Cephalometric Evaluation of Dental Class II Correction Using the Xbow® Appliance in Different Facial Patterns

By

Dr. Randeep S. Chana

A Thesis submitted to
the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfilment of the requirements for the degree of
MASTER OF SCIENCE

Department of Preventive Dental Science

Faculty of Dentistry
Division of Orthodontics
University of Manitoba
Winnipeg, Manitoba

Abstract

Objective: To determine the magnitude of the skeletal and dental movements in subjects with different facial patterns following Class II correction using the Xbow® appliance.

Materials and Methods: A retrospective sample consisting of 134 subjects exhibiting Class II malocclusions was used. Subjects were categorized into three growth types according to pre-treatment cephalometric variables (MPA and Y-axis), which yielded 27 brachycephalic, 70 mesocephalic, and 37 dolichocephalic subjects. Data collection was accomplished by performing digital cephalometric analysis on the pre-treatment (T1) and post-treatment (T2) radiographs. A paired t-test statistic was used to investigate the differences between the three facial groups at T1 and T2 time points.

Results: Dental changes induced by the Xbow™ appliance during Class II correction included: proclination of the lower incisors (L1-MP 7.3-12.3°±1.0° p<0.05), protrusion of the lower incisors (L1-APo 2.1-3.8mm±0.3mm p<0.05), mesial movement of the mandibular first molar (5.5-6.9mm±0.7mm p<0.05) and retrusion of the maxillary incisor (2.4-3.1mm±0.4mm p<0.05). No significant association between the amount of tooth movement and dolichocephaly was found, but there was an increased trend of proclination and protrusion of the lower incisor in the brachycephalic group. Retroclination of the maxillary incisor (U1-PP 0.2-0.8$^{o}\pm0.7^{o}$ $p>0.05$) and distal movement of the maxillary molar (0.4-0.7mm±0.3mm $p>0.05$) were not significantly influenced by Xbow™ treatment. Reduction of the skeletal Class II relationship was represented by a significant decrease of the Wits value (2.4-4.5mm±0.5mm $p<0.05$) in all three groups.

Conclusions: Correction of Class II malocclusions with the Xbow™ appliance is the result of mesial movement of the mandibular molar, proclination/protrusion of the lower incisor and retrusion of the upper incisor. Skeletal correction must be validated by more than one cephalometric variable. Facial growth pattern appears to be unrelated to the amount of dental movement and there is a trend for pronounced dental movements of the lower incisor in brachycephalic patients. Orthodontists should take these appliance induced effects into consideration when treatment planning the final position of the lower incisor and thus deciding on an appropriate retention protocol following Xbow™ treatment.

Acknowledgments

I would like to express my sincere gratitude to the members of my thesis committee Dr. William Wiltshire, Dr. Frank Hechter, and Dr. Stephan Ahing for their guidance and support. A special thank you for the time and effort taken to offer critique of my thesis project.

To Dr. William Wiltshire, my mentor, for your teaching and continued support. Thank you for giving me the opportunity to fulfill my dream of becoming an orthodontist. Your mentorship throughout the years has been invaluable. You have been a great teacher and friend.

To Dr. Hechter, thank you for your dedication to the program and mentorship to countless students. I was very fortunate to have had the opportunity to learn from you.

A special thank you to Dr. Tim Dumore. Thank you for your selfless dedication to our education at the University of Manitoba. I hope to emulate your passion for advancement of our profession through education and public service.

To my lovely daughters Naveen and Divya. You are my pride and joy. I look forward to watching you grow and fulfil your dreams.

Lastly, to my beautiful wife Amrit. Thank you for your selfless support and encouragement throughout my graduate training.

Dedication

To my beautiful wife Amrit, and lovely daughters Naveen and Divya. Thank you for filling my life with love, laughter and happiness.

Contents

Contents 6

List of Figures and Tables...11

1 Introduction 13

1.1 Preamble 13

Figure 1-1: Intraoral view of a fixed Xbow™ appliance........................ .14

1.2 Purpose...14

1.3 Null hypothesis...15

2 Literature Review 16

2.1 Classification of Malocclusion 16

Table 2-1: Classification of Malocclusion (Graber et al.2012).….............17

2.2 Etiology and Development of Malocclusion 18

Table 2-2:Graber's Classification of Etiological Factors 19

Table 2-3: Proffit's Classification of Causes of Malocclusion (Proffit and Fields, 2012) 20

2.3 Development of Class II Malocclusion...21

2.4 Dental Class II Correction (Treatment)...23

Table 2-4: Angle versus Soft Tissue Paradigms of Orthodontic Treatment (Proffit and Fields, 2012) 24

2.5 Use of Non-Compliant Class II Correctors..26

Figure 2-1: Herbst appliance (Chaukse et al. 2011)...28

2.6 Non-Compliant Spring Force Delivery Systems 28

*Table 2-5: A Classification of the Non-compliant Appliances (McSherry et al. 2000)*28

Figure 2-2: Jasper JumperTM (McSherry et al. 2000) 29

2.7 Xbow™ (Crossbow) Appliance..30

2.8 Defining Facial Patterns...33

3 Materials and Methods 38

3.1 Sample Selection....38

Table 3-1: Summary statistics for the treatment group 39

3.2 Data Collection 40

3.2.1 Calibration....40

3.2.2 Defining Facial Types....40

Table 3-2: Differences between groups prior to Xbow^{TM} treatment (Time 1)....41

3.3.3 Growth Considerations 41

Figure3-1: Growth prediction using the Bolton Algorithm....43

3.3 Statistical Analysis....43

Table 3-3: Variables examined, distribution, and type of statistical analysis....44

3.4 Xbow ^{TM} Appliance 45

Figure 3-2. Intra-oral photos of a typical Xbow^{TM} used in this study 46

3.5 Cephalometric Analysis....47

3.5.1 Natural Head position 47

3.5.2 Computerized Cephalometrics....48

3.5.3 Growth Visual Treatment Objective(VTO)-Growth Prediction....48

3.5.4 Superimposition....49

3.5.5 Cephalometric Landmarks....49

Figure 3-3: Landmarks used in a modified Steiner's analysis (Adapted from Jacobson, 1995) 50

Figure 3-4: Landmarks used in a modified Rickett's analysis (Adapted from Jacobson, 1995) 50

*Figure 3-5: Landmarks used in a modified Pancherz's analysis (Wu JY et. al. 2010)*51

Table 3-4: Description of the cephalometric landmarks. 52

3.5.6 Cephalometric Planes....53

Table 3-5: Description of cephalometric planes....53

4 Results 58

4.1 Reliability..59
Table 4-1: ICC and F test values for the intra-examiner reliability..........................60
Table 4-2: ICC and F test values for the inter-examiner reliability...........61

4.2 Growth Considerations 62
Table 4-3: Growth prediction algorithms..62

4.3 Differences Between Groups Prior to Xbow TM Treatment (T1).........................64
4.3.1 Difference Between Brachycephalic and Dolichocephalic Prior to Xbow TM Treatment (T1) 64
Table 4-4: Difference Between Brachycephalic and Dolichocephalic Prior to Xbow TM Treatment (T1)..65
4.3.2 Difference Between Brachycephalic and Mesocephalic Prior to Xbow TM Treatment (T1) 67
Table 4-5: Difference Between Brachycephalic and Mesocephalic Prior to Xbow TM Treatment (T1)..68
4.3.3 Difference Between Dolichocephalic and Mesocephalic Prior to Xbow TM Treatment (T1) 69
Table 4-6: Difference Between Dolichocephalic and Mesocephalic Prior to Xbow TM Treatment (T1)..70
4.4 Differences Between Groups Following Xbow TM Treatment (T2) 70
4.4.1 Difference Between Brachycephalic and Dolichocephalic Following Xbow TM Treatment (T2)..71
Table 4-7: Difference Between Brachycephalic and Dolichocephalic Following Xbow TM Treatment (T2)..72
4.4.2 Difference Between Brachycephalic and Mesocephalic Following Xbow TM Treatment (T2) 74
Table 4-8: Difference Between Brachycephalic and Mesocephalic Following Xbow TM Treatment (T2)..75
4.4.3 Difference Between Dolichocephalic and Mesocephalic Following Xbow TM Treatment (T2) 76

Table 4-9: Difference Between Dolichocephalic and Mesocephalic Following Xbow ^{TM} Treatment (T2)...76
4.5 The Difference Within Each Group Before and After Xbow ^{TM} Treatment (T2-T1)77
4.5.1 Difference Between Initial and Final Treatment for Brachycephalic Group (n=27) (T2-T1) 78
Table 4-10: Difference Between Initial and Final Treatment for the Brachycephalic Group (n=27) (T2-T1) 79
4.5.2 Difference Between Initial and Final Treatment for Dolichocephalic Group (n=37) (T2-T1)..80
Table 4-11: Difference Between Initial and Final Treatment for the Dolichocephalic Group (n=37) (T2-T1) 82
4.5.2 Difference Between Initial and Final Treatment for the Mesocephalic Group (n=70) (T2-T1) 82
Table 4-12: Difference Between Initial and Final Treatment for the Mesocephalic Group (n=70) (T2-T1) 84
Figure 4-1. Summary of the overall skeletal and dental movements of the Xbow^{TM} appliance..86

5 Discussion **87**
Table 5-1: Comparison Studies...90
Table 5-2: Difference Between Brachycephalic and Dolichocephalic Prior to Treatment (T1)...93

6 Conclusions **96**
6.1 Recommendations...97

7 References **98**
8 Appendix **105**
8.1 Abstract and article...106

8.2 Ethics approval and renewal (See Attached Document)……………….121

8.3 Manuscript submission (See Attached Document)...........................124

List of Figures and Tables

Figure 1-1: Intraoral view of a fixed Xbow™ appliance……………………..14

Table 2-1: Classification of Malocclusion (Graber et al. 2012)……………...17

Table 2-2:Graber's Classification of Etiological Factors ……………………..19

Table 2-3: Proffit's Classification of Causes of Malocclusion (Proffit and Fields, 2012)... ……………20

Table 2-4: Angle versus Soft Tissue Paradigms of Orthodontic Treatment (Proffit and Fields, 2012) .... …….24

Figure 2-1: Herbst appliance (Chaukse et al. 2011)................................... 28

Table 2-5: A Classification of the Non-compliant Appliances (McSherry et al. 2000).. 28

Figure 2-2: Jasper JumperTM (McSherry et al. 2000).............................. 29

Table 3-1: Summary statistics for the treatment group............................. 39

Table 3-2: Differences between groups prior to Xbow™ treatment (Time 1)..41

Figure3-1: Growth prediction using the Bolton Algorithm.....................43

Table 3-3: Variables examined, distribution, and statistical analysis ..... .44

Figure 3-2. Intra-oral photos of a typical Xbow™ used in this study 46

Figure 3-3: Landmarks used in a modified Steiner's analysis (Adapted from Jacobson, 1995) 50

Figure 3-4: Landmarks used in a modified Rickett's analysis (Adapted from Jacobson, 1995) 50

Figure 3-5: Landmarks used in a modified Pancherz's analysis (Wu JY et. al. 2010).. 51

Table 3-4: Description of the cephalometric landmarks. 52
Table 3-5: Description of cephalometric planes....................................53
Table 4-1: ICC and F test values for the intra-examiner reliability..........60
Table 4-2: ICC and F test calues for the inter-examiner reliability.......61
Table 4-3: Growth prediction algorithms...62
Table 4-4: Difference Between Brachycephalic and Dolichocephalic Prior to Xbow ™ Treatment (T1).. 65
Table 4-5: Difference Between Brachycephalic and Mesocephalic Prior to Xbow ™ Treatment (T1).. 68
Table 4-6: Difference Between Dolichocephalic and Mesocephalic Prior to Xbow ™ Treatment (T1).. 70
Table 4-7: Difference Between Brachycephalic and Dolichocephalic Following Xbow ™ Treatment (T2) 72
Table 4-8: Difference Between Brachycephalic and Mesocephalic Following Xbow ™ Treatment (T2).. 75
Table 4-9: Difference Between Dolichocephalic and Mesocephalic Following Xbow ™ Treatment (T2).. 76
Table 4-10: Difference Between Initial and Final Treatment for the Brachycephalic Group (n=27) (T2-T1) 79
Table 4-11: Difference Between Initial and Final Treatment for the Dolichocephalic Group (n=37) (T2-T1) 82
Table 4-12: Difference Between Initial and Final Treatment for the Mesocephalic Group (n=70) (T2-T1) 84
Figure 4-1. Summary of the overall skeletal and dental movements of the Xbow™ appliance 86
Table 5-1: Comparison Studies..90
Table 5-2: Difference Between Brachycephalic and Dolichocephalic Prior to Treatment (T1)...93

Chapter 1

Introduction

1.1 Preamble

Orthodontics is continually changing with the advancement in technology and biomaterials. Clinicians should critically analyze innovations and examine their biological effects on patients. Scrutiny of innovative appliances is accomplished through evidence-based medicine (EBM). As described by Sackett (1996), it is our responsibility to base clinical decisions about the care of individual patients on the conscientious, explicit, and judicious use of current best evidence.

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^{TM} fatigue resistant device (FRD) springs (3M Unitek, Monrovia, Calif). The Forsus^{TM} spring is placed in the head-gear tube of the maxillary first molar band and 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 mandibular labial and lingual bows are in passive contact with the mandibular incisors (Flores-Mir et al., 2009). Forsus™ FRD springs do not rigidly hold the mandible forward and allow the patient to function in centric occlusion. It could thus be categorized as a non-protrusive inter-arch Class II corrector (Figure 1-1).

Figure 1-1. Intraoral view of a fixed Xbow™ appliance

Although there has been significant evolution of the Xbow™ appliance over the past two decades, future research on the dental and skeletal effects may lead to improvements in the design and use of the appliance.

1.2 Pupose

The purpose of this study was to determine the magnitude of the skeletal and dental movements in subjects with different facial patterns following Class II correction using the Xbow™ appliance.

1.3 Null Hypothesis

There is no significant difference in the skeletal and dental movements in subjects with different facial patterns following Class II correction using the Xbow™ appliance.

Chapter 2

Literature Review

2.1 Classification of Malocclusion

A successful outcome in orthodontics is accomplished by maximizing the relationship of the skeletal, dental, and soft tissue relationships in the transverse, vertical, and antero-posterior dimension. Edward Angle referred to a malocclusion as the misalignment of teeth or incorrect relation between the teeth of the two opposing dental arches (Gruenbaum, 2010). Since the inception of modern orthodontics in the late 1800's, there have been many indices to classify the extent of a malocclusion. The main classifications of malocclusion are mainly concerned with the identification of deviation from the biological norm in quantitative and qualitative terms. Correspondingly, there are both qualitative and quantitative methods of classifying malocclusion (Table 2-1).

Qualitative Methods	***Quantitative Methods (or) Indices Used for Epidemiological Purpose***

✓ Angle's classification (1899) ✓ Modification of Angle's classification (Dewey's classification) ✓ Simon's classification ✓ Bjork's classification ✓ Bennett's classification ✓ Skeletal classification ✓ WHO/FDI classification ✓ Etiologic classification ✓ Incisor classification	✓ Massler and Frankel ✓ Mal-alignment index by van Kurt and Pennel ✓ Handicapping labiolingual deviation index by Draker ✓ Occlusal feature index by Poulton ✓ Malocclusion severity estimate by Grainer ✓ Occlusal index by Summers ✓ Treatment priority index by Grainger ✓ Handicapping malocclusion assessment record by Salzman ✓ Index for orthodontic treatment need (IOTN) by Shaw

Table 2-1. Classification of Malocclusion (Graber et al. 2012)

2.2 Etiology and Development of Malocclusion

The etiology of malocclusion is multifactorial because the discrepancy can be a combination of a skeletal or dental abnormality. Rakosi, Jonas, and Graber noted that the etiological assessment of malocclusion is a vital aspect of orthodontics, since the genesis of the disorder opens clues to planning the intervention (Rakosi et al. 1993). In the simplest of terms, growth and development is primarily governed by genetics and is influenced by environmental factors. The challenge in the identification of a malocclusion is that “the developmental process of the dentition and craniofacial growth takes place over a period of many years, whereby the environment has a modeling impact on the genotype, being an integral part of the factors of heredity” (Rakosi, Jonas, and Graber, 1993). Some popular classification types for etiology of malocclusion include the classifications of Graber, Proffit, Johnson, and Bronsky. Graber’s classification of etiological factors can be seen below (Graber, 2012)(Table 2-2).

General factors	***Local factors***

✓ Heredity ✓ Congenital defects (cleft palate, torticollis; cerebral palsy; syphilis) ✓ Environment (prenatal – trauma, maternal diet and metabolism; German measles; post-natal – birth injury, TMJ injury, etc.) ✓ Predisposing metabolic climate and diseases (endocrine imbalance; infections, metabolic disturbance) ✓ Nutritional deficiency ✓ Pressure habits and functional aberrations (abnormal sucking, thumb and finger sucking, lip and nail biting, abnormal swallowing habits, speech defects, etc.) ✓ Posture ✓ Trauma and accidents	✓ Anomalies of number (missing or supernumerary teeth) ✓ Anomalies of tooth size ✓ Anomalies of tooth shape ✓ Mucosal barriers, persistent frenums ✓ Premature loss of teeth ✓ Prolonged retention ✓ Delayed eruption ✓ Abnormal eruption ✓ Ankylosis ✓ Dental caries ✓ Improper restoration

Table 2-2. Graber's Classification of Etiological Factors

Proffit's classification of malocclusion was defined according to local, genetic, and environmental influences. The classification of Proffit can be seen below (Table 2-3).

Local	***Genetic influences***	***Environmental influences***

✓ Disturbances in embryologic development-teratogens ✓ Skeletal growth disturbances ✓ Muscle dysfunction ✓ Acromegaly and hemimandibular hypertrophy ✓ Disturbances of dental development ✓ Improper guidance of eruption ✓ Trauma of teeth	✓ Heredity	✓ Equilibrium effects (on dentition and jaws) ✓ Functional influences (masticatory function, function and dental arch size, biting force and eruption, sucking and other habits, tongue thrusting, and respiratory pattern)

Table 2-3. Proffit's Classification of Causes of Malocclusion (Proffit and Fields, 2012)

Many authors, including Graber recognize additional contributing factors regarding the etiology and development of malocclusion, such as; deciduous tooth loss, eruption sequence, familial inheritance influencing the growth of the underlying basal and cranial bone structures, soft tissue influence of growth of skeletal structures and the position of teeth within the dental arches (Graber, 2012). Congenital factors also play an essential role in the development of malocclusion and present as developmental malformations at the time of birth (Phulari, 2011). General factors include abnormal state during pregnancy, malnutrition, endocrinopathology, intrauterine pressure, and trauma. Local congenital factors include; abnormalities of jaw development because of the irregular intrauterine position of the fetus, cyst of the face and palate, macroglossia, microglossia, and cleidocranial dystosis (Phulari, 2011).

2.3 Development of Class II Malocclusion

As Gorlovsky noted, the malocclusion of Class I is considered normal; Class II is considered a relative mandibular deficiency, while the Class III malocclusion is a relative mandibular prognathism (Gorlovsky, 2009). Taking into account that all three classes of malocclusion deserve special attention, the malocclusion of Class II is the most frequent. A Class II malocclusion has a variety of characteristics depending on its dental, skeletal, and/or functional aspects. Papel indicated that a Class II malocclusion is skeletally and dentally based, “the mesial buccal cusp of the first maxillary molar is mesial, or in front of the first mandibular molar” (Papel, 2009). However, Class II malocclusions are also subdivided into two types with marked clinical differences. A Class II subdivision 1 is characterized by proclination and protrusion of the maxillary incisors leading to an increased overjet and reduced overbite. Retroclined maxillary central incisors, proclined lateral incisors, a reduced overjet and an increased overbite characterize a Class II subdivision 2 malocclusion (Papel, 2009). In some rare cases of Class II division 2 malocclusions, the mandibular labial gingival tissues may be traumatized by the lingually inclined maxillary incisors, particularly in the absence of overjet (Bishara, 2006). Both divisions of Class II malocclusion are usually characterized by unilateral or bilateral relationship of molars. Unilateral cases of Class II malocclusion are usually seen as the affected side subdivision.

