

A long-term evaluation of overbite relapse in treated Class I & II malocclusions with varied craniofacial patterns

By

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B.Sc. D.M.D

A thesis submitted to the Faculty of Graduate Studies of the
University of Manitoba in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

**Dental of Preventative Dental Science
Division of Orthodontics**

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Table of Contents

	Page Number
Dedication	iv
Abstract	v
Acknowledgements	vi
List of Figures	vii-viii
List of Tables	ix-x
List of Graphs	xi
List of Appendices	xii
1.0 Introduction	1-2
2.0 Review of the Literature	
2.1 Overbite changes in the natural dentition – untreated	3-6
2.2 The stability of overbite correction	6-10
2.3 Identification of facial pattern	10-14
2.4 Jaw growth and rotation	14-17
2.5 Facial pattern and musculature	18-21
2.6 Null Hypothesis	21
3.0 Methods and Materials	
3.1 Subject Selection	22-29
3.2 Overbite Measurement	29-30
3.3 Investigator Error	30
3.4 Statistical Analysis	31

4.0 Results	
4.1 Cephalometric Calibration	32-33
4.2 Overbite Calibration	34
4.3 Cephalometrics	34-47
4.4 Overbite	47-55
5.0 Discussion	
5.1 Cephalometrics	55-60
5.2 Overbite	60-66
6.0 Conclusion & Future Research	
6.1 Conclusion	67
6.2 Future Research	67-68
7.0 References	69-80
8.0 Appendix	81-86

Dedication

To my wife Tricia and daughter Lily, for filling my life with love and happiness.

Thesis Abstract

Principle Investigator: Dr. Brent Douglas
Advisory Committee: Dr. B. McFarlane
Dr. C. Lavelle
Dr. W. Wiltshire

A long-term evaluation of overbite relapse in treated Class I & II malocclusions with varied craniofacial patterns

The purpose of this study is to ask the question: Does overbite relapse differ in subjects with varying degrees of vertical dysplasia? Records of Class I & II patients between the ages of 12-17 years were selected from the University of Manitoba Graduate Orthodontic Clinic. All patients selected had full fixed edgewise orthodontic treatment and were treated non-extraction. Patients selected had complete T1, T2, and T3 records (pre-treatment, post-treatment, and 5 years post-treatment). Two calibrated operators digitized the lateral cephalograms. The patients were grouped on the basis of 5 cephalometric measurements commonly utilized by orthodontists to detect vertical growth patterns: PP-MP, MP-SN, Y-Axis, UAFH/LAFH, P-A FH. Patients that had 3 or more of the above measures that were greater or less than 1 SD from the normal values were considered to be either brachycephalic or dolicephalic; the remaining patients were classified as mesocephalic. 10 dolicocephalic, 9 brachycephalic, and 25 mesocephalic patients were selected as the experimental group. The patients' overbite was measured, by a single calibrated operator, on the pre-treatment, post-treatment and 5 year post-treatment orthodontic casts, and the amount of relapse was analyzed. The results of the current study do not demonstrate a significant association between overbite relapse and various vertical growth patterns.

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To my mother, for your years of support and understanding, and teaching me that anything is possible.

To Lily, my beautiful daughter, thank you for giving me so much joy and love at this special time in my life.

I most deeply and sincerely cherish the love and selfless support, which I have received throughout this graduate program from my Tricia, my wife. It is now my turn to offer the same to her.

List of Figures

Figure	Page Number
2.11 Overbite < 0	4
2.12 Overbite > 5mm	4
2.21 Anterior biteplate	9
2.22 High-pull headgear	9
2.31 Divergent Facial Planes – minimal overbite	13
2.32 Parallel Facial Planes – deep-bite	13
2.41 Forwards Rotator	15
3.11 PP-MP	24
3.12 MP-SN	25
3.13 Y-Axis	25
3.14 UAFH/LAFH	26
3.15 PA Face Height	27
3.16 Example Brachycephalic at T1	27
3.17 Example Mesocephalic at T1	28
3.18 Example Dolicocephalic at T1	28
3.21 CE electronic digital calliper	30
3.22 Overbite measurement on tooth #31	30
4.31 Lateral Cephalogram at T1, T2 and T3	34
4.32 T1 Lateral Cephalogram from: mesocephalic, dolicocephalic, and brachycephalic	37

