically significant change in IMPA was noted in the mesocephalic group, however IMPA values were not found to have statistically significant changes in the brachycephalic and dolichocephalic treatment groups. Although both dolichocephalic and brachycephalic treatment groups did demonstrate increases in IMPA values following Xbow™ treatment favoring Class II malocclusion correction. Our study also demonstrated that L1-APo, overjet, overbite, mandibular incisor extrusion and molar relation showed significant changes for all facial growth types following Xbow™ treatment while angular changes in the upper incisor were insignificant.  A detailed table of statistically significant cephalometric dental measures for each facial type can be seen below in Table 4.1:

| | Brachycephalic | Dolichocephalic | Mesocephalic |
|---|---|---|---|
| U1 – SN (°) | X | X | X |
| U1 – Palatal Plane (°) | X | X | X |
| U1 – NA (°) | X | X | X |
| U1 – NA (mm) | X | X | X |
| Interincisal Angle (U1-L1) (°) | ✓ | X | X |
| IMPA (L1-MP) (°) | X | X | ✓ |
| L1 Protrusion (L1-APo) (mm) | X | X | ✓ |
| L1 -NB | X | X | ✓ |
| L1 – NB (mm) | X | X | ✓ |
| L1 to A-Po (mm) | ✓ | ✓ | ✓ |

| | | | |
|---|---|---|---|
| Overjet (mm) | ✓ | ✓ | ✓ |
| Overbite (mm) | ✓ | ✓ | ✓ |
| Mandibular incisor extrusion (mm) | ✓ | ✓ | ✓ |
| Molar relation | ✓ | ✓ | ✓ |

Table 4.1 Presence and absence of statistically significant cephalometric dental changes in each facial growth type

In the study by Flores-Mir et al (2009), skeletal measures for SNA and ANB showed a reduction between pre-treatment and post-treatment cephalometric measures, which is consistent with Class II skeletal correction. Our study also showed a statistically significant reduction in ANB across all facial pattern treatment groups. Unlike Flores-Mir et al., for the current study, only the mesocephalic facial growth group demonstrated a SNA reduction that was considered statistically significant. The skeletal changes observed by Flores-Mir et al. included diminution of maxillary protrusion, increased vertical dimension and no effect on mandibular advancement (Flores-Mir et al., 2009). Similarly, in our study, SNB changes were not found to be statistically significant in any of the facial growth groups, demonstrating that Xbow™ treatment also had no effect on mandibular advancement. Although the SNA values were reduced in each group, a diminution in maxillary growth can only be concluded from the mesocephalic group that demonstrated a statistically significant reduction in SNA value over the course of Xbow™ appliance treatment. A detailed table of statistically significant cephalometric skeletal measures for each facial type can be seen below in table 4.2:

| | Brachycephalic | Dolichocephalic | Mesocephalic |
|---|---|---|---|
| ANB (°) | ✓ | ✓ | ✓ |
| SNA | X | X | ✓ |
| SNB | X | X | X |
| Wits Appraisal (mm) | ✓ | ✓ | ✓ |

Table 4.2 Presence and absence of statistically significant cephalometric skeletal changes in each facial growth type

Chana et al. (2013) also investigated skeletal and dental movements in growing patients with different facial types treated with the Xbow$^{TM}$ appliance. Dentally, the groups demonstrated a collective increase in proclination and protrusion of the lower incisors as well as mesial movement of the mandibular first molars and retrusion of the maxillary incisors. As previously mentioned, the present study found a significant change in IMPA in the mesocephalic group, however IMPA values were not found to have statistically significant changes in the brachycephalic and dolichocephalic treatment groups. Although both dolichocephalic and brachycephalic did demonstrate increases in IMPA values (1.89±4.18° and 2.67±5.55°, respectively) following Xbow$^{TM}$ treatment which favors Class II correction. Our study was similar to Chana et al. (2013) in that all facial growth pattern groups demonstrated movement of the lower incisors being significant with an increase in the mean Protrusion to APog value. Skeletally, Chana et al. demonstrated that all facial growth types demonstrated a decrease in Wits appraisal consistent with Class II correction (Chana et al., 2013). This finding is reproduced in our study as well with all facial pattern groups demonstrating a statistically significant decrease in Wits appraisal across each facial growth pattern group. Chana et al (2013) found that ANB values were significant in the brachycephalic growth group but not in the dolichocephalic or mesocephalic group. This finding differs from our study in which all facial growth types produced statistically significant differences in ANB values.