The Class II division 1 malocclusion develops differently in contrast to other types of class II malocclusions in terms of traverse dental arch relationship. The presence of a relative constriction of the maxillary arch was present at the earlier stages of the development of a Class II malocclusion (McNamara, 1981). However, disagreement still exists in the clinical investigation of this issue, thus it is thought by some authors to treat a transverse discrepancy as an anteroposterior discrepancy when dealing with a class II malocclusion (Bishara, 2006).

Cephalometric research of Class II malocclusions helps in delineating the key characteristics of the disorder. There are specific cephalometric characteristics of both divisions of Class II malocclusions. According to Bishara (2006), the following features characterize a Class II division 1 malocclusion:

- Anterior location of the maxilla and teeth in relationship to the cranium.
- Anterior location of the maxillary teeth in a normally positioned maxilla.
- Posterior location of the mandible, which is of normal size.
- Deficient development of the mandible.
- Posterior placement of the mandibular teeth on a mandible situated in the normal position.
- A combination of any of the above characteristics.

Comprehensive studies of McNamara indicate that Class II malocclusions do not occur as a single clinical entity, and usually represents the result of numerous combinations of contributing orthodontic factors. Moreover, only a small number of the reviewed cases included maxillary skeletal protrusion related to the cranial base structures, which indicates that the maxilla is predominantly found in the neutral position. When the maxilla is not in the neutral position, the retruded position is more frequent than the protruded one (McNamara, 1981). The most typical characteristics of a Class II malocclusion were mandibular skeletal retrusion with excessive vertical development (McNamara, 1981).

2.4 Dental Class II Correction (Treatment)

As Proffit and Fields noted, “attempts to correct crowded, irregular, and protruding teeth go back at least to 1000 BC” (Proffit and Fields, 2012). The modern treatment of malocclusion is directed at returning teeth to their regular, healthy state while satisfying esthetic goals. Graber et al (2012) defined the key objectives of orthodontic treatment to be:

1. Improving the smile and facial appearance to improve the individual’s self-esteem and social wellbeing.
2. Obtaining optimal proximal and occlusal contacts of the individual’s teeth.
3. Establishing the normal oral function that allows for adequate physiologic adaptation.
4. Achieving stability of the dentition within the boundaries of the expected physiologic relapse.

There is a clear contrast between the soft tissue paradigm, which states that the key objective is to restore soft tissue relationships versus the Angle paradigm, which emphasizes the need to correct the teeth and bone positions. An overview of the criteria of each paradigm is described below (Table 2-4):

Parameter	***Angle Paradigm***	***Soft Tissue Paradigm***
Primary treatment goal	Ideal dental occlusion	Normal soft tissue proportions and adaptations
Secondary goal	Ideal jaw relationships	Functional occlusion
Hard/soft tissue relationships	Ideal hard tissue proportions produce ideal soft tissues	Ideal soft tissue proportions define ideal hard tissues
Diagnostic emphasis	dental casts, cephalometric radiographs	Clinical examination of intraoral and facial soft tissues
Treatment Approach	Obtain ideal dental and skeletal relationships, assume the soft tissues will be OK	Plan ideal soft tissue relationships and then place teeth and jaws as needed to achieve this
Function emphasis	TM joint in relation to dental occlusion	Soft tissue movement in relation to display of teeth
Stability of result	Related primarily to dental occlusion	Related primarily to soft tissue pressure/ equilibrium effects

Table 2-4. Angle versus Soft Tissue Paradigms of Orthodontic Treatment (Proffit and Fields, 2012)

There are several alternatives for the treatment of a class II malocclusion depending on the etiology and treatment objectives. Chaukse et al. stated that the “correction of a skeletal class II malocclusion can be achieved using myofunctional appliances such as an activator, Frankel’s appliance and the Twin Block when dealing with a growing patient (Chaukse et al. 2011). Chaukse also proposed using fixed functional appliances during the deceleration phase of growth to achieve the Class II skeletal correction (Chaukse et al. 2011). Rickett’s introduction of the Bioprogressive Technique involved considerations of growth and development when assessing the areas of skeletal dysplasia (Ricketts et al. 1979).

Bishara’s research concluded that patients with a Class II malocclusion might have a normal skeletal pattern, maxillary protrusion or mandibular retrusion often superimposed on a vertical dental and/or skeletal discrepancy (Bishara, 2006). Therefore, the researcher concluded that treatment of a Class II malocclusion should be designed individually to obtain the treatment outcomes necessary for each particular case. The treatment process, in Bishara’s view, should take into account the maxilla and mandible treatment factors. According to Bishara (2006), treatment of the maxilla can be accomplished by:

- ✓ Inhibiting the normal forward and downward growth of the maxilla.
- ✓ Inhibiting the normal forward movement of the maxillary dentition.
- ✓ Moving the maxillary dentition distally.
- ✓ Influencing the eruption pattern of the maxillary teeth.
- ✓ Creating spaces by selective extractions to allow for differential tooth

movement.

With regard to treatment of the mandible, factors may include (Bishara, 2006):

- ✓ Stimulating the horizontal growth of the mandible.
- ✓ Anterior repositioning of the body of mandible.
- ✓ Influencing the eruption pattern of the mandibular teeth.
- ✓ Moving the mandibular dentition forward on its skeletal base.
- ✓ Creating space by selective extractions to allow for the desired tooth movements.

2.5 Use of Non-Compliant Class II Correctors

The treatment of Class II malocclusions is a collaborative process in which both the orthodontist and the patient take an equal role, and the cooperation of both influences the amount of dental correction. Positive treatment outcomes depend on patient compliance with respect to wearing headgear and other orthodontic correction appliances (McSherry et al. 2000). However, not all patients are responsible and consistent in their treatment procedures, and many of them ignore the orthodontists' recommendations, thus compromising the treatment outcome. Papadopoulos states, "Non-compliance approaches provide an important treatment alternative for patients with a Class II malocclusion who present minimal or no cooperation, especially when non-extraction protocols have to be utilized" (Papadopoulos, 2006). In the past, when the most common appliances used for correction of Class II malocclusions included headgears and functional/removable appliances, the cooperation of patients in the correction process was a significant challenge for orthodontists, since they were still the key contributors to the treatment outcomes. Fortunately, the advancements made in non-compliance techniques and appliances have minimized the role of patients' compliance with certain treatment regimes. The purpose of fixed Class II correctors is the advancement of the mandible in a more forward position or the distalization of the maxillary molars into a Class one relationship (Papadopoulos, 2006). Debate still exists over the contribution of skeletal correction of tooth borne fixed correctors.

The Herbst appliance is recognized as an effective method of Class II malocclusion treatment. Created in Berlin in 1905, the Herbst appliance is an upper and lower fixed appliance linked by a telescopic mechanism (Figure 2-1). "This mechanism holds the mandible forward in a protruded position throughout treatment to modify mandibular growth" (Chaukse et al. 2011). Although expensive and hard to assemble, the Herbst appliance is an effective method of correcting Class II malocclusions (Chaukse et al. 2011).

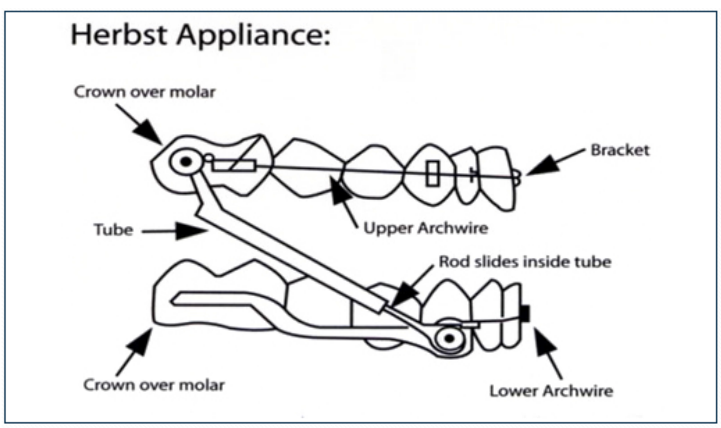

Figure 2-1. Herbst appliance (Chaukse et al. 2011)

Despite its relatively high price, the Herbst appliance is still one of the most widely used Class II malocclusion correction appliances with a skeletal influence; it can have a restraining effect on the growth of the maxilla, and stimulating effect on the growth of the mandible (McSherry et al. 2000).

2.6 Non-Compliant Spring Force Delivery Systems

Spring-force delivery systems have gained popularity over the past 10 years. These fixed sagittal correctors were primarily developed to eliminate the need for patient compliant elastics and headgear. McSherry et al. provided a detailed list of inter and intra-arch non-compliant appliances (Table 2-5).

Inter-arch	**Intra-arch**
Herbst appliance	Pendulum/Pend-X appliance
Jasper Jumper™	Distal jet
Adjustable bite corrector™	Modified Nance arch with nickel-titanium coils or wire
Eureka Spring™	Magnetic appliances
Saif Springs	Jones Jig™
Mandibular anterior repositioning appliance	Lokar distalizing appliance
Klapper SUPERSpring™	Molar distalizing bow
	Absolute anchorage
	Palatal implants

Table 2-5. A Classification of the Non-compliant Appliances (McSherry et al. 2000)

The Jasper Jumper™ is a patented fixed inter-arch Class II corrector. The appliance consists of two vinyl coated auxiliary springs, which are fitted, to fully banded upper and lower fixed appliances (Figure 2.7.2). Jumpers are usually attached to the previously installed orthodontic appliances to facilitate their function (Papadopoulos, 2006). The flexible springs are attached to the maxillary first molar bands; they also have an anterior attachment to the mandibular arch wire, which protrudes the mandible to contribute to the Class II correction (McSherry et al. 2000) (Figure 2-2).

Figure 2-2. Jasper JumperTM (McSherry et al. 2000)

2.7 Xbow™ (Crossbow) Appliance

Patented by Dr. Duncan W. Higgins, the Xbow™ appliance uses inter-arch springs as a phase 1 appliance to correct sagittal discrepancies in the late mixed or early permanent dentition (Flores-Mir et al. 2009). The Xbow™ appliance consists of a maxillary hyrax expander, a mandibular labial and lingual bow, and Forsus™ springs (3M Unitek, Monrovia, Calif). The Forsus™ spring is stopped anteriorly by a Gurin lock (3M Unitek) around the mandibular canine area (Flores-Mir et al.,2009). The lock allows for reactivation of the Forsus™ device without the need for a longer push rod (Flores-Mir et al., 2009).

The creation of Xbow™ was based off of Higgin's philosophy that the most useful contribution to the maintenance of a Class I malocclusion after the correction of a Class II malocclusion is the socked in buccal occlusion

The idea of the Xbow™ emerged in 1979, and has significantly evolved over the years. In 1979, Dr. Higgins enrolled into the orthodontic program at the University of Indiana were he got acquainted with the works of Ricketts, Roth, Alexander, and McNamara. Dr. Higgins focused his attention towards the deficiencies in Class II correction appliances and mechanics such as the breakage and side effects of spring based appliances. Hence, Dr. Higgins started to experiment with the spring-loaded Herbst system, which later became the Xbow™ appliance (Higgins, 2006).

The basic features of the Xbow™ appliance, as described by Dr. Higgins, included (Higgins, 2006):

- ✓ Achieving a Class I buccal occlusion by means of over-correcting the first maxillary bicuspids and allowing for physiologic rebound.
- ✓ A reduction in treatment time with the use of non-compliance Forsus™ Fatigue Resistant Devices in the correction of Class II malocclusions.
- ✓ Space maintenance and regaining through maxillary sutural expansion and

preservation of leeway space.

- ✓ Reduced risk of root resorption and decalcification associated with prolonged treatment times.

Previous studies have demonstrated the effectiveness of the Xbow™ appliance in the correction of Class II malocclusions. Flores-Mir et al. analyzed the lateral cephalometric radiographs of 67 consecutively treated Xbow™ patients and compared them to non-treated controls. The mean treatment time was 4.5 months. The post-treatment radiographs were taken at an average of 6.4 months after Forsus™ removal. Growth was factored using controls from the Burlington growth study. Based on the results of the 2009 study, the following conclusions were made regarding the short-term skeletal and dental effects of the Xbow™ appliance (Flores-Mir et al. 2009):

- Class II correction was due to a combination of dental and skeletal changes. Skeletally, the ANB angle was reduced due to a diminution of maxillary protrusion (decrease in A Point) without mandibular advancement.

- Significant differences contributing to Class II correction included SNA, ANB, L1-MP, L1 minus Pg, overjet, U6 minus A, L6 minus Pg, and A-OLp.

- Insignificant differences following Xbow™ treatment included SNB, U1-SN, U1 minus A, Pg-OLp, or Ar-OLp.

- Overjet was reduced by 3.0 mm; 0.9 mm of this was from maxillary incisor posterior movement (U1 minus A) and 0.9 mm from mandibular incisor anterior movement (L1 minus Pg). The remaining 1.2 mm (40%) was attributed to the mandible's outgrowth of the maxilla (shown by changes in Pg-OLp and A-OLp).

- The maxillary molars were significantly distalized, and the mandibular molars were significantly mesialized.

In 2010, Flores-Mir et al. evaluated the changes in the lower incisor inclination associated with the vertical facial type in Class II patients treated with the Xbow™ appliance. This study involved 172 consecutively treated Xbow™ patients. The sample was divided into three groups based on their vertical facial type (24 short, 122 normal, and 25 long facial types). The mean age was 11.11 years prior to treatment with a mean active treatment time of 4.5 months (Flores-Mir et al. 2010). A mean time of 6.4 months passed after Xbow™ deactivation, at which time a post-treatment radiograph was taken. The results of this study found no significant association between the amount of lower incisor proclination and vertical facial type. Due to large individual variability, the differences between the groups could not be statistically supported. However, a trend was identified for more proclination of the lower incisor in the shorter face types. Consequently, the authors concluded that despite the fact that lower incisors do procline with the use of the Xbow™ appliance, the vertical facial type does not influence the amount of proclination due to large individual variability (Flores-Mir et al.

2010).

The results of the previous studies on the Xbow™ appliance have shown that the short-term correction of a Class II malocclusion is due to a combination of dental and skeletal effects. The main skeletal influence appears to be a restrictive headgear effect on the maxilla. The remaining correction is accomplished primarily by dental changes equally in both dental arches. Further studies are required to shed some light on the amount of true skeletal correction possible with fixed Class II correctors.

2.8 Defining Facial Patterns

As spring-based appliances gain popularity, it is important to investigate the impact they have on individuals with different facial musculature patterns. Ricketts described how individuals of different facial patterns have either a stronger or a weaker musculature, which could counteract the effects of orthodontic forces, leading to either desirable or undesirable outcomes (Ricketts, 1979). Ricketts further stressed the need to monitor or modify treatment procedures for individuals with weaker anchorage support (Ricketts, 1979). It has been observed clinically that those facial types that exhibit the stronger musculature are characterized by a deep bite, low mandibular plane and brachyfacial structures (Ricketts, 1979). Individuals with a high mandibular plane angle, vertical pattern, open bite tendency, dolichofacial characteristics have a weaker musculature and are less able to overcome the adverse orthodontic treatment forces that tend to open the bite and rotate the mandible clockwise(Ricketts, 1979).

Generally, head shapes are divided into two broad categories – dolichocephalic (long, narrow, vertical growers) and brachycephalic (short, wide, horizontal growers); there is also an intermediary shape called mesocephalic (Nanci, 2012). Three parts of the head are used to determine the facial type – the cranium, the maxilla, and the mandible (Nanci, 2012). The criteria according to which facial types are distinguished are based on the assumption that the set of facial bones forming the midfacial region of the head is attached to the cranial base; for this reason, the cranial floor represents the pattern predetermining the majority of facial features (Nanci, 2012).

The characteristics of a dolichocephalic facial pattern contribute to the formation of the open cranial base flexure, which in its turn leads to a more downward mandibular rotation. This set of factors results in the downward inclination of the occlusal plane, and the clear curve of occlusion (Nanci, 2012). The mesocephalic facial structure that falls between the brachycephalic and mesocephalic facial patterns is the most common. Gallois stated that the term mesocephalic describes an individual with an average cranial width (Gallois, 2012).

Cephalometric analysis is used to identify the relationship between the skeletal pattern and the malocclusion. It is the tool used in dentistry and orthodontics to evaluate the relationships between the teeth, soft tissue, and the human facial skeleton (Gallois, 2012). It is conducted with the help of the lateral cephalometric radiograph, which "gives an orthodontist a sagittal view of the skeletal, dental, and soft tissues" (Gallois, 2012). By means of cephalometric analysis, an orthodontist can determine the skeletal pattern of the patient's malocclusion.

The differences between horizontal and vertical growers can be visualized cephalometrically. Several authors have confirmed vertical growers to have a short posterior facial height, a long lower anterior face height, large cranial base angles, a Class II malocclusion, and anterior teeth protrusion, underdeveloped mandible with antigonial notching, obtuse gonial angle, and a receded skeletal chin (Sassouni, 1969, Nanda 1990). In contrast, horizontal facial patterns demonstrate larger posterior facial heights, smaller lower anterior facial heights, a well developed mandible and a stronger skeletal chin (Sassouni, 1969). The mandibular plane is often used to classify a vertical or horizontal growth pattern. The work of Bjork and Skieller has shown vertical growers to be associated with backwards (clockwise) rotation of the mandible (Bjork et al. 1972). When the vertical growth of the alveolus and sutures exceeds the vertical growth at the condyle, the mandible rotates in a clockwise direction, increasing the mandibular plane angle (Sassouni, 1969, Bjork and Skieller, 1972). Conversely, excessive growth at the condyle results in the counterclockwise rotation of the mandible and a lower mandibular plane angle. It is important to note that although mandibular plane angle is an indicator of growth pattern, many authors believe that not one single parameter can accurately identify a given facial type (Nanda, 1990; Bishara, 1975, Opdebeeck, 1978; Baumrind, 1984).

The work of Sassouni described the phenotypic expression of the soft tissues associated with vertical and horizontal growers (Sassouni, 1969). The backwards rotating mandibles seen in vertical growth patterns increase tension within the stretched facial muscles disrupting the equilibrium of the orofacial muscles. This imbalance in muscle tension results in constriction of the maxilla (Bjork and Skieller, 1972). In addition, the increased vertical dimension requires hyperactivity of the mentalis muscle in an attempt to maintain lip competence that results in lower incisor crowding (Bjork and Skieller, 1972). The implant studies of Bjork found lower incisor crowding due to excessive mandibular growth rotations (Bjork and Skieller, 1972). Sassouni reported a higher mesial component of force in vertical growers resulting in dental protrusion (Sassouni, 1969). Horizontal growers exhibit excessive growth at the posterior cranial base and condyle resulting in counter clockwise rotation of the mandible (Sassouni, 1969). The counter clockwise rotation favors laxity of the muscles allowing the maxillary arch to broaden (Sassouni 1969, Bjork and Skieller, 1972). Bjork reported more mesial eruption of posterior teeth and increased lower incisor proclination in horizontal growers with forward rotation (Bjork, 1969).

Dentoalveolar position is another useful criteria used to give an indication of the skeletal pattern. Tooth movement or compensation occurs in the presence of unequal jaw growth to maintain occlusal relationships (Bjork and Skieller, 1972). Dentoalveolar compensations give an indication of the excessive or deficient skeletal discrepancy. Kim et al. demonstrated the molar and incisor compensations in subjects with different skeletal patterns (Kim et al. 2002). Kim demonstrated that the amount of tooth movement varied according to the underlying growth pattern in which Class III skeletal patterns had more mesial displacement of the maxillary molar and incisor, mandibular incisor uprighting, and counterclockwise rotation of the occlusal plane (Kim et al. 2002). In contrast, subjects with a Class II skeletal pattern had the mandibular molar and incisor moving more mesially and labially (Kim et al. 2002). Given that fact that dental compensations exist for varying facial patterns, it is important to investigate the potential post-treatment differences in skeletal and dental movements considering facial type.