5.11 T1, T2, and T3 profiles of a dolicocephalic subject	56
5.12 T1, T2, and T3 profiles of a brachycephalic subject	57

List of Tables

Table	Page Number
3.11 Age at T1 and Subject Sex	29
3.12 Mean Treatment Time	29
4.11 Intra-Class Correlation Coefficients – Cephalometrics – B. Douglas	32
4.12 Intra-Class Correlation Coefficients – Cephalometrics – I. Meldrum	32
4.13 Inter-Class Correlation Coefficients – Cephalometrics – Douglas & Meldrum	33
4.14 Dahlberg for Operator B. Douglas	33
4.15 Dahlberg for Operator I. Meldrum	33
4.21 Intra-Class Correlation Coefficients – Overbite	34
4.31 Number of patients with each Facial Pattern at each Timepoint	35
4.32 Palatal Plane – Mandibular Plane at each Timepoint	38
4.33 Mandibular Plane to Sella-Nasion at each Timepoint	40
4.34 Y-Axis at each Timepoint	42
4.35 Posterior-Anterior Face Height at each Timepoint	44
4.36 Upper Anterior Face Height / Lower Anterior Face Height at each Timepoint	46
4.41 Overbite at each Timepoint – Mean and Standard Deviation	51
4.42 Mean Overbite change between Timepoints	52
4.43 Mean Overbite at each Timepoint – separated by facial type and sex	53

4.44 Mean Overbite change between Timepoints

– separated by facial type and sex

54

List of Graphs

Graph	Page Number
4.31 Number of patients with each Facial Pattern at each Timepoint	36
4.32 Palatal Plane – Mandibular Plane at each Timepoint	39
4.33 Mandibular Plane to Sella-Nasion at each Timepoint	41
4.34 Y-Axis at each Timepoint	43
4.35 Posterior-Anterior Face Height at each Timepoint	45
4.36 Upper Anterior Face Height / Lower Anterior Face Height at each Timepoint	47
4.41 Overbite at each Timepoint – Mean and Standard Deviation	51
4.42 Mean Overbite change between Timepoints	52
4.43 Mean Overbite at each Timepoint – separated by facial type and sex	53
4.44 Mean Overbite change between Timepoints – separated by facial type and sex	54

List of Appendices

	Page Number
T1 Cephalometric Values	82
T2 Cephalometric Values	83
T3 Cephalometric Values	84
Overbite Measurements	85-86

Chapter 1 Introduction

Skeletal differences among individuals with varying degrees of overbite have long been recognized. For example, those with “long-faces” are thought to have minimal overbites, or open-bites, whereas people with “short-faces” tend towards deep-bites. Moreover, the horizontal facial planes tend to be steeper and more divergent in individuals with large lower face heights and minimal overbites, whereas those with deep-bites have small lower face heights and more parallel facial planes (Sassouni 1964, Sassouni 1969, Isaacson et al. 1977, Naumann et al. 2000). Although considerable importance is given to such skeletal patterns prior to the initiation of orthodontic treatment, little thought is given to post-treatment skeletal growth patterns and neuromusculature changes that affect long-term treatment outcomes.

A review of the literature by Blake and Bibby (1998) suggests orthodontic relapse is pandemic and occurs in all parameters. Studies on the assessment of post-treatment results in orthodontics have indicated the majority of cases exhibit some relapse and no reliable predictor of stability or relapse has yet been identified (Little, 1981, 1988, 1989; Shields, 1985). A proper functional occlusion requires an adequate, but not excessive, overbite: reducing or preventing overbite relapse is therefore one of the most important treatment goals. However, overbite may be the orthodontic correction that is most susceptible to relapse, as generally only 30-50% of the correction is retained. (Simons, 1973; Sadowsky and Sakols, 1982; Berg, 1983; Glen, 1987; Drake and Sinclair, 1989; Sadowsky et al., 1994; Fidler et al., 1995; Blake and Bibby, 1998).

Nanda et al. (1992) was one of the first to suggest that retention devices should be differentially selected on the basis of dentofacial morphology and the anticipated magnitude and direction of subsequent growth. For example, Nanda et al. (1992) recommended the use of anterior biteplates during the retention phase of “short-face syndrome” patients and high-pull headgears in the retention phase of “long-face syndrome” patients. These recommendations make intuitive sense. However, at this time there is almost no research that demonstrates a clear association between overbite relapse and vertical facial patterns.