The above studies demonstrate that the Xbow$^{TM}$ appliance is used to correct Class II malocclusion through a combination of dental and skeletal effects. Skeletally, Flores-Mir et al (2009) proposed that the Xbow$^{TM}$ appliance applies a restrictive headgear effect on the maxilla while the corresponding Class II dental correction occurs simultaneously.  Our study was consistent with this finding for the mesocephalic growth pattern; however, dolichocephalic and brachycephalic facial patterns did not demonstrate this. Our study was consistent with Flores-Mir et al and Chana et al in that SNB was not significantly changed following Xbow$^{TM}$ therapy, and thus demonstrates there is no effect on mandibular advancement. Significant changes in SNA and SNB were not found overall (except for SNA in the mesocephalic group). Skeletal changes leading to a reduction in Class II skeletal cephalometric values following Xbow$^{TM}$ treatment were represented by a reduction in ANB and Wits appraisal. It is important to note that skeletal correction represented by Wits appraisal must be interpreted with caution considering the inverse relationship of Wits appraisal with changes in the occlusal plane angle. Although our study did not produce statistically significant changes in Occlusal Plane to SN the mean change in each group was increased and thus could affect the Wits appraisal value. It is also important to consider bone remodeling and orthodontic tooth movement effects on A and B point as a potential source of error. Surface remodeling of the maxilla results in bone being resorbed from the anterior surface except for the area around the anterior nasal spine (Proffit, 2019). Alveolar remodeling has the potential to affect A point up to a few milometers which in turn would impact

SNA and ANB measures representing skeletal changes (Phulari B., 2013). Therefore, assessing A and B point as a skeletal reference during growth may be questionable. It is important to understand the limitations of each cephalometric variable and how the result may be impacted by other variables such as growth, remodelling, and the associated occlusal plane angle.

In terms of growth pattern, the current study showed both mesocephalic and brachycephalic groups demonstrating significant changes in Y-axis while the dolichocephalic facial pattern did not produce a significant change following Xbow™ treatment. This finding differs from Chana et al (2013) whereby all three facial patterns were shown to have insignificant changes in Y-axis suggesting that the Xbow™ appliance did not affect the pre-existing facial pattern. Significant changes in the mesocephalic and brachycephalic groups could be indicative of the improved potential for mandibular growth compared to the dolichocephalic group (Rongo et al., 2014). Brachycephalic and mesocephalic patients are referred to as "good growers" in comparison to dolichocephalic and thus it would support improved changes in gnathion point from mandibular growth leading to a statistically significant value for Y-axis compared to dolichocephalic. In addition, the Xbow™ appliance is used during a patient's growth spurt to optimize the mandibular growth and help with the correction of Class II malocclusion. Therefore, increased changes in the gnathion point from growth in the brachycephalic and mesocephalic group would be expected compared to the hyperdivergent dolichocephalic group as the brachycephalic and mesocephalic would demonstrate normodivergent and hypodivergent mandibular growth patterns. This signifies that the growth pattern may be related to the amount of dental movement and thus clinicians should take special consideration of growth patterns when formulating individual orthodontic treatment plans.

Different dental movements based on the facial growth pattern types could be explained by pre-existing dental compensations for different facial patterns. Rickets et al (1979) emphasized that dolichocephalic facial types display weak musculature while brachycephalic facial types display strong musculature, which in turn can influence the corresponding dental compensations. Mandibular plane angle changes were found to be insignificant for all facial types in both Chana et al. and the present study (Chana et al., 2013). This would indicate that clinicians can expect the pre-existing facial pattern to remain the same following correction of Class II malocclusions in dolichocephalic facial growth types, but there may be more variability in pre-treatment and post-treatment facial growth types following Xbow™ treatment for mesocephalic and dolichocephalic subjects.

# Chapter 5

# Conclusions

1) Based on the results of this study, we reject the null hypothesis which states there is no significant difference in cephalometric values attained for dental and skeletal changes in subjects with different facial patterns treated with the Xbow$^{TM}$ appliance for Class II correction. We conclude that significant differences in cephalometric values for skeletal and dental variables in subjects with different facial patterns (i.e. mesocephalic, brachycephalic, dolichocephalic) treated with the Xbow$^{TM}$ appliance for Class II correction were found. Therefore, clinicians can expect the majority of changes from dental movements with minor skeletal changes in favor of Class II correction although these changes can vary from one facial growth pattern to another.