Chapter 3

Materials and Methods

3.1 Sample Selection

The treatment sample was obtained from the private orthodontic practice of an orthodontist in Winnipeg, Manitoba. All digital cephalometric radiographs were taken with a ProMax S3 Pan/Ceph (Planmeca, Inc. Helsinki, Finland).

Both pre-treatment (T1) and post-treatment (T2) lateral cephalometric radiographs were taken between January 23rd, 2008 and July 30th, 2011. The total sample size of 134 consisted of 65 males and 69 females. Because gender was closely matched, the sample is described as gender neutral. The mean age of the patients was 12 years 7 months (SD 1yr. 7mo.) at T1 and 13 years 4 months (SD 1yr. 7mo.) at T2. Standard treatment protocol involved activation of the springs every 4-6 weeks until a Class III overcorrection in the buccal segments was attained. Following the active phase (4.26 months SD 1.22 mo.), the appliance was passively retained for an additional average time of 3.07 months SD 1.06 mo. Therefore, the total mean time the appliance was in the mouth was 7.33 months SD 1.82 mo. at which time the appliance was removed and a T2 radiograph taken. A summary of the treatment sample is described in Table 3-1.

Parameter	***Mean***	***Min.***	***Max.***	***SD***
Age at T1 (years)	12.58	9.92	16.92	1.58
Age at T2 (years)	13.33	10.75	17.08	1.58
Total time between T1/T2 (months)	7.33	4.10	13.10	1.82

Table 3-1. Summary statistics for the treatment group

The following inclusion criteria were used to select the subjects:

1. A complete permanent dentition;
2. Subjects with a ¾ to 1 full cusp Class II dental malocclusion;
3. Subjects treated with the Xbow appliance;
4. Subjects with a pre and post cephalometric radiograph of acceptable quality.

The subjects were excluded from the study based on:

1. Subjects missing either a pre or post cephalometric radiograph;
2. Cephalometric radiographs of poor diagnostic quality;
3. Mutilated dentitions;
4. Congenitally missing teeth other than third molars;
5. Previous orthodontic treatment.

3.2 Data Collection

3.2.1 Calibration

The radiographs were labeled with a code for blinding purposes. No information on the radiographs indicated the age, gender, or if the radiograph was from pre or post Xbow treatment. A single investigator using the DolphinTM 11.5 treatment planning software (Dolphin Imaging and Management Systems, Chatsworth, CA, USA) digitally traced all of the lateral cephalometric radiographs. Magnification was accounted for using a digital calibration within the software, which matched actual known ruler distances captured on the lateral cephalogram.

The intra and inter-examiner reliability of the measurements was assessed using an interclass correlation coefficient (ICC) test on 10% of the studied sample. Fifteen cephalometric radiographs were chosen randomly and re-measured by two separate examiners 12 weeks after the original measurements to identify landmark identification error. Statistical software, SAS 9.2, was used to analyze the data.

3.2.2 Defining Facial Types

Subjects were categorized into three growth types according to two pre-treatment cephalometric variables; mandibular plane angle (MPA) and growth axis (Y-axis). Subjects within two standard deviations for MPA (32° SD 2°) and one standard deviation for Y-axis (66° SD 5°) yielded 27 brachycephalic, 70 mesocephalic, and 37 dolichocephalic subjects.

A Kolmogorov-Smirnov test was used to determine if the samples were of normal distribution. A paired *t*-test was used to determine if there was a significant difference between the three groups prior to Xbow™ treatment. The p value was considered significant at $\alpha<0.05$. Group 1 represents the brachycephalic group with mean Y-axis of 64.7°±0.5° and a mean MPA of 25.3°±0.6°. Group 2 represents the dolichocephalic group with a mean Y-axis of 72.2°±0.5° and a mean MPA of 38.0°±0.5°. Group 3 represents the mesocephalic group with a mean Y-axis of 68.4°±0.3° and a mean MPA of 31.9°±0.4°. A summary of the three groups prior to Xbow™ treatment is described in Table 3-2.

Variables	Group 1	Group 2	Group 3	p-value
Y-Axis(SGn-SN) º	64.7±0.5	72.2±0.5	68.4±0.3	<0.0001
MPA MP - SN º	25.3±0.6	38.0±0.5	31.9±0.4	<0.0001

Table 3-2. Differences between groups prior to XbowTM treatment (Time 1).

Group 1 – brachycephalic, Group 2 - dolichocephalic, Group 3 – mesocephalic.

3.2.3 Growth Considerations

Post-treatment cephalometric radiographs used to examine the effects of Xbow™ treatment were taken on the day of appliance removal. The mean treatment time with the

Xbow™ in place was 7.33 months (SD 1.82 months). Dolphin Imaging™ 11.5 software was used to predict the amount of growth that occurred over the period of treatment. Dolphin Imaging™ software uses growth prediction algorithms to quantify the amount of growth given parameters of age and time of treatment. Several computer programs using growth prediction algorithms have shown to be accurate, with respect to a clinical reference mean of 1.5mm, including the Bolton growth prediction used for this sample (Sanun, 2012). The Bolton growth forecast of Dolphin Imaging™ allows:

1. Simulation of growth on a traced x-ray, or tracing overlaid on a photo by inputting current skeletal age and desired duration of growth.
2. Superimposition of one or more growth tracings over original tracing, aligned to any desired reference plane.
3. Viewing and analysis of post-growth measurements and the grown image.
4. A choice of Bolton or Ricketts growth algorithms.

The following figure is an example of a growth prediction superimposition using the Bolton algorithm for this patient's specific treatment time of 6.30 months (Figure 3-1).

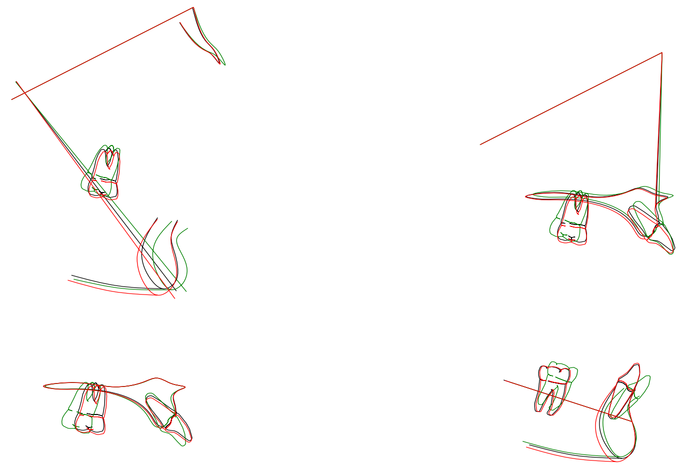

Figure 3-1. A growth prediction superimposition using the Bolton algorithm

A (black)- pre-treatment tracing, B (red)- expected growth without treatment (Bolton algorithm), C (green)- Post-treatment (Xbow^{TM}).

The skeletal and dental effects of growth over the treatment period were assessed on 30% of the studied sample. Fifteen pre-treatment cephalometric radiographs were chosen randomly from each group and were subject to the Bolton growth prediction algorithm. A Kolmogorov-Smirnov test was used to determine if the samples were of normal distribution. A paired *t*-test was used to determine if there was a significant difference between the cephalometric variables from expected growth versus pre-treatment cephalometric variables. The p value was considered significant at $\alpha<0.05$.

3.3 Statistical Analysis

A Kolmogorov-Smirnov test was used to determine if the samples were of normal distribution. Skewed variables (molar and incisor positions) were normalized by means of Log transformation. Following confirmation of normal distribution, an analysis of variance (ANOVA) statistic was used analyze the skeletal and dental effects of treatment over time between the three groups (Table 3-3). A summary of distribution and the type of analysis used is shown in Table 3-3.

Variable	***Distribution***	***Statistical Analysis***
Occ Plane to SN (º)	Normal	ANOVA
ANB (º)	Normal	ANOVA
SNA (º)	Normal	ANOVA
SNB (º)	Normal	ANOVA
MP - SN (º)	Normal	ANOVA
Wits Appraisal (mm)	Normal	ANOVA
U1 - SN (º)	Normal	ANOVA
U1 - Palatal Plane (º)	Normal	ANOVA
U1 - NA (º)	Normal	ANOVA
U1 - NA (mm)	Normal	ANOVA
Interincisal Angle (U1-L1) (º)	Normal	ANOVA
IMPA (L1-MP) (º)	Normal	ANOVA
L1 Protrusion (L1-APo) (mm)	Normal	ANOVA
L1 - NB (º)	Normal	ANOVA
L1 - NB (mm)	Normal	ANOVA
L1 to A-Po (mm)	Normal	ANOVA
Y-axis (º)	Normal	ANOVA

Overjet (mm)	Normal	ANOVA
Overbite (mm)	Normal	ANOVA
Mand Incisor Extrusion (mm)	Normal	ANOVA
Maxillary Incisor Position (mm)	Log transformed for normal distribution	ANOVA
Mandibular Incisor Position (mm)	Log transformed for normal distribution	ANOVA
Maxillary Molar Position (mm)	Log transformed for normal distribution	ANOVA
Mandibular Molar Position (mm)	Log transformed for normal distribution	ANOVA

Table 3-3. Variables examined, distribution, and type of statistical analysis

3.4 Xbow ^{TM} Appliance

The appliance used in this study was the typical Xbow^{TM} fixed Class II corrector that consisted of 3 main components: a maxillary hyrax expander, a mandibular labial and lingual bow, and Forsus^{TM} fatigue resistant device (FRD) springs (3M Unitek, Monrovia, Calif). The maxillary hyrax included bands on the maxillary first molars and first premolars.

One end of the Forsus^{TM} spring was inserted into the headgear tube of the maxillary first molar band and the opposite end was hooked around the labial bow near the mandibular canine area. A Gurin lock (3M Unitek) on the lower labial bow stopped the ForsusTM spring anteriorly. The mandibular labial and lingual bows were in passive contact with the mandibular incisors and were retained in the mouth by bands on the first molars and occlusal rests bonded to the first premolars. Forsus™ springs do not rigidly hold the mandible forward and allow the patient to function in centric occlusion (Mir et al, 2009). It could thus be categorized as a non-protrusive inter-arch Class II corrector (Figure 3-2).

Figure 3-2. Intra-oral photos of a typical Xbow™ used in this study

The treatment protocol used on the sample was similar irrespective of the amount of expansion required or if there was a Class II dental asymmetry.

The maxillary and mandibular appliance was inserted on the same day with Forsus™ springs bilaterally on every patient. Standard treatment protocol involved activation of the springs every 4-6 weeks until a Class III overcorrection in the buccal segments was accomplished.

Transverse discrepancies were calculated pre-treatment and expansion was completed prior to AP correction. The hyrax screw was activated if expansion was deemed necessary. If expansion was completed it was retained for 4 months with the hyrax passively in place. The Xbow™ appliance was left in place for the entire treatment period of 7.33 SD 1.82 months on average.

Following Class II overcorrection, phase two treatment involved full fixed upper and lower braces with the use of inter-arch elastics if required.

3.5 Cephalometric Analysis

3.5.1 Natural Head position

Positioning of the patients consistently when taking the cephalometric radiographs was assumed for this retrospective study. Judging by the quality of the radiographs selected for analysis, it is assumed the patients were positioned in the natural head position for the radiograph. Natural head position is a standardized orientation of the head that is reproducible for each individual and is used as a means of standardization during analysis of dentofacial morphology both for photos and for radiographs (Jacobson, 2006). To accomplish natural head position, the patient was asked to gaze ahead as if he/she were looking at the horizon with the interpupillary line parallel to the floor.

All radiographs for this study were taken with the same Pan/Ceph ProMax S3 (Planmeca, Inc. Helsinki, Finland). The radiograph of the head was taken with the x-ray beam perpendicular to the patient's sagittal plane. The beam entered on the patient's left side, with the film cassette adjacent to the patient's right side. Each radiograph was analyzed with the patient's head oriented to the right.

3.5.2 Computerized Cephalometrics

The cephalometric data was transferred in JPEG digital format into Dolphin Imaging™ 11.5 for cephalometric analysis. The images were then 'digitized' to allow for tracing of the digital image. Digitization is the conversion of landmarks on a radiograph or tracing to numerical values on a two dimensional coordinate system, usually for the purpose of computerized cephalometric analysis (Jacobson, 2006). The process allows for automatic measurement of landmark relationships. Once digitized, manual landmark identification was carried out by a single investigator.

3.5.3 Growth Visual Treatment Objective (VTO) - Growth Prediction

A growth VTO is an estimate of the expected growth of a patient over a definitive period. To rule out if growth had a significant contribution to any skeletal or dental movements over the treatment period, thirty percent of the total sample's pre-treatment tracings were subject to Dolphin Imaging™ Bolton growth prediction algorithm. The Bolton growth prediction algorithm has been shown to be accurate with respect to a clinical reference mean of 1.5mm (Sagun 2012). The pre-treatment tracings were modified to demonstrate the growth changes that would be anticipated without Xbow™ treatment within the treatment period. This data was then subject to statistical analysis to quantify growth changes of the subjects.

3.5.4 Superimposition

Superimposition is the process of placing two or more images upon each other. The images are registered on structures that remain relatively stable during the time period. This allows for a greater visualization of the changes brought about by growth and/or treatment.

3.5.5 Cephalometric Landmarks

A cephalometric landmark is a recognizable point on a tracing that represents a hard or soft tissue anatomical structure called anatomical landmarks. Landmarks involving the intersections of lines are called constructed landmarks.

Landmarks are used as reference points for the construction of various lines or planes and for subsequent numerical determination of cephalometric measurements (Jacobson, 2006). Rickett's, Steiner's, and Pancherz's analyses were used to analyze the skeletal and dental changes before and after Xbow^{TM} treatment. The cephalometric landmarks used in a modified Steiner’s analysis are shown in Figure 3-3. Landmarks used in a Rickett’s analysis are shown in Figure 3-4. Landmarks used in this study from the Pancherz’s analysis are shown in Figure 3-5.

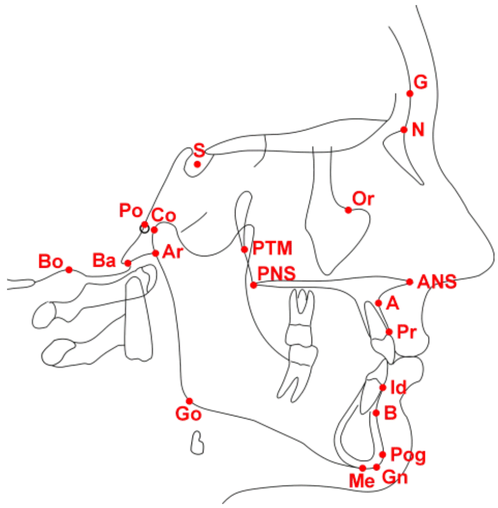

Figure 3-3. Landmarks used in a modified Steiner's analysis (Adapted from Jacobson, 1995)

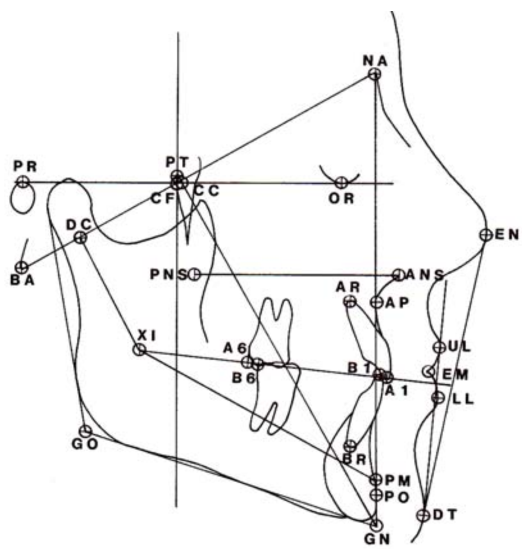

Figure 3-4. Landmarks used in a modified Rickett's analysis (Adapted from Jacobson, 1995)

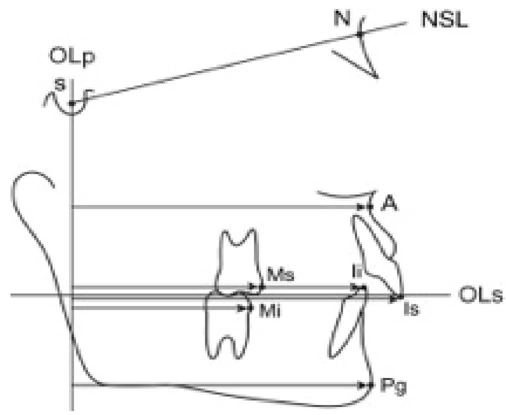

Figure 3-5. Landmarks used in a modified Pancherz's analysis (Wu JY et. al. 2010)

A description of the landmarks used in this study is provided in Table 3-4. It is important to note that some of the cephalometric landmarks are repeated in the three analyses. By convention, 'midsagittal' identifies landmarks lying on the midsagittal plane, 'unilateral' identifies landmarks corresponding to unilateral structures and 'bilateral' applies to landmarks corresponding to bilateral structures (Jacobson, 2006).

Landmark	***Analysis***	***Description***	***Midsagittal/ Bilateral***	***Reference***
A-point (Subspinale, ss)	Steiner Ricketts Pancherz	Deepest, posterior midline point on the curvature between the ANS and prosthion.	Midsagittal	Broadbent, 1975 Jacobson, 1995
Anterior nasal spine (ANS)	Steiner Ricketts	Tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane. Used to define the anterior end of the palatal plane of the nasal floor.	Midsagittal	Broadbent, 1975 Jacobson, 1995
Articulare (Ar)	Steiner Ricketts	Constructed point representing the intersection of three radiographic images: the inferior surface of the cranial base and the posterior outlines of the ascending rami or mandibular condyle.	Bilateral	Broadbent, 1975 Jacobson, 1995
B-point (Point B, Supramentale, sm)	Steiner Ricketts Pancherz	Deepest most posterior midline point on the bony curvature of the anterior mandible, between infradentale and pogonion.	Midsagittal	Broadbent, 1975 Jacobson, 1995
Bastion (Ba)	Steiner Ricketts	Most anterior inferior point on the margin of the foramen magnum, in the midsagittal plane. Located on the inferior border of the basilar part of the occipital bone to its posterior limit, superior to the dens of the axis.	Midsagittal	Broadbent, 1975 Jacobson, 1995
Bolton (Bo)	Steiner Ricketts	The highest points on the outlines of the retrocondylar fossae of the occipital bone, approximating the center of the foramen magnum.	Bilateral	Broadbent, 1975 Jacobson, 1995
CC Point (CC) Ricketts	Ricketts	Crossing of the facial axis with the BaN plane known as the Cranial Center	Midsagittal	Broadbent, 1975 Jacobson, 1995

Condylion (Co)	Steiner Ricketts	Most superior posterior point on the head of the mandibular condyle.	Bilateral	Broadbent, 1975 Jacobson, 1995
DC Point (Ricketts)	Ricketts	Center of the neck of the condyle on the Basion Nasion line.	Bilateral	Broadbent, 1975 Jacobson, 1995
Glabella (G)	Steiner Ricketts Pancherz	Most prominent point of the anterior contour of the frontal bone in the midsagittal plane.	Midsagittal	Broadbent, 1975 Jacobson, 1995
Gnathion (Gn)	Steiner Ricketts Pancherz	Most anterior inferior point on the bony chin in the midsagittal plane.	Midsagittal	Broadbent, 1975 Jacobson, 1995

Table 3-4. Description of the cephalometric landmarks.

3.5.6 Cephalometric Planes

A description of the planes used in this study is provided in Table 3-5. Most analyses utilize one or more cephalometric lines that join two landmarks, are tangent to an outline from a landmark, or are perpendicular to another line from a landmark (Jacobson, 1995).