A better understanding of orthodontic relapse as it relates to facial pattern is therefore imperative, as this would allow orthodontists to mitigate the anticipated relapse. A more comprehensive understanding of relapse would also allow “active retention” of the dentition to adjust to late growth changes and maturation of neuromuscular balance. This study is therefore designed to address the question: **“Does relapse in overbite differ in subjects with varying degrees of vertical dysplasia?”** The purpose of this study was to provide a more complete understanding of overbite relapse linked with various vertical growth patterns, so that clinicians can adapt their treatment and retention mechanics accordingly.

Chapter 2 Review of Literature

This review comprises 5 sections, and is designed to provide an overview of:

2.1 Overbite changes in the natural dentition - untreated

2.2 The stability of overbite correction

2.3 Identification of facial pattern

2.4 Jaw growth and rotation

2.5 Facial pattern and musculature

2.6 Null Hypothesis

2.1 Overbite: Untreated Persons

Overbite is defined as “The overlapping of the lower teeth, especially the incisors, by corresponding upper teeth; now usually confined to overlap in a vertical direction” (Oxford English Dictionary, 1989). Based on the NHANES III survey (The National Health and Nutrition Examination) (Brunnelle, 1996; Drury, 1996) the average “normal” overbite in the United States of America is about 3mm. There is however a wide spectrum of variants around this “normal”, which ranges from approximately 14% with an overbite less than or equal to zero, to 16% with overbites ≥ 5 mm.

Figure 2.11 Overbite < 0,
openbite



Figure 2.12 Overbite >
5mm, deepbite



In fact, the high prevalence of overbite problems in society has stimulated numerous studies to examine the stability of overbite correction. The majority of these studies suggest that overbite correction is prone to relapse (Simons, 1973; Sadowsky and Sakols, 1982; Berg, 1983; Glen, 1987; Drake and Sinclair, 1989; Sadowsky et al., 1994). In an attempt to control overbite and vertical relapse, Nanda et al. (1992) has suggested that post-treatment retention devices should be differentially selected on the basis of dentofacial morphology and the anticipated magnitude and direction of growth. However, a comprehensive review of the literature revealed only one study that identifies the relationship between post-orthodontic overbite relapse and the patients vertical facial growth patterns (McAlpine, 1980).

Generally, studies agree that overbite increases slightly from 9 years of age to 12, and then decrease from 12 to 16 years of age (Goldstein et al., 1936; Baume, 1950; Björk, 1953; Björk, 1955; Brown et al., 1955; Murphy, 1959; Flemming, 1961; Fröhlich, 1962; Björk et al., 1972; Herness et al., 1973; Bergersen, 1988). Although natural changes in overbite are usually minimal, Moorrees (1958) reported overbite could increase up to 1.7mm or decrease up to 4mm subsequent to the time of permanent tooth eruption to 18 years of age. Björk and Skieller (1972) demonstrated a range of change in overbite from

a 4mm increase to a 4mm decrease in 6 years, although the underlying mechanisms of the changes remain obscure.

A study by Bishara and Jakobsen (1998) evaluated the changes in overbite and face height from 5 to 45 years in 35 normal, non-orthodontically treated subjects. Overbite in most of the cases (94%) increased during the transition from the deciduous to the mixed dentition. Subsequent to the mixed dentition stage, no age changes in overbite were apparent. However, when the subjects were also grouped relative to severity of overbite at 25 years of age and retrospectively analysed to establish the deviation from the original overbite, males with minimal overbite in the deciduous dentition tended to have the least amount of overbite. Various vertical skeletal parameters relative to absolute overbite values showed no significant correlations with vertical skeletal parameters ($p < 0.1$). Comparative incremental changes in overbite with several vertical parameters, however, showed a few significant correlations. For example, in males overbite changes were correlated with variation in Mandibular Plane angles to the Sella-Nasion line (MP:SN) and the ratios of the linear distances between Nasion to Anterior Nasal Spine over the distance between Nasion to Menton (N-ANS/N-Me) during the 10-15 year growth period. In females, overbite changes were correlated with changes in ratios of the distances between Articular and Gonion over that between Sella to Gonion as a percentage (Ar-Go/S-Go%) during the 15-25 year growth period and changes in N-ANS/N-Me during the 10 to 15 year period. Although these correlations were statistically significant ($p < 0.05$), they were not considered clinically useful predictors of subsequent outcomes. The main deficiency stemmed from the potential growth of the alveolar process, since

this might be more influential in determining the amount of overbite for an individual, than changes in the vertical parameters of the craniofacial skeleton.