2) Correction of Class II malocclusions with the Xbow$^{TM}$ appliance is the result of:
    a. Reduction of the Class II skeletal relationship represented by a small decrease in the Wits appraisal and ANB value.
    b. Moderate reduction in SNA values indicating a restrictive headgear effect (for mesocephalic patients).
    c. Mild to moderate amounts of proclination and major amounts of protrusion of the lower incisor, with significant protrusion in all groups relative to A-Pog.
    d. Insignificant changes to the angulation and position of the maxillary incisors.

3) There was a tendency for pronounced dental movements in mesocephalic subjects, specifically in the lower incisor position and angulation. Clinicians should be aware that Xbow™ treatment may lead to significant dental changes in mesocephalic facial patterns and should consider how these dental changes could affect the final treatment outcome.

## 5.1 Recommendations

1) Treatment considerations regarding different facial growth patterns should be in place when planning to use the Xbow™ appliance in terms of how the pre-existing dental compensations may affect the final result with Xbow™ treatment.
2) Orthodontists should pay special attention to periodontal health in the lower incisor region prior to and during Xbow™ appliance therapy due to significant protrusion of the lower incisor and changes in proclination.
3) When treating mesocephalic patients, orthodontists should carefully monitor dental changes as there is an increased tendency for dental movements in this facial growth group.

## 5.2 Limitations

1) Due to a strict inclusion criterion, the sample size for this study was limited and thus affects bias and random variation.
2) Subjects from this study were all from a single orthodontic private practice, being treated by one orthodontist. This limits the widespread applicability as this study is limited to the results of one clinic and one orthodontist.

## 5.3 Future Studies

1) Further investigation regarding the effects of the Xbow™ appliance on producing changes in the pre-existing facial growth patterns.
2) Future studies with fixed Class II correctors should continue to focus on the skeletal effects on growing patients and the magnitude of change produced by the Xbow™ appliance.
3) Future studies including a larger sample size and patients being treated with the Xbow™ appliance across different private practices could improve applicability of the results and reduce inherent bias that may occur from findings obtained from a single orthodontic practice.

# Chapter Six

# References

Atik, E., Coskuner, H., Kocadereli, I. (2017). Dentoskeletal and airway effects of the X-Bow appliance versus removable functional appliances (Frankel-2 and Trainer) in prepubertal Class II division 1 malocclusion patients. Australasian Orthodontic Journal. 33. 10.21307/aoj-2020-079.

Baccetti T, Franchi L, McNamara JA Jr, Tollaro I. Early dentofacial features of Class II malocclusion: a longitudinal study from the deciduous through the mixed dentition. Am J Orthod Dentofacial Orthop. 1997 May;111(5):502-9. doi: 10.1016/s0889-5406(97)70287-7. PMID: 155809.

Bansal N, Singla J, Gera G, Gupta M, Kaur G. Reliability of natural head position in orthodontic diagnosis: A cephalometric study. Contemp Clin Dent. 2012 Apr;3(2):180-3. doi: 10.4103/0976-237X.96824. PMID: 22919219; PMCID: PMC3425102.

Basavaraddi S, Gandedkar NH, Belludi A, Patil A. Correction of an adult Class II division 2 individual using fixed functional appliance: A noncompliance approach. Contemp Clin Dent. 2016 Jan-Mar;7(1):82-6. doi: 10.4103/0976-237X.177114. PMID: 27041908; PMCID: PMC4792063.

Bhavani G., Navaneethan R. (2017). Forsus appliance – a review. Retrieved from: https://rjptonline.org/HTML_Papers/Research%20Journal%20of%20Pharmacy%20and%20Technology__PID__2017-10-5-44.html

Broadbent BH Sr., Broadbent BH Jr., Gloden WH. Bolton standards of dentofacial development growth. St. Louis: Mosby, 1975.

Chana, R. (2013). Cephalometric evaluation of dental class II correction using the xbow appliance in different facial patterns. Retrieved from: file:///Users/ /Downloads/chana_randeep.pdf

Cope JB, Buschang PH, Cope DD, Parker J, Blackwood HO 3rd. Quantitative evaluation of craniofacial changes with Jasper jumper therapy. Angle Orthod 1994;64:113-22.