Plane	Analysis	Description	Reference
Basion-Nasion line (Ba-N)	Ricketts	Represent the cranial base similar to the SN line or the Bolton plane.	Broadbent, 1975 Jacobson, 1995
E-line (E-plane, Esthetic line of Ricketts)	Ricketts	Tangent to the chin and nose to assess lip fullness.	Broadbent, 1975 Jacobson, 1995

Facial axis of Ricketts	Ricketts	A line connecting gnathion with cranial point "Pt," defined as the lower border of the foramen rotundum and the most posterosuperior point of the outline of the pterygomaxillary fissure.	Broadbent, 1975 Jacobson, 1995
Facial plane (FP, Facial line)	Steiner Ricketts	A line extending from nasion to pogonion.	Broadbent, 1975 Jacobson, 1995
Frankfort horizontal plane (FH, Frankfort horizontal line, Auriculo-orbital plane, Eye-ear plane)	Steiner Ricketts	Horizontal plane passing through the lowest point in the floor of the orbit and the highest point on the margins of the external auditory meatus (porion).	Broadbent, 1975 Jacobson, 1995
H-line (Harmony line of Holdaway)	Ricketts	A line tangent to the soft tissue chin and the upper lip to assess of the soft tissue profile.	Broadbent, 1975 Jacobson, 1995
Mandibular plane (MP, Mandibular line, ML)	Steiner Ricketts	A line passing through the mandibular borders (bilaterally) joining points gonion and gnathion.	Broadbent, 1975 Jacobson, 1995
Occlusal plane (OP)	Steiner Ricketts Pancherz	A line drawn through the occlusal surfaces of the maxillary and mandibular first permanent molars and first and second premolars.	Broadbent, 1975 Jacobson, 1995
Palatal plane (ANS-PNS, PP, Nasal line, Nasal floor, Spinal plane)	Steiner Ricketts	A line joining PNS and ANS.	Broadbent, 1975 Jacobson, 1995
S-line (Esthetic plane of Steiner)	Steiner	A line connecting the midpoint of the columella of the nose to the soft tissue pogonion.	Broadbent, 1975 Jacobson, 1995
Sella-Nasion line (SN, Nasion-Sella line, NSL)	Steiner	Reference line representing the anterior cranial base. A line joining points S and Na.	Broadbent, 1975 Jacobson, 1995

Y-axis (Growth axis)	Steiner Ricketts	A line connecting points sella and gnathion. This angle gives an indication of the direction of mandibular growth.	Broadbent, 1975 Jacobson, 1995
Angle of convexity (NAPog)	Steiner Ricketts	Assessment of the degree of convexity (or concavity) of the skeletal profile. The angle is formed by the lines NA and A-Pog and has a positive value in convex and negative value in concave profiles.	Broadbent, 1975 Jacobson, 1995
ANB angle	Steiner Ricketts	The difference between angles SNA and SNB. Is an evaluation of the anteroposterior relationship between the maxillary and mandibular apical bases.	Broadbent, 1975 Jacobson, 1995
SNA angle	Steiner Ricketts	Assessment of the anteroposterior position of the maxilla with regards to the cranial base. The inferior posterior angle formed by the intersection of lines SN and NA is measured.	Broadbent, 1975 Jacobson, 1995
SNB angle	Steiner Ricketts	Assessment of the anteroposterior position of the mandible in relation to the cranial base. The inferior posterior angle formed by the intersection of lines NA and NB is measured.	Broadbent, 1975 Jacobson, 1995
Facial angle (FH-NPog)	Steiner Ricketts	The inferior posterior angle formed by the intersection of the Frankfort horizontal and the facial plane (N-Pog).	Broadbent, 1975 Jacobson, 1995
Facial axis angle of Ricketts (Ba-Pt-Gn)	Ricketts	The inferior angle formed by the intersection of the facial axis of Ricketts and the Ba-N line. This angle gives an indication of growth pattern.	Broadbent, 1975 Jacobson, 1995

Facial height, Anterior; Posterior; and Total	Steiner Ricketts Pancherz	Vertical dimension appraisal of the face. The anterior lower facial height is expressed by the linear millimetric distance between the ANS and menton. The percent ratio of the previous linear measurement (ANS-Me) over the total anterior facial height (N-Me) provides an assessment of the relative proportionality of the anterior face in the vertical dimension. Similarly, the linear measurement from S to Go on the lateral cephalometric radiograph provides an assessment of posterior facial height.	Broadbent, 1975 Jacobson, 1995
Gonial angle (Angle of the mandible, Condylar angle)	Steiner	The anterior angle formed by the intersection of a line tangent to the posterior border of the ramus and the mandibular plane. It may give an indication about mandibular growth direction.	Broadbent, 1975 Jacobson, 1995
Holdaway ratio (LI-NB/Pg-NB)	Steiner	Used to evaluate the relative prominence of the mandibular incisors, as compared to the size of the bony chin. It is calculated as the ratio of 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.	Broadbent, 1975 Jacobson, 1995
Interincisal angle	Steiner Ricketts	The angle formed by the intersection of the long axis of the maxillary and mandibular central incisors.	Broadbent, 1975 Jacobson, 1995
LI-to-AP distance	Steiner	The perpendicular distance of the incisal edge of the mandibular central incisors to the A-Pog line.	Broadbent, 1975 Jacobson, 1995
Mandibular plane angle	Steiner Ricketts	Assessment of the steepness of the mandibular plane in relation to the cranial base. The anterior angle formed by the intersection of SN and GoGn.	Broadbent, 1975 Jacobson, 1995

Nasolabial angle (NLA)	Steiner Ricketts	The anterior inferior angle formed by the intersection of a line tangent to the columella of the nose and a line drawn from subnasale to the mucocutaneous border of the upper lip.	Broadbent, 1975 Jacobson, 1995
Wits appraisal	Steiner	Perpendicular lines to functional occlusal plane from points A and B, and subsequently measuring the distance between the two points of intersection of the two perpendicular lines. The greater the deviation of this reading from 0 mm in females and 1.0 mm in males, the greater the degree of sagittal discrepancy between the maxilla and mandible.	Broadbent, 1975 Jacobson, 1995
Is-OLp–Ii-OLp	Pancherz	Represents overjet, which is the linear discrepancy between the upper and lower incisor in a positive or negative relationship.	Wu JY,Pancherz H, et. al, 2010
Is-OLp	Pancherz	Linear sagittal measurement of the maxillary central incisor position in reference to constructed OLp	Wu JY et. al, 2010
Ii-OLp	Pancherz	Linear sagittal measurement of the mandibular central incisor position in reference to constructed OLp	Wu JY et. al, 2010
Ms-OLp	Pancherz	Linear sagittal measurement of the maxillary first permanent molar position in reference to constructed OLp	Wu JY et. al, 2010
Mi-OLp	Pancherz	Linear sagittal measurement of the mandibular first permanent molar position in reference to constructed OLp	Wu JY et. al, 2010

Table 3-5. ***Cephalometric planes used in this study.***

Chapter 4

Results

4.1 Reliability

The reliability of the measurements was assessed using an intraclass correlation coefficient (ICC) test on 10% of the studied sample. Fifteen cephalometric radiographs were chosen randomly and re-measured by two separate examiners 12 weeks after the original measurements to identify landmark identification error. The level of reliability can be assessed based on ICC values ranging from 0 (no agreement) to 1 (perfect agreement). The intra-examiner results showed a high consistency in the repeated measurements; all ICC values were greater or equal to 0.924 (SNA) and none of the 95% confidence limits had a lower limit less than 0.837 (ANB) (Table 4.1). An F test was used to confirm there were no significant differences between the cephalometric variables from TI to T2 (Table 4.1).

Variables examined TI to T2	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower limit	Upper limit	Value	df1	df2	Sig
Occ_Plane_SN	.992	.977	.998	262.953	13	13	.000
SNA	.924	.863	.985	42.237	13	13	.000
SNB	.962	.887	.988	52.209	13	13	.000
ANB	.945	.837	.982	35.153	13	13	.000
MP - SN (º)	.966	.898	.989	57.978	13	13	.000
Convexity	.958	.875	.986	46.667	13	13	.000
Wits Appraisal (mm)	.983	.947	.994	114.035	13	13	.000
U1 - SN (º)	.987	.961	.996	158.526	13	13	.000
U1 - Palatal Plane (º)	.975	.923	.992	77.828	13	13	.000
U1 - NA (º)	.970	.911	.990	66.535	13	13	.000
U1 - NA (mm)	.933	.806	.978	29.059	13	13	.000
Interincisal Angle (U1-L1) (º)	.991	.973	.997	228.390	13	13	.000
IMPA (L1-MP) (º)	.990	.968	.997	191.618	13	13	.000
L1 Protrusion (L1-APo) (mm)	.980	.940	.994	100.035	13	13	.000
L1 - NB (º)	.986	.957	.995	140.960	13	13	.000
L1 - NB (mm)	.988	.962	.996	161.187	13	13	.000
L1 to A-Po (mm)	.980	.939	.994	99.557	13	13	.000
Y-axis (º)	.912	.935	.897	91.024	13	13	.000
Overjet (mm)	.975	.923	.992	77.967	13	13	.000
Overbite (mm)	.979	.937	.993	96.219	13	13	.000

Mand Incisor Extrusion (mm)	.981	.941	.994	102.756	13	13	.000
Maxillary Incisor Position (mm)	.993	.977	.998	268.113	13	13	.000
Mandibular Incisor Position (mm)	.994	.982	.998	348.203	13	13	.000
Maxillary Molar Position (mm)	.994	.982	.998	350.093	13	13	.000
Mandibular Molar Position (mm)	.994	.982	.998	344.583	13	13	.000
Average	.973	.931	.989	141.755	13	13	.000

Table 4-1. ICC and F test values for the intra-examiner reliability

Overall, the inter-examiner ICC values had a wider reliability interval (0.916-0.970) and overall lower average correlation (0.954). However, there was still strong agreement of the values with correlation coefficients greater than 0.887 (SNA) (Table 4.2). Once again, an F test was used to confirm there were no significant differences between the cephalometric variables from TI to T2 (Table 4-2). Based on these results, we can be confident that the reproducibility of the cephalometric variables is reliable within a 12-week period.

Variables examined TI to T2	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower limit	Upper limit	Value	df1	df2	Sig

Occ_Plane_SN	.963	.943	.988	245.447	13	13	.000
SNA	.887	.807	.923	38.196	13	13	.000
SNB	.921	.855	.967	47.192	13	13	.000
ANB	.926	.899	.954	31.147	13	13	.000
MP - SN (º)	.963	.857	.969	56.969	13	13	.000
Convexity	.929	.895	.964	49.654	13	13	.000
Wits Appraisal (mm)	.954	.921	.980	109.028	13	13	.000
U1 - SN (º)	.963	.947	.989	153.498	13	13	.000
U1 - Palatal Plane (º)	.933	.918	.955	69.789	13	13	.000
U1 - NA (º)	.947	.922	.968	67.519	13	13	.000
U1 - NA (mm)	.939	.817	.949	25.047	13	13	.000
Interincisal Angle (U1-L1) (º)	.936	.911	.953	218.277	13	13	.000
IMPA (L1-MP) (º)	.967	.935	.989	198.579	13	13	.000
L1 Protrusion (L1-APo) (mm)	.976	.968	.987	99.004	13	13	.000
L1 - NB (º)	.969	.945	.979	140.888	13	13	.000
L1 - NB (mm)	.979	.968	.991	158.064	13	13	.000
L1 to A-Po (mm)	.937	.911	.948	97.909	13	13	.000
Y-axis (º)	.968	.839	.898	88.048	13	13	.000
Overjet (mm)	.961	.955	.979	76.988	13	13	.000
Overbite (mm)	.974	.941	.981	95.187	13	13	.000
Mand Incisor Extrusion (mm)	.958	.913	.983	100.676	13	13	.000
Maxillary Incisor Position (mm)	.978	.967	.991	258.112	13	13	.000

Mandibular Incisor Position (mm)	.947	.936	.988	322.77	13	13	.000
Maxillary Molar Position (mm)	.980	.973	.986	346.134	13	13	.000
Mandibular Molar Position (mm)	.983	.969	.991	327.358	13	13	.000
Average	.954	.916	.970	136.86	13	13	.000

Table 4-2. ICC and F test values for the inter-examiner reliability

4.2 Growth Considerations

Dolphin Imaging™ 11.5 software was used to predict the amount of growth that occurred over the treatment period (mean time of 7.33 months SD 1.82 mo.). Dolphin Imaging™ software uses growth prediction algorithms to quantify the amount of growth given parameters of age and time of treatment. Several computer programs using growth prediction algorithms have shown to be accurate, with respect to a clinical reference mean of 1.5mm, including the Bolton growth prediction used for this sample (Sagun, 2012). A *t*-test showed that the mean differences of the majority of variables were insignificant. One value that was significantly different ($p \leq 0.05$) was the inclination of the upper incisor to NA (nasion- A point) (Table 4.3). The p value was considered significant at $\alpha < 0.05$.

Variables	Mean	Std Dev	Std Err	Upper 95% CL	Lower 95% CL	p value	Significance

Occ Plane to SN (º)	0.028	0.14	0.025	-0.023	0.079	0.27	NS
ANB (º)	0.15	0.49	0.86	-0.029	0.32	0.099	NS
SNA (º)	-0.063	0.094	0.017	-0.097	-0.029	0.081	NS
SNB (º)	-0.1	0.18	0.031	-0.16	-0.036	0.061	NS
MP - SN (º)	-0.11	0.23	0.041	-0.20	-0.029	0.072	NS
WitsAppraisal (mm)	0.0063	0.14	0.025	-0.044	0.056	0.80	NS
U1 - SN (º)	-0.047	0.36	0.064	-0.18	0.084	0.47	NS
U1 - Palatal Plane (º)	0.03	1.27	0.22	-0.43	0.49	0.90	NS
U1 - NA (º)	-0.72	0.14	-0.1	-0.44	1.01	<0.0001	S
U1 - NA (mm)	-0.075	0.17	0.031	-0.14	-0.013	0.20	NS
Interincisal Angle (U1-L1) (º)	0.097	0.2	0.035	0.025	0.17	0.066	NS
IMPA (L1-MP) (º)	-0.081	0.2	0.036	-0.15	0.0077	0.089	NS
L1 Protrusion (L1-APo) (mm)	-0.053	0.08	0.014	-0.082	-0.024	0.093	NS
L1 - NB (º)	-0.091	0.089	0.016	-0.122	-0.058	0.12	NS
L1 - NB (mm)	-0.067	0.064	0.011	-0.092	0.046	0.067	NS
L1 to A-Po (mm)	1.47	2.05	0.55	0.29	2.66	0.12	NS
Y-axis (º)	0.18	1	0.18	-0.19	0.54	0.33	NS
Overjet (mm)	0.013	0.29	0.051	-0.092	0.12	0.81	NS
Overbite (mm)	0.038	0.066	0.012	0.014	0.061	0.073	NS
Mand Incisor Extrusion (mm)	0.025	0.051	0.009	0.0067	0.043	0.099	NS
Maxillary Incisor Position (mm)	-0.13	0.28	0.049	-0.23	-0.032	0.097	NS
Mandibular Incisor Position (mm)	0.35	0.64	0.17	-0.021	0.72	0.063	NS
Maxillary Molar Position (mm)	-0.047	0.2	0.036	-0.12	0.2	0.20	NS

Mandibular Molar Position (mm)	-0.059	0.38	0.067	-0.20	0.077	0.38	NS

Table 4-3. Growth prediction of 30% of the sample (n=45)

Mean change; Std Dev - Standard deviation; Std Err – Standard error; CL – Confidence limit; S - Significant difference ($p \leq 0.05$); NS – No significant difference ($p > 0.05$).

4.3 Differences Between Groups Prior to Xbow ™ Treatment (T1).

A retrospective sample of 134 patients exhibiting a Class II malocclusion treated with the Xbow appliance was used. Subjects were then categorized into three growth types based on pre-treatment cephalometric variables (MPA and Y-axis); 27 brachycephalic (group 1), 37 dolichocephalic (group2), and 70 mesocephalic (group 3).

4.3.1 Difference Between Brachycephalic and Dolichocephalic Prior to Xbow ™ Treatment (T1) (Table 4-4).

i) **Growth Pattern** - Both Y-axis and MPA showed a statistically significant difference between the brachycephalic and dolichocephalic groups ($p < 0.05$), signifying two distinct facial patterns prior to Xbow™ treatment.

ii) **Skeletal Pattern –** ANB and Wits appraisal were not statistically different between the brachycephalic and dolichocephalic group (p>0.05), classifying both groups as having a Class II skeletal pattern. SNB was significantly different between the two groups with B point more retrusive in the dolichocephalic group.

iii) Dental Variables – Interestingly, facial pattern did not influence the position of the upper incisor and molars, as they were not significantly different between the groups (p>0.05) prior to Xbow^{TM} treatment. As one would expect, dental compensations for varying facial patterns were reflected in the position of the lower incisor prior to Xbow^{TM} treatment. The angular position of the lower incisor to mandibular plane was significantly different between the two groups, being more proclined in the brachycephalic group but more protruded in the dolichocephalic group. Both the overjet and overbite were excessive in both groups and were not significantly different (p>0.05) between the two groups prior to treatment.

Variables	Group 1 (Brachy)	Group 2 (Dolicho)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (º)	12.1±0.7	18.3±0.6	<0.0001
ANB (º)	4.7±0.4	5.8±0.4	0.42
SNA	83.6±0.7	79.4±0.6	0.0001
SNB	79±0.6	73.7±0.5	<0.0001
Y-Axis (SGn-SN) (º)	64.7±0.5	72.2±0.5	<0.0001

MP - SN (º)	25.3±0.6	38.0±0.5	<0.0001
Wits Appraisal (mm)	3.7±0.5	3.9±0.5	1
U1 - SN (º)	105.4±1.3	100.8±1.1	0.1
U1 - Palatal Plane (º)	109.8±1.3	108.4±1.1	0.96
U1 - NA (º)	21.7±1.4	21.3±1.2	1
U1 - NA (mm)	3.3±0.5	2.9±0.4	0.98
Interincisal Angle (U1-L1) (º)	130.6±1.9	128.7±1.6	0.98
IMPA (L1-MP) (º)	98.8±1.4	92.6±1.1	<0.0001
L1 Protrusion (L1-APo) (mm)	-0.09±0.4	0.9±0.4	<0.0001
L1 - NB (º)	23.1±1.4	24.2±1.2	0.99
L1 - NB (mm)	3.9±0.5	4.8±0.4	<0.0001
L1 to A-Po (mm)	-0.09±0.4	0.9±0.4	<0.0001
Overjet (mm)	5.9±0.5	5.9±0.4	1
Overbite (mm)	3.7±0.4	2.2±0.3	0.07
Mand Incisor Extrusion (mm)	1.8±0.2	1.1±0.2	0.08
Maxillary Incisor Position (mm)	91.3±7.4	81.8±0.7	0.2
Mandibular Incisor Position (mm)	84.8±6.7	75.6±0.7	0.2
Maxillary Molar Position (mm)	59.7±4.8	52.9±0.7	0.2
Mandibular Molar Position (mm)	58.8±4.7	52.1±0.8	0.2

Table 4-4. Difference Between Brachycephalic and Dolichocephalic Prior to Xbow ^{TM}

Treatment (T1).

4.3.2 Difference Between Brachycephalic and Mesocephalic Prior to Xbow TM Treatment (T1) (Table 4-5).

i) **Growth Pattern -** Both Y-axis and MPA showed a statistically significant difference between the brachycephalic and mesocephalic groups ($p<0.05$), signifying two distinct facial patterns prior to Xbow^{TM} treatment.

ii) **Skeletal Pattern –** ANB and Wits appraisal were not statistically different between the brachycephalic and mesocephalic group ($p>0.05$), classifying both groups as having a Class II skeletal pattern. Both SNA and SNB were significantly different between the two groups with A point and B point being more protrusive in the brachycephalic group.

iii) **Dental Variables –** When comparing the brachycephalic group to the mesocephalic group, we find the facial pattern are similar enough not to influence the position of the incisors and molars, as they were not significantly different between the groups ($p>0.05$) prior to Xbow^{TM} treatment. Unlike the comparison of the lower position to the dolichocephalic facial pattern, when compared to the mesocephalic group the position of the lower incisor was not significantly different. Thus, the dental compensations for the brachycephalic and mesocephalic groups are similar prior to Xbow^{TM} treatment. Both the overjet and overbite were excessive in both groups and were not significantly different (p>0.05) between the two groups prior to treatment.

Variables	Group 1 (Brachy)	Group 3 (Meso)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (º)	12.1±0.7	14.6±0.5	0.05
ANB (º)	4.7±0.4	5.1±0.3	0.98
SNA	83.6±0.7	81.1±0.4	0.03
SNB	79±0.6	76.5±0.4	0.02
Y-Axis (SGn-SN) (º)	64.7±0.5	68.4±0.3	<0.0001
MP - SN (º)	25.3±0.6	31.9±0.4	<0.0001
Wits Appraisal (mm)	3.7±0.5	4.2±0.3	0.96
U1 - SN (º)	105.4±1.3	102.0±0.8	0.27
U1 - Palatal Plane (º)	109.8±1.3	107.9±0.8	0.82
U1 - NA (º)	21.7±1.4	20.8±0.9	1
U1 - NA (mm)	3.3±0.5	3.0±0.3	0.99
Interincisal Angle (U1-L1) (º)	130.6±1.9	130.2±1.2	1
IMPA (L1-MP) (º)	98.8±1.4	95.9±0.9	0.44
L1 Protrusion (L1-APo) (mm)	-0.09±0.4	0.4±0.3	0.92
L1 - NB (º)	23.1±1.4	23.9±0.9	1
L1 - NB (mm)	3.9±0.5	4.1±0.3	1
L1 to A-Po (mm)	-0.09±0.4	0.4±0.3	0.92
Overjet (mm)	5.9±0.5	5.7±0.3	1
Overbite (mm)	3.7±0.4	3.4±0.3	1
Mand Incisor Extrusion (mm)	1.8±0.2	1.7±0.1	1

Maxillary Incisor Position (mm)	91.3±7.4	84.9±2.9	0.4
Mandibular Incisor Position (mm)	84.8±6.7	78.7±2.8	0.4
Maxillary Molar Position (mm)	59.7±4.8	55.5±2.0	0.4
Mandibular Molar Position (mm)	58.8±4.7	54.5±2.1	0.4

Table 4-5. Difference Between Brachycephalic and Mesocephalic Prior to Xbow ™ Treatment (T1).

4.3.3 Difference Between Dolichocephalic and Mesocephalic Prior to Xbow™ Treatment (T1) (Table 4-6).

i) **Growth Pattern -** Both Y-axis and MPA showed a statistically significant difference between the dolichocephalic and mesocephalic groups ($p<0.05$), signifying two distinct facial patterns prior to Xbow™ treatment.

ii) **Skeletal Pattern –** ANB and Wits appraisal were not statistically different between the dolichocephalic and mesocephalic group ($p>0.05$), classifying both groups as having a Class II skeletal pattern. SNB was significantly different between the two groups with B point more retrusive in the dolichocephalic group.

iii) **Dental Variables –** When comparing the dolichocephalic group to the mesocephalic group, we find the facial pattern are similar enough not to influence the position of the incisors and molars, as they were not significantly different between the groups ($p>0.05$) prior to Xbow™ treatment. Unlike the comparison of the lower position to the brachycephalic facial pattern, when compared to the mesocephalic group the position of the lower incisor was not significantly different. Thus, the dental compensations for the dolichocephalic and mesocephalic groups are similar prior to Xbow™ treatment. Both the overjet and overbite were excessive in both groups. The overjet was significantly different ($p<0.05$) between the two groups prior to treatment being greater in the dolichocephalic group.

Variables	Group 2 (Dolicho)	Group 3 (Meso)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (º)	18.3±0.6	14.6±0.5	<0.0001
ANB (º)	5.8±0.4	5.1±0.3	0.65
SNA	79.4±0.6	81.1±0.4	0.2
SNB	73.7±0.5	76.5±0.4	0.0004
Y-Axis (SGn-SN) (º)	72.2±0.5	68.4±0.3	<0.0001
MP - SN (º)	38.0±0.5	31.9±0.4	<0.0001
Wits Appraisal (mm)	3.9±0.5	4.2±0.3	0.99
U1 - SN (º)	100.8±1.1	102.0±0.8	0.96
U1 - Palatal Plane (º)	108.4±1.1	107.9±0.8	1
U1 - NA (º)	21.3±1.2	20.8±0.9	1
U1 - NA (mm)	2.9±0.4	3.0±0.3	1
Interincisal Angle (U1-L1) (º)	128.7±1.6	130.2±1.2	0.98

IMPA (L1-MP) (º)	92.6±1.1	95.9±0.9	0.2
L1 Protrusion (L1-APo) (mm)	0.9±0.4	0.4±0.3	0.93
L1 - NB (º)	24.2±1.2	23.9±0.9	1
L1 - NB (mm)	4.8±0.4	4.1±0.3	0.88
L1 to A-Po (mm)	0.9±0.4	0.4±0.3	0.93
Lower Face Height (ANS-Xi-Pm)(º)	45.9±0.5	42.2±0.4	<0.0001
U6 - PT Vertical (mm)	2.8±0.04	2.9±0.03	0.05
Overjet (mm)	5.9±0.4	5.7±0.3	<0.0001
Overbite (mm)	2.2±0.3	3.4±0.3	0.07
SN-Palatal Plane (º)	7.5±0.5	5.9±0.4	0.11
Mand Incisor Extrusion (mm)	1.1±0.2	1.7±0.1	0.07
Maxillary Incisor Position (mm)	81.8±0.7	84.9±2.9	0.3
Mandibular Incisor Position (mm)	75.6±0.7	78.7±2.8	0.3
Maxillary Molar Position (mm)	52.9±0.7	55.5±2.0	0.2
Mandibular Molar Position (mm)	52.1±0.8	54.5±2.1	0.3
U6 - PP (UPDH) (mm)	3.0±0.03	3.0±0.02	0.97

Table 4-6. Difference Between Dolichocephalic and Mesocephalic Prior to Xbow ™ Treatment (T1).

4.4 Differences Between Groups Following Xbow ™ Treatment (T2).

4.4.1 Difference Between Brachycephalic and Dolichocephalic Following Xbow ™ Treatment (T2) (Table 4-7).

i) **Growth Pattern - **Both Y-axis and MPA were significantly between the brachycephalic and dolichocephalic groups ($p<0.05$) following Xbow™ treatment. Therefore, Xbow™ treatment did not change the pre-existing facial pattern.

ii) **Skeletal Pattern –** ANB was significantly different between the two groups following treatment. Although there was a reduction in Wits following treatment, Wits appraisal was not statistically different between the brachycephalic and dolichocephalic group ($p>0.05$) at T2.

iii) **Dental Variables –** The facial pattern did not influence the movements of the upper incisor and molars, as they were not significantly different between the groups ($p>0.05$) following Xbow™ treatment. The final angular position of the lower incisor to mandibular plane was significantly different between the two groups being more proclined in the brachycephalic group. As one would expect, both the overjet and overbite were reduced with treatment in both groups and were not significantly different ($p>0.05$) at T2.

Variables	Group 1 (Brachy)	Group 2 (Dolicho)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (º)	16.6±0.7	22.01±0.6	<0.0001
ANB (º)	3.5±0.4	5.6±0.4	0.0046

SNA	82.5±0.7	79.3±0.6	0.006
SNB	79±0.6	73.7±0.5	<0.0001
Y-Axis (SGn-SN) (º)	65.2±0.5	72.7±0.5	<0.0001
MP - SN (º)	25.4±0.6	38.4±0.5	<0.0001
Wits Appraisal (mm)	-0.6±0.5	1.5±0.5	0.08
U1 - SN (º)	104.3±1.3	99.4±1.1	0.08
U1 - Palatal Plane (º)	109.4±1.3	107.6±1.1	0.92
U1 - NA (º)	21.7±1.4	20.1±1.2	0.96
U1 - NA (mm)	3.3±0.5	2.1±0.4	0.32
Interincisal Angle (U1-L1) (º)	119.2±1.9	122.3±1.6	0.83
IMPA (L1-MP) (º)	111.1±1.4	99.9±1.1	<0.0001
L1 Protrusion (L1-APo) (mm)	3.7±0.4	3.0±0.4	0.83
L1 - NB (º)	35.6±1.4	31.9±1.2	0.35
L1 - NB (mm)	6.6±0.5	6.7±0.4	1
L1 to A-Po (mm)	3.7±0.4	3.0±0.4	0.83
Overjet (mm)	1.8±0.5	3.1±0.4	0.33
Overbite (mm)	0.2±0.4	0.2±0.3	1
Mand Incisor Extrusion (mm)	0.09±0.2	0.09±0.2	1
Maxillary Incisor Position (mm)	94.5±7.4	84.2±0.6	0.2
Mandibular Incisor Position (mm)	92.7±7.6	81.1±0.7	0.1
Maxillary Molar Position (mm)	60.2±4.8	53.5±0.5	0.2
Mandibular Molar Position (mm)	65.7±5.1	57.6±0.7	0.1

Table 4-7. Difference Between Brachycephalic and Dolichocephalic Following Xbow TM Treatment (T2).

4.4.2 Difference Between Brachycephalic and Mesocephalic Following Xbow TM Treatment (T2) (Table 4-8).

i) **Growth Pattern - ** Both Y-axis and MPA were significantly different between the brachycephalic and mesocephalic groups ($p<0.05$) following XbowTM treatment. Therefore, XbowTM treatment did not change the pre-existing facial pattern.

ii) **Skeletal Pattern –** ANB and Wits appraisal were not significantly different between the brachycephalic and mesocephalic group ($p>0.05$) at T2. SNB was significantly different between the two groups with B point being more protrusive in the brachycephalic group at T2.

iii) **Dental Variables –** The facial pattern between the two groups are similar enough not to have influenced the treatment induced movements of the incisors and molars, as they were not significantly different between the groups ($p>0.05$) at T2. Both the overjet and overbite were reduced in both groups and were not significantly different ($p>0.05$) following treatment.

Variables	Group 1 (Brachy)	Group 3 (Meso)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (º)	16.6±0.7	18.6±0.5	0.2

ANB (º)	3.5±0.4	4.7±0.3	0.21
SNA	82.5±0.7	81.2±0.4	0.6
SNB	79±0.6	76.5±0.4	0.01
Y-Axis (SGn-SN) (º)	65.2±0.5	68.5±0.3	<0.0001
MP - SN (º)	25.4±0.6	32.4±0.4	<0.0001
Wits Appraisal (mm)	-0.6±0.5	1.2±0.3	0.12
U1 - SN (º)	104.3±1.3	101.3±0.8	0.43
U1 - Palatal Plane (º)	109.4±1.3	107.7±0.8	0.89
U1 - NA (º)	21.7±1.4	20.2±0.9	0.94
U1 - NA (mm)	3.3±0.5	2.6±0.3	0.73
Interincisal Angle (U1-L1) (º)	119.2±1.9	119.9±1.2	1
IMPA (L1-MP) (º)	111.1±1.4	106.5±0.9	0.05
L1 Protrusion (L1-APo) (mm)	3.7±0.4	3.3±0.3	0.99
L1 - NB (º)	35.6±1.4	35.3±0.9	1
L1 - NB (mm)	6.6±0.5	6.8±0.3	1
L1 to A-Po (mm)	3.7±0.4	3.3±0.3	0.99
Overjet (mm)	1.8±0.5	2.1±0.3	0.99
Overbite (mm)	0.2±0.4	0.2±0.3	1
Mand Incisor Extrusion (mm)	0.09±0.2	0.07±0.1	1
Maxillary Incisor Position (mm)	94.5±7.4	87.4±2.9	0.4
Mandibular Incisor Position (mm)	92.7±7.6	85.2±2.7	0.4
Maxillary Molar Position (mm)	60.2±4.8	55.9±2.0	0.4
Mandibular Molar Position (mm)	65.7±5.1	60.8±1.9	0.4

Table 4-8. Difference Between Brachycephalic and Mesocephalic Following Xbow ™

Treatment (T2).

4.4.3 Difference Between Dolichocephalic and Mesocephalic Following Xbow ^{TM} Treatment (T2) (Table 4-9).

i) **Growth Pattern** - Both Y-axis and MPA were significantly different between the dolichocephalic and mesocephalic groups ($p<0.05$) at T2. Therefore, Xbow^{TM} did not change the pre-existing facial pattern with treatment.

ii) **Skeletal Pattern –** ANB and Wits appraisal were not statistically different between the dolichocephalic and mesocephalic group ($p>0.05$) at T2. SNB was significantly different between the two groups with B point more retrusive in the dolichocephalic group.

iii) **Dental Variables –** The facial patterns were similar enough not to influence the final position of the upper incisors and molars, as they were not significantly different between the groups ($p>0.05$) following Xbow^{TM} treatment. The final angular position of the lower incisor to mandibular plane was significantly different between the two groups being more proclined in the dolichocephalic group. As one would expect, both the overjet and overbite were reduced with treatment in both groups and were not significantly different ($p>0.05$) at T2.

Variables	Group 2 (Dolicho)	Group 3 (Meso)	p-value
	Mean±SE	Mean±SE	
Occ Plane to SN (°)	22.01±0.6	18.6±0.5	0.0002

ANB (º)	5.6±0.4	4.7±0.3	0.34
SNA	79.3±0.6	81.2±0.4	0.1
SNB	73.7±0.5	76.5±0.4	0.0007
Y-Axis (SGn-SN) (º)	72.7±0.5	68.5±0.3	<0.0001
MP - SN (º)	38.4±0.5	32.4±0.4	<0.0001
Wits Appraisal (mm)	1.5±0.5	1.2±0.3	1
U1 - SN (º)	99.4±1.1	101.3±0.8	0.78
U1 - Palatal Plane (º)	107.6±1.1	107.7±0.8	1
U1 - NA (º)	20.1±1.2	20.2±0.9	1
U1 - NA (mm)	2.1±0.4	2.6±0.3	0.92
Interincisal Angle (U1-L1) (º)	122.3±1.6	119.9±1.2	0.84
IMPA (L1-MP) (º)	99.9±1.1	106.5±0.9	0.0001
L1 Protrusion (L1-APo) (mm)	3.0±0.4	3.3±0.4	0.98
L1 - NB (º)	31.9±1.2	35.3±0.9	0.21
L1 - NB (mm)	26.7±0.4	6.8±0.3	1
L1 to A-Po (mm)	3.0±0.4	3.3±0.3	0.98
Overjet (mm)	3.1±0.4	2.1±0.3	0.48
Overbite (mm)	0.2±0.3	0.2±0.3	1
Mand Incisor Extrusion (mm)	0.09±0.2	0.07±0.1	1
Maxillary Incisor Position (mm)	84.2±0.6	87.4±2.9	0.9
Mandibular Incisor Position (mm)	81.1±0.7	85.2±2.7	0.1
Maxillary Molar Position (mm)	53.5±0.5	55.9±2.0	0.2
Mandibular Molar Position (mm)	57.6±0.7	60.8±1.9	0.1

Table 4-9. Difference Between Dolichocephalic and Mesocephalic Following Xbow ™

Treatment (T2).

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

4.5.1 Difference Between Initial and Final Treatment for Brachycephalic Group (n=27) (T2-T1) (Table 4-10).

i) **Growth Pattern - ** Both Y-axis and MPA were not significantly different before and after treatment ($p>0.05$), suggesting the appliance does not influence the original facial pattern in the brachycephalic group.

ii) **Skeletal Pattern –** ANB was significantly reduced by an average of 1.2±0.3 degrees with Xbow™ treatment. Wits appraisal was also statistically different ($p<0.05$) following treatment, with a mean reduction of 4.2±0.6 mm.

iii) **Dental Variables –** Overall within the brachycephalic group, the dental movements of the Xbow™ appliance were in favor of Class II Dentoalveolar correction. Angular changes of the upper incisor were not significant ($p>0.05$). Retrusion of the upper incisor was significant at an average distance of 3.1±0.6mm (Pancherz analysis). Movement of the lower incisor was significant ($p<0.05$) with increased mean proclination to MP (12.3 ± 1.3^{o}) and NB (12.5 ± 1.3^{o}) and an increased mean protrusion to APog (3.8+0.4mm), NB (2.8+0.4mm) and Pancherz analysis (7.8±1.1mm). The lower incisor did extrude significantly 1.7±0.2 mm. Pancherz analysis did reveal an insignificant amount of distalization of the maxillary molar (0.5±0.4mm) and significant amount of protraction of the mandibular molar (6.9±0.9mm) at $p<0.05$. Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Variables	Group 1 T1/T2	p-value
	Mean±SE	
Occ Plane to SN (º)	4.5±0.6	<0.0001
ANB (º)	-1.2±0.3	0.0011
SNA (º)	-1.1±0.4	0.1
SNB (º)	0.03±0.6	1
MP - SN (º)	0.2±0.4	1
Wits Appraisal (mm)	-4.2±0.6	<0.0001
U1 - SN (º)	-1.1±1.1	0.9
U1 - Palatal Plane (º)	-0.5±1.1	1
U1 - NA (º)	0.01±1.1	1
U1 - NA (mm)	-0.01±0.4	1
Interincisal Angle (U1-L1) (º)	-11.3±1.6	<0.0001
IMPA (L1-MP) (º)	12.3±1.3	<0.0001
L1 Protrusion (L1-APo) (mm)	3.8±0.4	<0.0001
L1 - NB (º)	12.5±1.3	<0.0001
L1 - NB (mm)	2.8±0.4	<0.0001
L1 to A-Po (mm)	3.8±04	<0.0001

Y-axis (º)	0.5±0.3	0.4
Overjet (mm)	-4.2±0.5	<0.0001
Overbite (mm)	-3.5±0.4	<0.0001
Mand Incisor Extrusion (mm)	-1.7±0.2	<0.0001
Maxillary Incisor Position (mm)	-3.1±0.6	<0.0001
Mandibular Incisor Position (mm)	7.8±1.1	<0.0001
Maxillary Molar Position (mm)	-0.5±0.4	0.2
Mandibular Molar Position (mm)	6.9±0.9	<0.0001

Table 4-10. Difference Between Initial and Final Treatment for the Brachycephalic Group (n=27) (T2-T1).

4.5.2 Difference Between Initial and Final Treatment for Dolichocephalic Group (n=27) (T2-T1) (Table 4-11).

i) **Growth Pattern - ** Both Y-axis and MPA were not statistically significant different before and after treatment ($p>0.05$), suggesting the appliance does not influence the original facial pattern in the dolichocephalic group.

ii) **Skeletal Pattern –** ANB was not significantly changed with Xbow™ treatment. Wits appraisal was statistically different ($p<0.05$) following treatment, with a mean reduction of 2.4+0.5 mm.

iii) **Dental Variables –** Overall within the dolichocephalic group, the dental movements of the Xbow™ appliance were in favor of Class II Dentoalveolar correction. Angular changes of the upper incisor were not significant ($p>0.05$). Retrusion of the upper incisor was significant at an average distance of 2.4±0.4mm (Pancherz analysis). Movement of the lower incisor was significant ($p<0.05$) with increased mean proclination to MP (7.3±1.1°) and NB (7.7±1.1°) and an increased mean protrusion to APog (2.1±0.3mm), NB (2.0+0.4mm) and Pancherz analysis (5.5±0.6mm). The lower incisor did extrude significantly 1.0±0.2 mm. Pancherz analysis did reveal an insignificant amount of distalization of the maxillary molar (0.7±0.4mm) and significant amount of protraction of the mandibular molar (5.5±0.6mm) at $p<0.05$. Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Variables	Group 2 T1/T2	p-value
	Mean±SE	
Occ Plane to SN (°)	-3.72±0.5	<0.0001
ANB (°)	0.2±0.2	1
SNA (°)	0.2±0.4	1
SNB (°)	0.01±0.5	1
MP - SN (°)	-0.4±0.3	0.7
Wits Appraisal (mm)	2.4±0.5	<0.0001
U1 - SN (°)	1.3±1.0	0.7
U1 - Palatal Plane (°)	0.8±1.0	1
U1 - NA (°)	1.2±0.9	0.8

U1 - NA (mm)	0.8±0.3	0.1
Interincisal Angle (U1-L1) (º)	6.4±1.4	0.0001
IMPA (L1-MP) (º)	-7.3±1.1	<0.0001
L1 Protrusion (L1-APo) (mm)	-2.1±0.3	<0.0001
L1 - NB (º)	-7.7±1.1	<0.0001
L1 - NB (mm)	-2.0±0.4	<0.0001
L1 to A-Po (mm)	-2.1±0.3	<0.0001
Y-axis (º)	-0.5±0.2	0.4
Overjet (mm)	2.9±0.4	<0.0001
Overbite (mm)	2.0±0.4	<0.0001
Mand Incisor Extrusion (mm)	1.0±0.2	<0.0001
Maxillary Incisor Position (mm)	2.4±0.4	<0.0001
Mandibular Incisor Position (mm)	-5.5±0.6	<0.0001
Maxillary Molar Position (mm)	0.7±0.4	0.1
Mandibular Molar Position (mm)	-5.5±0.6	<0.0001

Table 4-11. Difference Between Initial and Final Treatment for the Dolichocephalic Group (n=37) (T2-T1).