Ehsani S, Nebbe B, Normando D, Lagravere MO, Flores-Mir C. Dental and skeletal changes in mild to moderate Class II malocclusions treated by either a Twin-block or Xbow appliance followed by full fixed orthodontic treatment. Angle Orthod. 2015

Nov;85(6):997-1002. doi: 10.2319/092814-696.1. PMID: 26516710; PMCID: PMC8612043.

Flores-Mir C, Young A, Greiss A, Woynorowski M, Peng J. Lower incisor inclination changes during Xbow treatment according to vertical facial type. Angle Orthod. 2010 Nov;80(6):1075-80. doi: 10.2319/033110-180.1. PMID: 20677957; PMCID: PMC8929497.

Ghodasra R, Brizuela M. Orthodontics, Malocclusion. [Updated 2023 Apr 23]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK592395/

Higgins, W. Duncan. “Xbow™: Straight to the Target when Straight is the Target”. Orthodontic Perspectives XIII. 2 (2006). Web. 23 Oct. 2012.

Insabralde NM, Rodrigues de Almeida M, Rodrigues de Almeida-Pedrin R, Flores-Mir C, Castanha Henriques JF. (2021). Retrospective comparison of dental and skeletal effects in the treatment of Class II malocclusion between Herbst and Xbow appliances. Am J Orthod Dentofacial Orthop. 2021 Oct;160(4):544-551. doi: 10.1016/j.ajodo.2020.05.021. Epub 2021 Jul 15. PMID: 34274201.

Jacobson A. Radiographic cephalometry: From basics to video imaging.Quintessence Publishing Co., Illinois. 1995.

Jacobson A, Jacobson RL. Radiographic cephalometry: From basics to 3-D imaging. Quintessence Publishing Co., Illinois. 2006.

Paulsen HU. Morphological changes of the TMJ condyles of 100 patients treated with the Herbst appliance in the period of puberty to adulthood: a long-term radiographic study. Eur J Orthod. 1997 Dec;19(6):657-68. doi: 10.1093/ejo/19.6.657. PMID: 9458599.

Proffit, William R. Contemporary Orthodontics. Elsevier, 2019.

Phulari, Basavaraj. An Atlas on Cephalometric Landmarks. Jaypee Brothers Medical Publishers, 2013
.

Rabie AB, She TT, Hägg U. Functional appliance therapy accelerates and enhances condylar growth. Am J Orthod Dentofacial Orthop. 2003 Jan;123(1):40-8. doi: 10.1067/mod.2003.45. PMID: 12532062.

Rédua RB. Different approaches to the treatment of skeletal Class II malocclusion during growth: Bionator versus extraoral appliance. Dental Press J Orthod. 2020 Mar;25(2):69-85. doi: 10.1590/2177-6709.25.2.069-085.bbo. Epub 2020 May 29. PMID: 32490927; PMCID: PMC7265671.

Ricketts, R.M., Bench, R.W., Gugino, C.F., Hilgers, J.J. and Schulhof, R.J. (1979) Bioprogressive Therapy. Rocky Mountain Orthodontics, Denver.

Tareq Aldajani (2022). Temporomandibular joint condylar/fossa positional changes post herbst and xbow treatment sin adolescents assessed through CBCT imaging. Retrieved from: file:///Users/Evan/Downloads/Aldajani_Tareq_202209_MSc.pdf

**CONFLICT OF INTEREST**
No Principal or Co-Investigators of this study who are members of CHIPER HREB participated in the review or approval of this study.

**CONDITIONS OF APPROVAL:**

1. The study is acceptable on scientific and ethical grounds for the ethics of human use only. ***For logistics of performing the study, approval must be sought from the relevant institution(s).***
2. This research study/project is to be conducted by the local principal investigator listed on this certificate of approval.
3. The principal investigator has responsibility for any other administrative or regulatory approvals that may pertain to the research study/project, and for ensuring that the authorized research is carried out according to governing law.
4. **This approval is valid until the expiry date noted on this certificate of annual approval.** **An Annual Study Status Report** must be submitted to CHIPER within 15-30 days of this expiry date.
5. Any changes to the protocol (including recruitment procedures, etc.), informed consent form(s) or documents must be reported to CHIPER for consideration in advance of implementation of such changes on the **Research Amendment Form.**
6. Adverse events and unanticipated problems must be reported to CHIPER in accordance with its Standard Operating Procedures.
7. CHIPER must be notified regarding discontinuation or study/project closure on the **Final Study Status Report**.