4.5.3 Difference Between Initial and Final Treatment for the Mesocephalic Group (n=70) (T2-T1) (Table 4-12).

i) **Growth Pattern** **-** Both Y-axis and MPA were not statistically significant different before and after treatment ($p>0.05$), suggesting the appliance does not influence the original facial pattern in the mesocephalic group.

ii) Skeletal Pattern – ANB was not significantly changed with Xbow™ treatment. Wits appraisal was statistically different ($p<0.05$) following treatment with a mean reduction of 3.1+1.3 mm.

iii) **Dental Variables –** Overall within the mesocephalic group, the dental movements of the Xbow™ appliance were in favor of Class II Dentoalveolar correction. Angular changes of the upper incisor were not significant ($p>0.05$). Retrusion of the upper incisor was significant at an average distance of 2.5 ± 0.3mm (Pancherz analysis). Movement of the lower incisor was significant ($p<0.05$) with increased mean proclination to MP (10.6 ± 0.8^o) and NB (11.4 ± 0.8^o) and an increased mean protrusion to APog (2.9+0.2mm), NB (2.7+0.3mm) and Pancherz analysis (6.6 ± 0.5mm). The lower incisor did extrude significantly 1.6 ± 0.1 mm. Pancherz analysis did reveal an insignificant amount of distalization of the maxillary molar (0.4 ± 0.3mm) and significant amount of protraction of the mandibular molar (6.3 ± 0.5mm) at $p<0.05$. It is important to note that although the movements of the incisors and molars were in a similar direction as in the brachycephalic and dolichocephalic groups, the dental movements were intermediate in magnitude. Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Variables	Group 3 T1/T2	p-value
	Mean±SE	
Occ Plane to SN (º)	-4.0±0.4	<0.0001
ANB (º)	0.4±0.2	0.3
SNA (º)	0.06±0.3	1
SNB (º)	0.1±0.4	1
MP - SN (º)	0.4±0.2	0.4
Wits Appraisal (mm)	3.1±0.3	<0.0001
U1 - SN (º)	0.7±0.7	0.9
U1 - Palatal Plane (º)	0.2±0.7	1
U1 - NA (º)	0.6±0.7	0.9
U1 - NA (mm)	0.4±0.2	1
Interincisal Angle (U1-L1) (º)	10.4±1.0	<0.0001
IMPA (L1-MP) (º)	-10.6±0.8	<0.0001
L1 Protrusion (L1-APo) (mm)	-2.9±0.2	<0.0001
L1 - NB (º)	-11.4±0.8	<0.0001
L1 - NB (mm)	-2.7±0.3	<0.0001
L1 to A-Po (mm)	-2.9±0.2	<0.0001
Y-axis (º)	-0.1±0.2	1
Overbite (mm)	3.2±0.3	<0.0001

Mand Incisor Extrusion (mm)	1.6±0.1	<0.0001
Maxillary Incisor Position (mm)	2.5±0.3	<0.0001
Mandibular Incisor Position (mm)	-6.6±0.5	<0.0001
Maxillary Molar Position (mm)	0.4±0.3	0.2
Mandibular Molar Position (mm)	-6.3±0.5	<0.0001

Table 4-12. Difference Between Initial and Final Treatment for the Mesocephalic Group (n=70) (T2-T1) .

Figure 4-1. A summary of the overall skeletal and dental movements of the Xbow^{TM} appliance can be seen in Figure 4-1..

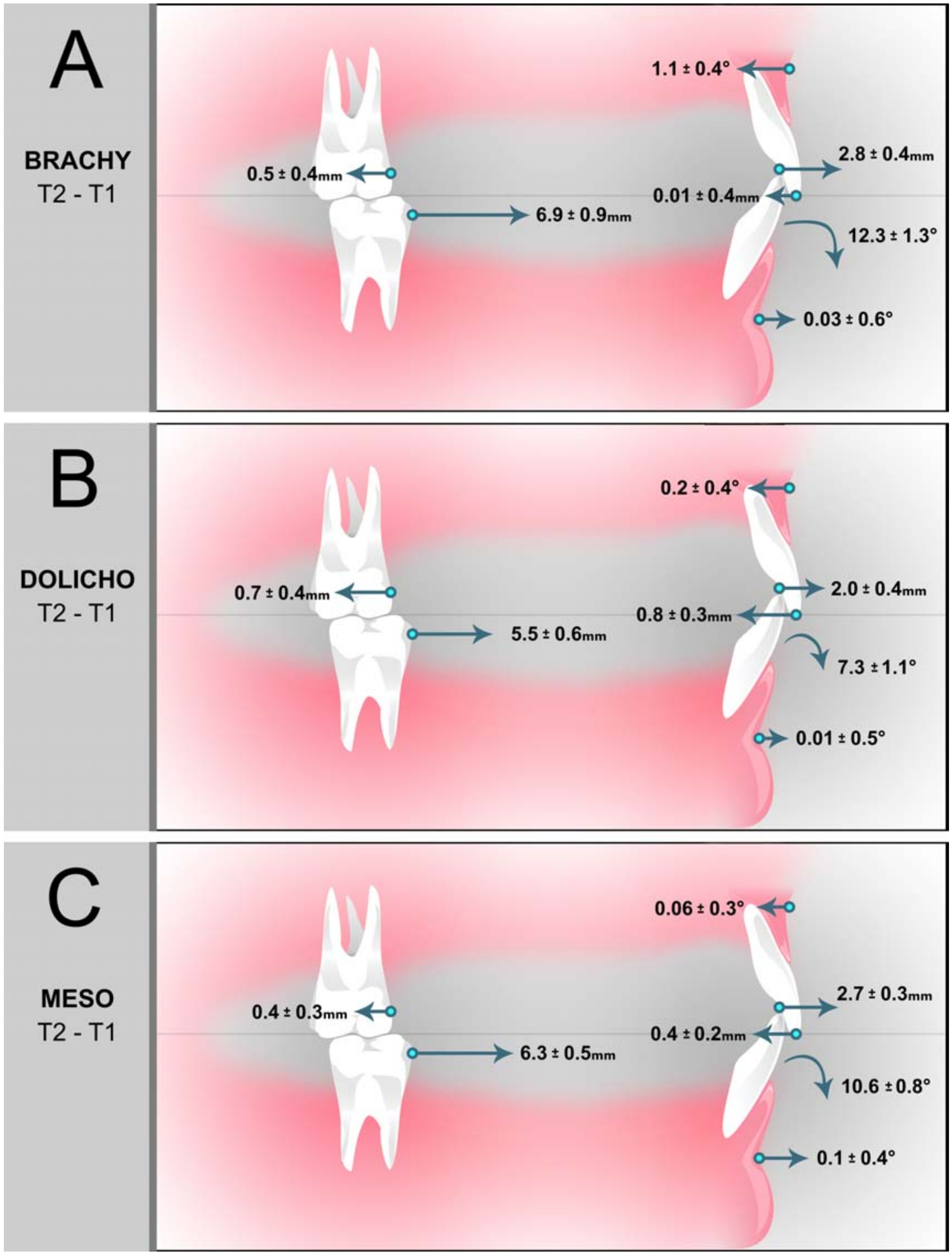

Figure 4-1. Summary of the overall skeletal/dental movements of the Xbow TM appliance.

Chapter 5

Discussion

There is no doubt that fixed Class II correctors have a place in orthodontics. Various inter-arch appliances have been used recently to minimize the need for patient compliance, effectively reducing treatment time (Rothenberg et al., 2004). What remains somewhat controversial is the amount of skeletal and dental changes these appliances induce, to accomplish the correction of a Class II malocclusion.

Fixed class II correctors (Jasper Jumper™ and Eureka Spring ™) with similar mechanisms of action to the Xbow™, have been shown to induce primarily orthodontic changes equally in both dental arches (Cope et al., 1994; Nalbantigil et al., 2005). It is important to understand how these appliances influence the jaws and move the dentition when treatment planning a Class II malocclusion due to either maxillary protrusion or mandibular retrusion. Previous studies on the Xbow™ appliance have shown a significant reduction in SNA (-1.3^{o} statistically significant $p<0.05$), representing a headgear effect on the maxilla as seen with the Herbst appliance (Konik et al., 1997; Rothenberg et al., 2004; Flores Mir et al., 2009). The main difference with the Herbst appliance over the Xbow™ and Jasper Jumper™ is its ability to distract the condyle from the glenoid fossa, theoretically influencing growth of the mandible. Studies on the Herbst appliance have shown Class II molar correction averaging 6.1mm, which was due to 37% skeletal and 63% dental changes (Konik et al., 1997).

If influencing growth to achieve the treatment objectives is desired, remaining growth and treatment timing must be considered. Malmgren et al., 1987, have found that for optimal results, functional appliances should be utilized during or just after the peak growth period. Pancherz and Hagg (1988) have shown that skeletal improvement with the Herbst appliance was related to somatic maturation. Future studies of the skeletal impact of Class II correctors such as the Xbow™ and Jasper Jumper™ on growing vs. non-growing patients are required to determine the true impact they have on the underlying skeletal pattern, if any at all.

The other important factors to consider are the magnitude and directions of the dental movements induced by the different types of correctors in order to effectively treatment plan and accomplish the treatment goals. Several studies have shown that the dental Class II correction can be accomplished with upper molar distalization, lower molar protrusion and lower incisor proclination (Konik et al., 1997; Rothenberg et al., 2004). Given the different designs between the Jasper Jumper™ and Xbow™ appliance, one may expect different tooth movements and/or orthopedic changes to satisfy specific treatment goals for a particular patient.

The original prospective study on the short-term effects of the Xbow™ appliance showed statistically significant differences for 9 of the 14 skeletal and dental cephalometric variables evaluated (Flores-Mir et al., 2009). Skeletally, there was a reduction in SNA and ANB (Flores-Mir et al., 2009). Dentally, there was a significant change in L1-MP, L1 minus Pg, overjet, U6 minus A, L6 minus Pg, and A-OLp in favor of the Class II correction (Flores-Mir et al., 2009). Based on these changes noted by Flores-Mir et al., it was concluded that Class II correction with the use of the Xbow™ appliance was accomplished via a combination of mainly dental and some skeletal changes (Table 7.1). Skeletal changes included diminution of maxillary protrusion, an increase in the vertical dimension and no influence on mandibular advancement. Dentally, Class II correction was accomplished by an increase in mandibular incisor protrusion, distalization of the maxillary molars, mesialization of the mandibular molars and an insignificant amount of movement of the maxillary incisors (Flores-Mir et al., 2009).

The findings of Flores-Mir et al. in 2009, are consistent with that of this study other than an insignificant skeletal change of the maxilla represented by a minimal change in SNA and an insignificant movement of the upper molar (Table 7.1). This study found Class II Correction with the Xbow™ appliance is the result of mesial movement of the mandibular molar, proclination and protrusion of the lower incisor, retrusion of the upper incisor, and a reduction of the Class II skeletal relationship represented by a reduction of the Wits value (Table 5-1). A comparison of the findings of studies on the Herbst, Xbow™ and the present study are shown in Table 5-1.

Variables	Pancherz, 1982	Flores-Mir et al., 2009	Present study
Sample size	22	67	134
Mean Treatment time	6 months	4.5 months	4.3 months
SNA(^{o})		-1.0*	-0.45
SNB(^{o})		-0.3*	-0.03
ANB(^{o})		-0.8*	-0.6
Wits			-3.2*
U1-NA (^{o})		-1.8	-0.6
U1-NA (mm)			-0.4
L1-MPA (^{o})		3.8*	10.1*
L1–NB(^{o})			10.5*
L1-NB (mm)			2.5*
L1-OL perp (mm)	1.8*	1.2*	6.6*
L6-OL perp (mm)	1.0*	0.6*	0.5
U1-OL perp (mm)	-0.5	-0.5	-2.7*
U6-OL perp (mm)	-2.8*	-2.0*	6.2*
Overjet (mm)	-5.5*	-2.4*	-3.5*

Table 5-1. Comparison of the findings between studies on the Herbst, Xbow^{TM} and the present study. (*) Indicates a significant difference ($p<0.05$) relative to the control group used in each study.

The skeletal influence of spring-based appliances that do not distract the condyle from the glenoid fossa is controversial (Cope et al., 1994; Flores Mir et al., 2009). One would not expect accelerated mandibular growth with spring-based appliances that do not posture the mandible forward. However, the results of this study do show a significant reduction of the Wits value in all three groups, which represents a reduction in the skeletal Class II relationship of the maxilla with the mandible. The amount of skeletal correction with the Xbow™ must be taken with a grain of salt considering the inverse relationship of Wits to changes in the occlusal plane angle (Nalbantigil, 1994). There was a significant increase in occlusal plane to SN for each group, which possibly contributed to the reduction in Wits with minimal actual skeletal change. Another source of error is the influence of bone remodeling and orthodontic tooth movement on A and B point. Studies have shown that the position of points A and B should account for growth as well as treatment when attempting to evaluate the true efficacy of orthodontic appliances on the skeletal bases (Abdwani et al., 2009). Unless all of these factors are considered, the validity of the studies using points A and B as stable skeletal reference points may be questionable, and this may affect the accuracy of the results (Abdwani et al., 2009). Overall, it is important to remember that no single parameter in Cephalometrics should be relied on entirely and interpreted as an absolute value (Jacobson, 1988).

Characteristic facial features of strong facial muscles are associated with short brachycephalic facial types. Conversely, weak facial musculature is characteristic of long dolichocephalic facial types (Ricketts et al., 1979). Ricketts stressed the need to modify treatment procedures to respect individuals that have either stronger or weaker musculature to counter act the effects of orthodontic forces (Ricketts et al., 1979). The facial musculature pattern influences the underlying dental compensations that exist to counteract vertical growth deviations (Janson et al., 1994; Enoki et al., 2004; Kuitert et al., 2006; Flores-Mir et al., 2010). For example, dental compensations for vertical facial type tend to include more upright lower incisors as a compensatory mechanism to maintain adequate overbite and overjet (Flores-Mir et al., 2010). Given that fact that different dental compensations exist for varying facial patterns, it is important to investigate the potential difference in skeletal and dental movements considering facial type.

One downside to the previous studies on fixed Class II correctors such as the Jasper Jumper™ and Herbst appliance is that they did not investigate the skeletal and dental changes related to vertical facial height. Unlike the study by Flores-Mir et al. in 2009, the present study separated the sample into different facial types and found the growth pattern appears to be unrelated to the amount of dental movement observed following Xbow™ treatment. The importance of this finding is that a clinician can expect similar dental movements in the correction of a Class II malocclusion regardless of the patient's pre-existing facial pattern.

An interesting finding of this study, consistent with Flores-Mir et al. study on the Xbow™ appliance in 2010, was the tendency for pronounced dental movements of the lower incisor in brachycephalic patients. We know that dental compensations exist to counteract skeletal discrepancies in all three planes of space. For example, the pre-treatment angular position of the lower incisor was significantly different between the brachycephalic and dolichocephalic groups, which are likely a natural compensation to maintain an acceptable overbite and overjet. The lower incisors were more proclined in the brachycephalic group but upright and protruded in the dolichocephalic group (Table 5-2).

Variables	Brachycephalic	Dolichocephalic	p value
IMPA (L1-MP) (º)	98.8±1.4	92.6±1.1	<0.0001
L1 Protrusion (L1-Apo) (mm)	-0.09±0.4	0.9±0.4	<0.0001

Table 5-2. Difference between brachycephalic and dolichocephalic prior to Xbow^{TM} treatment

Another important factor to consider when comparing the results of the present study to previous studies on the Xbow^{TM} is consideration of the treatment protocol during the clinical use of the appliance. Previous studies on the Xbow^{TM} appliance carried out expansion following Class II correction only if necessary. In the present study, expansion was carried out prior to AP correction. In 1993 McNamara stressed the importance of considering the transverse plane prior to diagnosing a Class II malocclusion because widening the maxilla led to a spontaneous forward posturing of the mandible. Some authors believe the expansion may cause a 'spontaneous' correction or improvement of a Class II malocclusion by removing occlusal interferences and allowing the mandible to move forward (Cozza et al., 2001). Farronatoa et al. in 2011 found that following maxillary expansion in Class II patients; the maxilla moved forward, but not to a statistically significant degree, while the mandible moved forward in all of the patients to a statistically significant degree. The ANB also decreased, statistically improving the skeletal relationship.

There is sufficient literature to validate the relationship between the improvement in transverse palatal expansion and the correction of the sagittal inter-maxillary relationship. The best analogy of this relationship is the example of a foot in a shoe, which respectively represents the mandible and the maxilla. If the shoe is too small, the foot will not slide fully into the shoe. A wider shoe will allow the foot to slide forward into a comfortable position (Farronatoa et al., 2011). Taking into consideration this phenomenon occurs, we can attribute some of the differences observed in the present study because expansion of the maxilla was done prior to AP correction, which could have influenced the magnitude and the direction of tooth movement.

An insignificant amount of distalization of the upper molar was also observed which was inconsistent with the findings of previous Xbow™ studies. The minimal upper molar movement may have been due to expansion of molars into the cortical bone increasing anchorage prior to AP correction. Ricketts first introduced the theory of cortical bone anchorage in 2008. The contention being that the cortical bone is denser with decreased blood supply and bone remodeling (Ricketts et al., 2008). Hence, teeth moved close to the cortical bone would have greater anchorage potential. Previous studies on the Xbow™ appliance expanded the molars following AP correction minimizing the amount of cortical bone anchorage, which may account for the significant upper molar distalization observed in their studies.

Although the actual treatment time, including passive retention was of short duration, (7.33 months at T2 radiograph) growth was still taken into consideration. Bolton growth prediction algorithms where used to quantify the amount of growth that may have occurred between the initial and final radiograph. The only value that was significantly significant ($p<0.05$) on the growth algorithm was the inclination of the upper incisor to NA (Nasion-A point). The disadvantage of historical growth studies are that the radiographs are usually taken over a 2 to 3 year period, which would not match the treatment time of the sample in this study. The disadvantage of growth algorithms are the fact that only one study by Sagun, 2012 can verify the accuracy of this method of growth prediction to a mean difference of 1.5mm. As this technology continues to improve and more studies confirm the accuracy of this method of growth quantification, it could serve as a valuable control for future studies.

Chapter 6

Conclusions

1) Based on the results of this study, we accept the null hypothesis and conclude that the pre-existing facial pattern is unrelated to the amount of skeletal and dental movements observed following Xbow^{TM} treatment. Therefore, clinicians can expect similar dental movements in the correction of a Class II malocclusion regardless of the patient's pre-existing facial pattern.

2) Correction of a Class II malocclusion with the Xbow^{TM} appliance is the result of:

- mesial movement of the mandibular molar
- proclination and protrusion of the lower incisor
- retrusion of the upper incisor
- Reduction of the Class II skeletal relationship represented by a reduction of the Wits value.

3) There was a tendency for pronounced dental movements of the lower incisor in brachycephalic subjects.

4) Prior correction of the transverse dimension causes different skeletal outcomes than those reported in the literature where expansion is done during or after Xbow^{TM} treatment. Cortical bone anchorage may play a role in this observation.

6.1 Recommendations

1) Investigation of the possible relationships between pre-existing conditions and final treatment outcomes are important to identify patients that might be at risk for undesirable tooth movements.
2) Further investigation of the impact of expansion prior to AP correction on magnitude and direction of tooth movement is required to appreciate the desired treatment outcomes.
3) Future studies on fixed Class II correctors should focus on the skeletal effects of these appliances in growing individuals.
4) Orthodontists should consider these appliance induced effects when planning the final position of the lower incisor and thus deciding on an appropriate retention protocol following Xbow^{TM} treatment.

Chapter 7

References

Abdwani RA, Moles D, Noar JH. Change of Incisor Inclination Effects on Points A and B. Angle Orthod. 2009;79:462–467.

Aziz T, Nassar U, Flores-Mir C. Prediction of lower incisor proclination during XbowTM treatment based on initial cephalometric variables. Angle Orthod. 2012; 82(3):472-9.

Baumrind S. Korn EL, West EE. Prediction of mandibular rotation; An empirical test of clinical performance. Am J Orthod 1984; 371-385.

Bishara SE, Augspurger EF. The role of mandibular plane angulation in orthodontic diagnosis. Angle Orthod 1975; 45:273-281.

Bjork A, Skieller V. Facial development and tooth eruption. An implant study at the age of puberty. Am J Orthod 1972; 52:339-338.

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

Buschang PH, Sankey W, English JD. Early treatment of hyperdivergent openbite malocclusions. Seminars in Orthodontics 2002;8(3): 130-140.

Chaukse, Ankur, Sandhya Jain, M. S. Rami Reddy, Rachma Dubey, Shan Mummen John, and Suma S. Treatment of Skeletal Class II Malocclusion Using the “Forsus” Appliance: A Case Report. People’s Journal of Scientific Research 4. 1 (2011): 39-42.

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.

Cozza P, Giancotti A, Petrosino A. Rapid palatal expansion in mixed dentition using a modified expander: a cephalometric investigation. J Orthod. 2001;28:129–134.

Enoki C, Telles Cde S, Matsumoto MA. Dental-skeletal dimensions in growing individuals with variations in the lower facial height. Braz Dent J. 2004;15:68–74.

Farronatoa G, Gianninib L, Galbiatic G, Masperod C. Sagittal and vertical effects of rapid maxillary expansion in Class I, II, and III occlusions. Angle Orthod. 2011;81:298–303.

Flores-Mir C, Barnett G, Higgins DW, Heo G, Major. PW. Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms. American Journal of Orthodontics and Dentofacial Orthopedics 136. 6 (2009): 822-832.

Flores-Mir C, Young A, Greiss A, Woynorowski M, Peng J. Lower incisor inclination changes during Xbow treatment according to the vertical facial type. Angle Orthodontist 80. 6 (2010): 1075-1080.

Flores-Mir C, Aziz T, Nassar U. Prediction of lower incisor proclination during Xbow treatment based on initial cephalometric variables. Angle Orthod. 2012 May; 82(3):472-9.

Gossett CB, Preston CB, Dunford R, Lampasso J. Prediction accuracy of computer-assisted surgical visual treatment objectives as compared with conventional visual treatment objectives. J Oral Maxillofac Surg 2005;63:609–617.

Graber, W. Lee, Robert L. Vanarsdall, and Katherine W. L. Wig. Orthodontics: Current Principles and Techniques. Philadelphia, PA: Elsevier. 2012.

Graber TM, Vanarsdall RL, Vig KW. Orthodontics: Current Principles & Techniques. Fourth Edition. Elsevier Inc. St. Louis, Missouri 2005.

Gruenbaum, Tamar. Famous Figures in Dentistry Mouth - JASDA 2010;30(1):18.

Hagg, U. and Pancherz, H.: Dentofacial orthopaedics in rela-tion to chronological age, growth period and skeletal develop-ment: An analysis of 72 male patients with Class II division I malocclusion treated with the Herbst appliance, Eur. J. Orthod.10:169-176, 1988.

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

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.

Jacobson A. Update of the Wits Appraisal. Angle Orthod. 1988;205-219.

Janson GR, Metaxas A, Woodside DG. Variation in maxillary and mandibular molar and incisor vertical dimension in 12-year-old subjects with excess, normal, and short lower anterior face height. Am J Orthod Dentofacial Orthop. 1994;106:409–418.

Kim YE, Nanda RS, Sinha PK. Transition of molar relationships in different skeletal growth patterns. Am J Orthod Dentofacial Orthop 2002;121:280-290.

Konik M, Pancherz H, Hansen K. The mechanism of Class II correction in late Herbst treatement. Am J Orthod Dentofacial Orthop. 1997 Jul;112(1):87-91.

Kuitert R, Beckmann S, van Loenen M, Tuinzing B, Zentner A. Dentoalveolar compensation in subjects with vertical skeletal dysplasia. Am J Orthod Dentofacial Orthop. 2006; 129:649–657.

Malmgren, O.; Omblus, J.; Hagg, U.; and Pancherz, H.: Treat-ment with an orthopedic appliance system in relation to treat-ment intensity and growth periods: A study of initial effects, Am. J. Orthod. 91:143-151, 1987.

McNamara, A. James. Components of Class II Malocclusion in Children 8-10 Years of Age. The Angle Orthodontist 51. 3 (1981): 177-200.

McNamara JA Jr. Orthodontic and Orthopedic Treatment in the Mixed Dentition. Ann Arbor, MI: Needham Press Inc; 1993.

McSherry, P. F., and H. Bradley. Class II Correction-Reducing Patient

Compliance: a Review of the Available Techniques. Journal of Orthodontics 27 (2000): 219-225.

Nalbantgil D, Arun T, Sayinsu K, Fulya I. Skeletal, dental and soft-tissue changes induced by the Jasper jumper appliance in late adolescence. Angle Orthod 2005;75:426-36.

Nanci A. Ten Cate's Oral histology, 8th Edition. Development, Structure and Function. Mosby, 2012.

Nanda SK. Growth patterns in subjects with long and short faces. Am J Orthod Dentofacial Orthop 1990;98:247-258.

Nimkarn Y, Miles PG. Reliability of computer-generated cephalometrics. Int J Adult Orthodon Orthognath Surg 1995;10:43–52. Opdebeeck H, Bell WH. The short face syndrome. Am J Orthod 1978;73:499-511.

Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D. Comparative study between the SFS and LFS rotation as a possible morphologic mechanism. Am J Orthod 1978;74:509-521.

Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. Am J Orthod 1982;82:104-13.

Pancherz, H. and Hagg, U.: Dentofacial orthopedics in relation to somatic maturation: An analysis of 70 consecutive cases treated with the Herbst appliance, Am. J. Orthod. 88:273-297,1985.

Papadopoulos, A. Moschos. Orthodontic Treatment of the Class II Noncompliant

Patient. Maryland Heights, MO: Mosby. 2006.

Papel I. Facial plastic and reconstructive surgery. Germany: Thieme. 2009.

Phulari BS. Orthodontics: Principles and Practice. New Delhi, India: JP Medical Ltd. 2011.

Polat-Ozsoy O, Gokcelik A, Toygar Memikoglu TU. Differences in cephalometric measurements: a comparison of digital versus hand-tracing methods. Eur J Orthod 2009;31:254–259.

Premkumar S. Textbook of craniofacial growth. JP Medical Ltd. 2011.

Proffit, R. William, Henry W. Fields, and David M. Sarver. Contemporary Orthodontics. 5th ed. St. Louis, MO: Elsevier. 2012.

Rakosi T, Jonas I, Graber T. Orthodontic Diagnosis. Germany: Thieme. 1993.

Ricketts, RM, Bench RW, Gugino CF, Hilgers JJ, Schulhof RJ. Bioprogressive Therapy. Rocky Mountain Orthodontics. Michigan. Jul. 2008;1-327.

Rothenberg J, Campbell ES, Nanda R. Class II correction with the Twin Force Bite Corrector. J Clinc Orthod. 2004 Apr;38(4):333-340, 2004.

Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. BMJ. 1996. 312 (7023): 71–2.

Sagun M. Assessment of computerized cephalometric growth prediction: A comparison of three methods. University of Illinois. 2012.

Sandler PJ. Reproducibility of cephalometric measurements. Br J Orthod 1988;15:105–110.

Sassouni V. A classification of skeletal facial types. Am J Orthod 1969;55: 109-123.

Wu JY, Hägg U, Pancherz H, Wong RW, McGrath C. Sagittal and vertical occlusal cephalometric analyses of Pancherz: Norms for Chinese children. Am J Orthod Dentofacial Orthop. 2010 Jun;137(6):816-24.

Chapter 8

Appendix

8.1 Abstract and article……………………….……………………..……….106

8.2 Ethics approval and renewal (See Attached Document)………………..121

8.3 Manuscript submission (See Attached Document)…………...….………..124

8.1 Abstract and Article

Cephalometric evaluation of dental Class II correction using the Xbow® appliance in different facial patterns

Randeep S Chana[a]; Tim D Dumore[b]; Stephen Ahing[c]; Frank J Hechter[d];William A Wiltshire[e]

[a] Graduate Student, Division of Orthodontics, University of Manitoba, Winnipeg, Manitoba, Canada.

[b] Assistant Professor, Part-time, Division of orthodontics, University of Manitoba, Winnipeg, Manitoba, Canada

[c] Associate Professor and Chair, Division of Oral Diagnosis and Radiology, University of Manitoba,Winnipeg, Manitoba, Canada.

[d] Professor, Part-time, Division of orthodontics, University of Manitoba, Winnipeg, Manitoba, Canada.

[e] Professor and Chair, Division of Orthodontics, University of Manitoba, Winnipeg, Manitoba, Canada.

Corresponding author: Dr Randeep Chana. Department of Preventive Dental Science, Graduate Orthodontics Program Faculty of Dentistry, 780 Bannatyne Avenue, University of Manitoba, Winnipeg, MB R3T 2N2 Canada.
(e-mail: umchanar@cc.umanitoba.ca)

ABSTRACT

Objective: To determine the magnitude of the skeletal and dental movements in subjects with different facial patterns following Class II correction using the Xbow™ appliance.

Materials and Methods: A retrospective sample of 134 subjects exhibiting Class II malocclusions was used. Subjects were categorized into three growth types according to pre-treatment cephalometric variables (MPA and Y-axis), which yielded 27 brachycephalic, 70 mesocephalic, and 37 dolichocephalic subjects. A *ANOVA* test statistic was used to investigate the differences between the three facial groups at pre and post-treatment time points.

Results: Dental changes induced by the Xbow^{TM} appliance included: proclination of the lower incisors (L1-MP 7.3-12.3^{o}±1.0^{o}), protrusion of the lower incisors (L1-APo 2.1-3.8mm±0.3mm), mesial movement of the mandibular first molar (5.5-6.9mm±0.7mm) and retrusion of the maxillary incisor (2.4-3.1mm±0.4mm). Retroclination of the maxillary incisor (U1-PP 0.2-0.8^{o}±0.7^{o}) and distal movement of the maxillary molar (0.4-0.7mm±0.3mm) were not significantly influenced by Xbow^{TM} treatment. Reduction of the skeletal Class II relationship was represented by a significant decrease of the Wits value (2.4-4.5mm±0.5mm) in all three groups. The *p* value was considered significant at $\alpha<0.05$.

Conclusions: Class II correction with the Xbow^{TM} appliance is the result of mesial movement of the mandibular molar, proclination/protrusion of the lower incisor and retrusion of the upper incisor. Skeletal correction must be validated by more than one cephalometric variable. Facial growth pattern appears to be unrelated to the amount of dental movement and there is a trend for pronounced dental movements of the lower incisor in brachycephalic patients.

KEY WORDS: Class II; Xbow^{TM}; Facial type; Dental effects, Skeletal effects

INTRODUCTION

The advantage of fixed inter-arch sagittal correctors are that they eliminate the need for patient compliance with elastics or headgear. Some examples of fixed spring force delivery systems are the Jasper Jumper™ (American Orthodontics) and Forsus™ springs (3M/Unitek, Monrovia, California).[1] These appliances induce primarily orthodontic changes equally in both dental arches.[1] Innovations such as the Xbow™ (Crossbow) appliance patented Higgins, uses inter-arch springs as a phase 1 appliance to correct sagittal discrepancies in the late mixed or early permanent dentition.[2]

The Xbow™ appliance is a fixed Class II corrector that consists of a maxillary hyrax expander, a mandibular labial and lingual bow, and Forsus™ fatigue resistant device (FRD) springs (3M Unitek, Monrovia, Calif).[2] The Forsus™ spring is placed in the head-gear tube of the maxillary first molar band and hooked around the labial bow, which is stopped by a Gurin lock (3M Unitek) around the mandibular canine area.[2] Forsus™ FRD springs do not rigidly hold the mandible forward and allow the patient to function in centric occlusion.[2] It could thus be categorized as a non-protrusive inter-arch Class II corrector (Figure 1).

Figure 1. Intraoral view of a fixed Xbow™ appliance.

Ricketts stressed the need to modify treatment procedures to respect individuals that have either stronger (brachycephalic) or weaker (dolichocephalic) musculature to counteract the effects of orthodontic forces.[3] The facial musculature pattern influences the underlying dental compensations that exist to counteract vertical growth deviations to maintain adequate overbite and overjet.[4-7] Given the fact that different dental compensations exist for varying facial patterns, it is important to investigate the potential differences in skeletal and dental movements taking facial type into consideration, when patients are treated with the Xbow™ appliance. Therefore the purpose of this study was to determine the magnitude of the skeletal and dental movements in subjects with different facial patterns following Class II correction using the Xbow™ appliance.

MATERIALS AND METHODS

Sample

The treatment sample was selected from the private orthodontic practice of an orthodontist. Inclusion criteria for the sample were subjects with a complete permanent dentition including second molars and a ¾ to full cusp Class II molar malocclusion. Subjects with a mutilated dentition and/or congenitally missing teeth other than 3rd molars were excluded from the sample. The total sample size of 134 consisted of 65 males and 69 females. The mean age of the patients was 12 yr 7 mo (SD 1yr 7mo, Range 11 yr 11mo to 13 yr 4 mo) at T1 and 13 yr 4 mo (SD 1yr 7mo, Range 12 yr 6 mo to 14 yr 3 mo) at T2. Transverse discrepancies were identified and corrected with the Hyrax appliance prior to AP correction. The Forsus™ springs were activated every 4-6 weeks until a Class III overcorrection in the premolar buccal segments was accomplished. Following the active phase (4.26 mo SD 1.22 mo), the appliance was passively retained for an additional average time of 3.07 mo SD 1.06 mo. Therefore, the total mean time the appliance was in the mouth was 7.33 months SD 1.82 mo at which time the appliance was removed and a T2 cephalometric radiograph taken.

Cephalometric analysis

All cephalometric radiographs were digitized using Dolphin Imaging™ 11.5 software. Rickett's, Steiner's and Pancherz's analyses were subject to statistical analysis to quantify the skeletal and dental changes.

Subjects were categorized into three growth types according to two pre-treatment cephalometric variables; MPA and Y-axis. Subjects within two standard deviations for MPA (32° SD 2°) and one standard deviation for Y-axis (66° SD 5°) yielded; 27 brachycephalic, 70 mesocephalic, and 37 dolichocephalic subjects.

An intraclass correlation coefficient (ICC) test on 10% of the sample was used to examine measurement reliability. Fifteen cephalometric radiographs were chosen randomly and re-measured by two separate examiners 12 weeks after the original measurements to identify possible landmark identification error.

To rule out if growth had a significant contribution on any skeletal or dental movements over the treatment period, growth was assessed on 30% of the studied sample. Fifteen pre-treatment cephalometric radiographs were chosen randomly from each group and subjected to the Bolton growth prediction algorithm. Dolphin Imaging™ software uses growth prediction algorithms to quantify the amount of growth given parameters of age and time of treatment. Several computer programs using growth prediction algorithms have shown to be accurate (with respect to a clinical reference mean of 1.5mm), including the Bolton growth prediction used for this sample.[9]

Statistical software SAS 9.2 was used to analyze the data. A Kolmogorov-Smirnov test was used to determine if the samples were of normal distribution. An *ANOVA* test statistic was used to determine if there was a significant difference in cephalometric variables following Xbow™ treatment. The p value was considered significant at $\propto<0.05$.

RESULTS

Reliability

The results showed that the intra-examiner measurements were consistant; all ICC values were > 0.924 (SNA) and none of the 95% confidence limits had a lower boundary of < 0.837 (ANB). Inter-examiner reliability had a wider interval and overall lower correlation. However, there was still strong agreement of the values with correlation coefficients greater than 0.800. Based on these results, reproducibility of the cephalometric variables are accurate within a 12 week period.

Growth patterns

A paired *t*-test was used to examine the differences between the cephalometric growth indicators of the groups before Xbow™ treatment. A summary of the three groups prior to Xbow™ treatment is described in Table 1. All groups showed highly statistically significant differences.

Variables	Group A	Group B	Group A	Group C	Group B	Group C	p-value
Y-Axisº	64.7±0.5	72.2±0.5	64.7±0.5	68.4±0.3	72.2±0.5	68.4±0.3	<0.0001
MP-SN º	25.3±0.6	38.0±0.5	25.3±0.6	31.9±0.4	38.0±0.5	31.9±0.4	<0.0001

Table 1. Differences between groups prior to Xbow™ treatment (T1). A = Brachycephalic; B= Dolichocephalic; C= Mesocephalic.

Growth Considerations

The Bolton growth prediction algorithm was used. All cephalometric values except one were insignificant ($p>0.05$) over a 6 month time period for 30% of the sample. The one value that was highly significant ($p<0.001$) was the inclination of the upper incisor to NA (nasion- A point) as shown in Table 2.

Variables	Mean	Std Dev	Std Err	95% CL	95% CL	*p*-value	Significance
U1 - NA (º)	-0.72	0.14	-0.1	-0.44	1.01	<0.0001	Significant

Table 2. Growth Considerations of 30% of Sample n=45. Comparison *t*-test of T2-T1.

OVERALL TREATMENT EFFECTS OF THE Xbow™ APPLIANCE

Difference between initial and final treatment for the Brachycephalic group (n=27) Table 3.

Skeletal Pattern – ANB was significantly reduced with Xbow™ treatment by an average of 1.2±0.3 degrees ($p<0.001$). Wits appraisal was also statistically different ($p<0.05$) with a mean reduction of 4.2+0.6 mm.

Dental Variables – Overall the dental movements were in favor of Class II dentoalveolar correction. Angular changes of the upper incisor were not significant ($p>0.05$). Retrusion of the upper incisor was significant at an average distance of 3.1±0.6mm. Movement of the lower incisor was significant (p<0.05) with increased mean proclination to MP (12.3±1.3^{o}), NB (12.5±1.3^{o}) and an increased mean protrusion to APog (3.8+0.4mm), NB (2.8+0.4mm) and Pancherz analysis (7.8±1.1mm). Pancherz' analysis revealed a minor amount of distalization of the maxillary molar (0.5±0.4mm) and a significant ($p<0.05$) amount of mesialization of the mandibular molar (6.9±0.9mm). Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Group A (Brachycephalic) Variables	T2-T1 Mean±SE	*p*-value
Occ Plane to SN (º)	4.5±0.6	<0.0001
ANB (º)	-1.2±0.3	0.0011
SNA (º)	-1.1±0.4	0.1
SNB (º)	0.03±0.6	1.0
MP - SN (º)	0.2±0.4	1.0
Wits Appraisal (mm)	-4.2±0.6	<0.0001
U1 - NA (º)	0.01±1.1	1.0
U1 - NA (mm)	-0.01±0.4	1.0
U1 - Palatal Plane (º)	-0.5±1.1	1
IMPA (L1-MP) (º)	12.3±1.3	<0.0001
L1 Protrusion (L1-APo) (mm)	3.8±0.4	<0.0001
L1 - NB (º)	12.5±1.3	<0.0001
L1 - NB (mm)	2.8±0.4	<0.0001
Y-axis (º)	0.5±0.3	0.4
Overjet (mm)	-4.2±0.5	<0.0001
Overbite (mm)	-3.5±0.4	<0.0001
Maxillary Incisor Position (mm)	-3.1±0.6	<0.0001
Mandibular Incisor Position (mm)	7.8±1.1	<0.0001
Maxillary Molar Position (mm)	-0.5±0.4	0.2
Mandibular Molar Position (mm)	6.9±0.9	<0.0001

Table 3. Difference between initial and final treatment for the Brachycephalic group (n=27)

Difference between initial and final treatment for the Dolicephalic group (n=37) Table 4.