Sincerely,

Dr. John Arnett, HREB Chair, CHIPER Digitally signed by Dr. John Arnett, HREB Chair, CHIPER
Date: 2025.07.28 12:09:01 -05'00'

John Arnett, PhD. C. Psych.
Chair, Health Research Ethics Board
CHIPER HREB



**Please quote the above Human Ethics Number on all correspondence.**
Inquiries should be directed to CHIPER@researchmb.ca

Research Improvements Through
Harmonization in Manitoba
A201 Chown Building
753 McDermot Avenue
Winnipeg, MB R3E 0T6

# CHIPER HEALTH RESEARCH ETHICS BOARD (HREB)

## CERTIFICATE OF ANNUAL APPROVAL

| PRINCIPAL INVESTIGATOR: | AFFILIATED INSTITUTION/DEPARTMENT: | ETHICS #: |
|---|---|---|
| Dr. Maron Higson | University of Manitoba/Preventive Dental Sciences | HS26546 (H2024:209) |
| **MEETING DATE (If applicable):** | **APPROVAL DATE:** July 28, 2025 | **EXPIRY DATE:** **August 8, 2026** |
| **STUDENT PRINCIPAL INVESTIGATOR SUPERVISOR (If applicable):** Dr. William Wiltshire | | |

| PROTOCOL NUMBER: | PROJECT OR PROTOCOL TITLE: |
|---|---|
| NA | Effects of the Xbow Appliance on Class II Malocclusion |
| **SPONSORING AGENCIES, FUNDING AGENCIES AND/OR COORDINATING GROUPS:** No funding | |

| Submission Date of Investigator Documents: | REB Receipt Date of Documents: |
|---|---|
| June 9, 2025 | June 9, 2025 |

**REVIEW CATEGORY OF ANNUAL REVIEW:** **Full Board Review** ☐ **Delegated Review** ☒

**THE FOLLOWING AMENDMENT(S) and DOCUMENTS ARE APPROVED FOR USE:**

| Document Name (if applicable) | Version (if applicable) | Date |
|---|---|---|

**Annual approval**

*Annual approval implies that the most recent **REB-approved** versions of the protocol, Investigator Brochures, advertisements, letters of initial contact or questionnaires, and recruitment methods, etc. are approved.*

**Consent and Assent Form(s):**

**CERTIFICATION**
CHIPER HREB has reviewed the annual study status report for the research study/project named on this ***Certificate of Annual Approval*** as per the category of review listed above and was found to be acceptable on ethical grounds for research involving human participants. Annual approval was granted by the Chair or Acting Chair, CHIPER HREB, per the response to the conditions of approval outlined during the initial review (full board or delegated) of the annual study status report.

**ATTESTATION**
CHIPER is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement 2, and the applicable laws and regulations of Manitoba. In respect to clinical trials, CHIPER complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations of Canada and carries out its functions in a manner consistent with Good Clinical Practices.

**QUALITY ASSURANCE**
The University of Manitoba Research Compliance Office may request to review research documentation from this research study/project to demonstrate compliance with this approved protocol and the University of Manitoba Policy on the Ethics of Research Involving Humans.

jco Journal of Clinical Orthodontics
ONLINE SUBMISSIONS AND REVIEW SYSTEM



| | |
|---|---|
| **Manuscript #** | 25233 |
| **Current Revision #** | 0 |
| **Submission Date** | 2025-08-28 20:16:13 |
| **Current Stage** | Initial QC Started |
| **Title** | Effects of the XbowTM on Class II Malocclusion in Different Facial Patterns |
| **Manuscript Type** | Unassigned |
| **Corresponding Author** | Dr. Maron Higson (University of Manitoba) |
| **Contributing Authors** | Dr. William Wiltshire , Prof. James Mah , Dr. Randeep Chana |
| **Abstract** | |
| **Article Subject Areas** | Functional appliances |
| **Conflict of Interest** | **No**, there is no conflict of interest that I should disclose, having read the above statement. |

**Manuscript Items**

1. Merged File containing manuscript text and 1 Table file. PDF (541KB)
   a. Article File PDF (434KB) Source File (DOCX) 44KB
   b. Tables PDF (254KB) Source File (DOCX) 26KB

**More Manuscript Info and Tools**

Send Manuscript Correspondence
Check Status