Skeletal Pattern – ANB was not significantly changed with Xbow™ treatment. Wits appraisal was statistically different ($p<0.05$) with a mean reduction of 2.4±0.5 mm.

Dental Variables – Overall the dental movements were in favor of Class II dentoalveolar correction. Angular changes of the upper incisor were not significant ($p<0.05$). Retrusion of the upper incisor was significant at an average distance of 2.4±0.4mm. Movement of the lower incisor was significant ($p<0.05$) with increased mean proclination to MP (7.3±1.1°), NB (7.7±1.1°) and an increased mean protrusion to APog (2.1±0.3mm), NB (2.0±0.4mm) and Pancherz analysis (5.5±0.6mm). Pancherz' analysis revealed a minor amount of distalization of the maxillary molar (0.7±0.4mm) and a significant ($p<0.05$) amount of mesialization of the mandibular molar (5.5±0.6mm). It is important to note that although the movements of the incisors and molars were in a similar direction they were more pronounced in the brachycephalic group. Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Group B (Dolichocephalic) Variables	T2-T1 Mean±SE	*p*-value
Occ Plane to SN (º)	3.72±0.5	<0.0001
ANB (º)	-0.2±0.2	1
SNA (º)	-0.2±0.4	1
SNB (º)	-0.01±0.5	1
MP - SN (º)	0.4±0.3	0.7
Wits Appraisal (mm)	-2.4±0.5	<0.0001
U1 - NA (º)	-1.2±0.9	0.8
U1 - NA (mm)	-0.8±0.3	0.1
U1 - Palatal Plane (º)	-0.5±1.1	1
IMPA (L1-MP) (º)	7.3±1.1	<0.0001
L1 Protrusion (L1-APo) (mm)	2.1±0.3	<0.0001
L1 - NB (º)	7.7±1.1	<0.0001

L1 - NB (mm)	2.0±0.4	<0.0001
Y-axis (º)	0.5±0.2	0.4
Overjet (mm)	-2.9±0.4	<0.0001
Overbite (mm)	-2.0±0.4	<0.0001
Maxillary Incisor Position (mm)	-2.4±0.4	<0.0001
Mandibular Incisor Position (mm)	5.5±0.6	<0.0001
Maxillary Molar Position (mm)	-0.7±0.4	0.1
Mandibular Molar Position (mm)	5.5±0.6	<0.0001

Table 4. Difference between initial and final treatment for the Dolicephalic group (n=37)

Difference between initial and final treatment for the Mesocephalic group (n=70) Table 5.

Skeletal Pattern – ANB was not significantly changed with Xbow™ treatment. Wits appraisal was statistically different (p<0.05) with a mean reduction of 3.1±1.3 mm.

Dental Variables – Overall the dental movements were in favor of Class II dentoalveolar correction. Angular changes of the upper incisor were not significant (p>0.05). Retrusion of the upper incisor was significant at an average distance of 2.5±0.3mm. Movement of the lower incisor was significant (p<0.05) with increased mean proclination to MP (10.6±0.8^{o}), NB (11.4±0.8^{o}) and an increased mean protrusion to APog (2.9±0.2mm), NB (2.7±0.3mm) and Pancherz analysis (6.6±0.5mm). Pancherz' analysis revealed a minor amount of distalization of the maxillary molar (0.4±0.3mm) and a significant (p<0.05) amount of mesialization of the mandibular molar (6.3±0.5mm). It is important to note that although the movements of the incisors and molars were in a similar direction as in the brachycephalic and dolichocephalic groups, the dental movements were intermediate in magnitude. Both the overjet and overbite were significantly reduced towards normal with Xbow™ treatment.

Group C (Mesocephalic) Variables	T2-T1 Mean±SE	p-value
Occ Plane to SN (º)	4.0±0.4	<0.0001
ANB (º)	-0.4±0.2	0.3
SNA (º)	-0.06±0.3	1
SNB (º)	-0.1±0.4	1
MP - SN (º)	-0.4±0.2	0.4
Wits Appraisal (mm)	-3.1±0.3	<0.0001
U1 - NA (º)	-0.6±0.7	0.9
U1 - NA (mm)	-0.4±0.2	1
U1 - Palatal Plane (º)	-0.2±0.7	1
IMPA (L1-MP) (º)	10.6±0.8	<0.0001
L1 Protrusion (L1-APo) (mm)	2.9±0.2	<0.0001
L1 - NB (º)	11.4±0.8	<0.0001
L1 - NB (mm)	2.7±0.3	<0.0001
Y-axis (º)	0.1±0.2	1
Overbite (mm)	-3.2±0.3	<0.0001
Maxillary Incisor Position (mm)	-2.5±0.3	<0.0001
Mandibular Incisor Position (mm)	6.6±0.5	<0.0001
Maxillary Molar Position (mm)	-0.4±0.3	0.2
Mandibular Molar Position (mm)	6.3±0.5	<0.0001

Table 5. Difference between initial and final treatment for the Mesocephalic group (n=70)

A summary of skeletal and dental movements before and after Xbow^{TM} treatment for all three groups is shown in Figure 2.

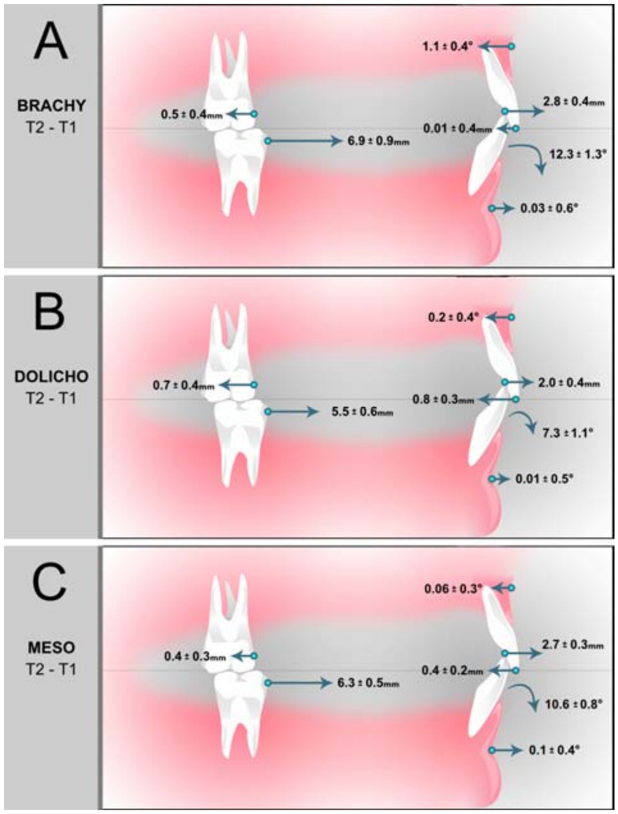

Figure 2. Overall skeletal and dental movements for all three groups.

DISCUSSION

Previous studies concluded that the short-term correction of Class II malocclusions with the Xbow^{TM} appliance is due to a combination of dental and skeletal effects.[2,10] Flores-Mir et al. (2009) found Class II correction with the Xbow^{TM} appliance was the result of:

iv) a skeletal restriction of maxilla,
v) mandibular incisor protrusion without maxillary incisor movement,
vi) maxillary molar distalization and mandibular molar mesialization.

The present study confirmed the findings of Flores-Mir et al. (2009) other than the skeletal restriction of the maxilla and significant distalization of the upper molar which he found in 2009.

The skeletal influence of spring based appliances that do not distract the condyle from the glenoid fossa is controversial.[2,11,-13] One would not expect accelerated mandibular growth with spring based appliances that do not posture the mandible forward.[2] However, the results of this study does show a significant reduction of the Wits value in all three groups, which represents a reduction in the skeletal Class II relationship of the maxilla with the mandible. One must consider the inverse relationship of Wits to changes in the occlusal plane angle.[14] There was a significant increase in occlusal plane to SN for each group, which possibly contributed to the reduction in Wits with minimal skeletal change. In addition, upper and lower incisor tipping could cause remodeling at A and B points which could effect "skeletal" changes being observed cephalometrically. In this case, it is important to remember that no single parameter in cephalometrics should be relied on entirely and interpreted as an absolute value.[15]

CONCLUSIONS

Correction of Class II malocclusions with the Xbow™ appliance is the result of:

- mesial movement of the mandibular molar,
- proclination and protrusion of the lower incisor,
- retrusion of the upper incisor,
- reduction of the Class II skeletal relationship represented by a reduction of the Wits value, but not by the ANB measurement.

Facial growth pattern appears to be unrelated to the amount of dental movement. Clinicians can expect similar dental movements in the correction of Class II malocclusions regardless of the patient's pre-existing facial pattern. However, there is a trend for pronounced dental movements of the lower incisor in brachycephalic patients. Orthodontists should take these appliance induced effects into consideration when treatment planning the final position of the lower incisor and thus deciding on an appropriate retention protocol following Xbow™ treatment.

The debate about the amount of true skeletal correction achieved by Class II correctors continues. When treatment planning, traditional functional appliances should be reserved for situations where the orthodontist is attempting to manipulate skeletal change via condylar protraction. In contrast, Class II correctors should be used in situations in which dentoalveolar correction is desired. This study found no evidence of skeletal changes with fixed Class II correctors, other than changes in Wits values. Wits values are a product of changes in the occlusal plane during treatment and the possibility of remodeling of A and B points as the incisors tip and translate. Thus, the clinician will err if extrapolating the changes in the Wits measurement, solely to bonafide skeletal change.

REFERENCES

- Graber TM, Vanarsdall RL, Vig KW. Orthodontics: Current Principles & Techniques. Fourth Edition. Elsevier Inc. St. Louis, Missouri 2005.
- Mir CF, Barnett G, Higgins DW, Heo G, Major PW. Short-term skeletal and dental effects of the Xbow appliance as measured on lateral cephalograms. Am J Orthod Dentofacial Orthop 2009;136:822-32.
- Ricketts, RM, Bench RW, Gugino CF, Hilgers JJ, Schulhof RJ. Bioprogressive Therapy. Rocky Mountain/Orthodontics. USA 1979.
- Flores-Mir C, Young A, Greiss A, Woynoroski M, Peng J. Lower incisor inclination changes during Xbow treatment according to vertical facial type. Angle Ortho. 2010;80:1075-1080.
- Janson GR, Metaxas A, Woodside DG. Variation in maxillary and mandibular molar and incisor vertical dimension in 12-year-old subjects with excess, normal, and short lower anterior face height. Am J Orthod Dentofacial Orthop. 1994;106:409–418.
- Enoki C, Telles Cde S, Matsumoto MA. Dental-skeletal dimensions in growing individuals with variations in the lower facial height. Braz Dent J. 2004;15:68–74.
- Kuitert R, Beckmann S, van Loenen M, Tuinzing B, Zentner A. Dentoalveolar compensation in subjects with vertical skeletal dysplasia. Am J Orthod Dentofacial Orthop. 2006; 129:649–657.
- Proffit W, Fields H, Sarver D. Contemporary Orthodontics. Chicago, IL: Elsevier; 2007.
- Sagun M. Assessment of computerized cephalometric growth prediction: A comparison of three methods. University of Illinois. 2012.
- Flores-Mir C, Young A, Greiss A, Woynoroski M, Peng J. Lower incisor inclination changes during XbowTM treatment according to vertical facial type. Angle Ortho. 2010;80:1075-1080.
- 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.
- Covell DA Jr, Trammell DW, Boero RP, West R. A cephalometric study of Class II Division 1 malocclusions treated with the Jasper jumper appliance. Angle Orthod. 1999;69:311-20.
- Nalbantgil D, Arun T, Sayinsu K, Fulya I. Skeletal, dental and soft-tissue changes induced by the Jasper jumper appliance in late adolescence. Angle Orthod 2005;75:426-36.

- Jacobson A. Update of the Wits Appraisal. Angle Orthod. 1988;205-219.
- Guest SS, McNamara JA, Tiziano Baccetti T, Franchic L. Improving Class II malocclusion as a side-effect of rapid maxillary expansion: A prospective clinical study. Am J Orthod Dentofacial Orthop 2010;138:582-91.

8.2 Ethics Approval and Renewal

P126 - 770 Bannatyne Avenue
Winnipeg, Manitoba
Canada R3E 0W3
Tel: (204) 789-3255
Fax: (204) 789-3414

UNIVERSITY OF MANITOBA | BANNATYNE CAMPUS
Research Ethics Boards

APPROVAL FORM

Principal Investigator: Dr. R. Chana

Ethics Reference Number: H2012:007
Date of Approval: December 19, 2011
Date of Expiry: December 19, 2012

Protocol Title: **Immediate Skeletal and Dental Effects of the X-bow Appliance on Different Facial Patterns**

The following is/are approved for use:

- **Protocol submitted November 30, 2011**
- **List of Fields submitted November 30, 2011**

The above underwent expedited review and was **approved as submitted** on December 19, 2011 by Dr. John Arnett, Ph.D., C. Psych., Health Research Ethics Board, Bannatyne Campus, University of Manitoba on behalf of the committee per your submission dated November 30, 2011. The Research Ethics Board is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement, and the applicable laws and regulations of Manitoba. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the *Food and Drug Regulations of Canada.*

This approval is valid for one year only. A study status report must be submitted annually and must accompany your request for re-approval. Any significant changes of the protocol and informed consent form should be reported to the Chair for consideration in advance of implementation of such changes. The REB must be notified regarding discontinuation or study closure.

This approval is for the ethics of human use only. For the logistics of performing the study, approval must be sought form the relevant institution, if required.

Sincerely yours,

John Arnett, Ph.D., C. Psych.
Chair, Health Research Ethics Board
Bannatyne Campus

Please quote the above Ethics Reference Number on all correspondence.
Inquiries should be directed to REB Secretary
Telephone: (204) 789-3255 / Fax: (204) 789-3414

UNIVERSITY OF MANITOBA | BANNATYNE CAMPUS
Research Ethics Boards

P126 - 770 Bannatyne Avenue
Winnipeg, Manitoba
Canada R3E 0W3
Telephone 204-789-3255
Fax 204-789-3414

HEALTH RESEARCH ETHICS BOARD (HREB)

CERTIFICATE OF ANNUAL APPROVAL

PRINCIPAL INVESTIGATOR: Dr. R. Chana	INSTITUTION/DEPARTMENT: UofM / Dentistry	ETHICS #: HS14814 (H2012:007)
HREB MEETING DATE (If applicable):	APPROVAL DATE: April 4, 2013	EXPIRY DATE: December 19, 2013
STUDENT PRINCIPAL INVESTIGATOR SUPERVISOR (If applicable):		

PROTOCOL NUMBER: NA	PROJECT OR PROTOCOL TITLE: Immediate Skeletal and Dental Effects of the X-bow Appliance on Different Facial Patterns
SPONSORING AGENCIES AND/OR COORDINATING GROUPS: NA	

Submission Date of Investigator Documents: March 21, 2013	HREB Receipt Date of Documents: April 2, 2013

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 **HREB 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
The University of Manitoba (UM) Health Research Board (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, UM HREB, per the response to the conditions of approval outlined during the initial review (full board or delegated) of the annual study status report.

HREB ATTESTATION
The University of Manitoba (UM) Health Research Board (HREB) 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, the HREB 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 Quality Management 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.

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 the 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. A Bannatyne Campus Annual Study Status Report** must be submitted to the REB within 15-30 days of this expiry date.
5. Any changes of the protocol (including recruitment procedures, etc.), informed consent form(s) or documents must be reported to the HREB for consideration in advance of implementation of such changes on the **Bannatyne Campus Research Amendment Form.**
6. Adverse events and unanticipated problems must be reported to the REB as per Bannatyne Campus Research Boards Standard Operating procedures.
7. The UM HREB must be notified regarding discontinuation or study/project closure on the **Bannatyne Campus Final Study Status Report**.

Sincerely,

John Arnett, PhD., C. Pysch.
Chair, Health Research Ethics Board
Bannatyne Campus

8.3 Manuscript Submission

The Angle Orthodontist

13-05-26 6:22 PM

THE ANGLE ORTHODONTIST

ONLINE MANUSCRIPT SUBMISSION AND PEER REVIEW

IMPORTANT: To ensure proper functionality of this site, both JavaScript and **Cookies** MUST be enabled. Click here to find out why.

CLICK HERE FOR LINKS TO UPGRADE OR INSTALL **ACROBAT READER** AND YOUR BROWSER.

Home

Detailed Status Information

Manuscript #	051213-366
Current Revision #	0
Submission Date	2013-05-12 22:39:36
Current Stage	Initial QC Started
Title	Cephalometric evaluation of dental Class II correction using the Xbow appliance in different facial patterns
Running Title	Effects of the Xbow in different facial patterns
Manuscript Type	Original Article
Special Section	N/A
Corresponding Author	randeep Chana (University of manitoba)
Contributing Authors	Tim Dumore , Stephen Ahing , Frank Hechter , William Wiltshire
Financial Disclosure	I have no relevant financial interests in this manuscript.
Abstract	Objective: To determine the magnitude of the skeletal and dental movements in subjects with different facial patterns following Class II correction using the XbowTM appliance. Materials and Methods: A retrospective sample of 134 subjects exhibiting Class II malocclusions was used. Subjects were categorized into three growth types according to pre-treatment cephalometric variables (MPA and Y-axis), which yielded 27 brachycephalic, 70 mesocephalic, and 37 dolichocephalic subjects. A ANOVA test statistic was used to investigate the differences between the three facial groups before and after treatment. Results: Dental changes induced by the XbowTM appliance included: proclination of the lower incisors (L1-MP 7.3-12.3o±1.0o), protrusion of the lower incisors (L1-APo 2.1-3.8mm±0.3mm), mesial movement of the mandibular first molar (5.5-6.9mm±0.7mm) and retrusion of the maxillary incisor (2.4-3.1mm±0.4mm). Retroclination of the maxillary incisor (U1-PP 0.2-0.8o±0.7o) and distal movement of the maxillary molar (0.4-0.7mm±0.3mm) were not significantly influenced by XbowTM treatment. Reduction of the skeletal Class II relationship was represented by a significant decrease of the Wits value (2.4-4.5mm ±0.5mm) in all three groups. The p value was considered significant at <0.05. Conclusions: Class II correction with the Xbow appliance is the result of mesial movement of the mandibular molar, proclination/protrusion of the lower incisor and retrusion of the upper incisor. Skeletal correction must be validated by more than one cephalometric variable. Facial growth pattern appears to be unrelated to the amount of dental movement and there is a trend for pronounced dental movements

http://angle.allentrack.net/cgi-bin/main.plex?form_type=status_details&j_id=1&ms_id=12141&ms_rev_no=0&ms_id_key=1OciLNYtK0bric6n6lnFA Page 1 of 2

	of the lower incisor in brachycephalic patients.
Assistant Editor	Not Assigned
Key Words	Class II malocclusion, Facial patterns, Xbow appliance
Conflict of Interest	**I have no conflict of interest that I should disclose.**

Stage	Start Date	End Date	Approximate Duration
Initial QC Started	2013-05-26 17:33:04		
Author Approved Converted Files	2013-05-26 17:33:04		
Waiting for Author Approval of Converted Files	2013-05-12 23:52:14		
File Conversion Complete	2013-05-12 23:52:14		
Waiting for File Conversion	2013-05-12 23:51:16		
	2013-05-12 23:47:50		
Manuscript Submitted	2013-05-12 23:47:50		
Manuscript Files Submitted	2013-05-12 23:47:50		
Preliminary Manuscript Data Submitted	2013-05-12 22:42:25		