A study by Ceylan and Eröz (2001) contributes to the importance of the alveolar process in determining overbite. They investigated the relationship between overbite and maxillary and mandibular morphology, where 20 patients with minimal overbite, or open-bite, had large dentoalveolar heights and a narrow symphysis. By contrast 20 subjects with large overbites had short dentoalveolar heights and large symphysis forms. The gonial angle was also significantly ($p < 0.001$) larger in the open-bite group and smaller in the deep-bite group. Overbite therefore appears to correlate closely with dentoalveolar heights, the shape of the symphysis, and the gonial angle, rather than the vertical parameters of the craniofacial skeleton. Such conclusions are, however constrained by the small sample sizes included in the study.

2.2 Stability of Overbite Correction

Numerous studies have been performed to quantify the amount of post retention relapse after orthodontic treatment (Simons, 1973; Sadowsky and Sakols, 1982; Berg, 1983; Glen, 1987; Drake and Sinclair, 1989; Sadowsky et al., 1994; Fidler et al., 1995). The degree of overbite is particularly relevant in this regard, since this parameter generally tends to increase after treatment subsequent to the decrease with treatment.

Fidler et al. (1995) evaluated the stability of overbite correction in 78 patients with Class II Division 1 malocclusions at the University of Washington. 14 years out of retention, the average overbite reduction was 1.5mm, with a 0.9mm relapse in the posttreatment period (60%). Sadowsky et al. (1994) examined 22 patients treated non-extraction in a long-term study of Class I and II patients. The average retention time was 8.4 +/- 3.2 yrs and the postretention period 6.3 +/- 1.8 years. Overbite correction during treatment averaged 1.9mm, of which 0.5mm +/- 1.1 (26%) relapsed in the posttreatment period. In another long-term study of orthodontic relapse, Sadowsky and Sakols (1982) found that overbite was outside the ideal in 56% of their pre-treatment sample, while long-term follow up showed that 41% had an (≥ 3.5 mm) excessive overbite.

A study by Drake and Sinclair (1989) on 60 Class II deep-bite, low angle adolescent non-extraction cases showed 20-34% overbite relapse 4 years post-treatment. Fifty percent of the sample was levelled with continuous "Tweed-type" techniques and fifty percent with "Ricketts-type" techniques, where the respective relapse were 20% and 34% (ie. those treated by Tweed showed less relapse than Ricketts).

In a study of 19 Class II Division 1 and 7 Class II Division 2 cases, all with deep impinging overbites, Berg (1983) also reported 20% relapse of overbite correction, although his subjects were out of retention an average of 5 years.

Simons & Joondeph (1973) used 70 cases from the University of Washington out of retention for at least 10 years, where levelling was accomplished by "Tweed-type"

technique. Patients with deep overbites prior to treatment were also found to have the predominant relapse and the deepest overbites 10 years post-retention, although they also maintained the greatest amount of correction or net decrease in overbite. Vertical mandibular growth both during and following orthodontic treatment appeared to correlate with overbite stability (ie. lack of mandibular growth or growth in a primarily horizontal direction was associated with greater overbite relapse).

A study by Glen et al. (1987) on 28 Class I and Class II patients evaluated a minimum of 3 years out of retention, displayed no significant overbite relapse following an average of 8 years post-retention period.

In view of these conflicting results, overbite differences from skeletal discrepancies are difficult to distinguish from those that are habit based. Conceptually this may cause an apparent lack of association between abnormal overbites and vertical skeletal dimensions (Naumann et al. 2000). However, Beckmann and Dietmar (2002) suggest the inclination of the mandible and compensatory growth of the alveolar bone of the symphysis is related to overbite at treatment completion, whereas post-treatment overbites do not reflect maxillary anterior alveolar and basal bone growth. The study by Naumann et al. (2000) on 181 subjects suggests that mandibular vertical growth and rotation are more important than maxillary determinants of overbite changes.

An interesting study by McDowell and Baker (1991) analyzed the skeletal and dental changes produced by orthodontic correction of a deep bite in fifteen adolescents (average

age 12.2 years) and fifteen adults (average age 26.7 years). On average, the molars were extruded 4.7 mm in the adolescent group, but the mandibular plane angles remained unchanged. By contrast, the adult sample experienced minimal extrusion (1.3mm) but failed to maintain their original mandibular plane angles. Greater posterior mandibular development observed in the growing patients may therefore account for these differences. "This study demonstrated that vertical changes produced by orthodontic treatment will be balanced by relatively stable vertical growth in patients with low to normal mandibular plane angle" (McDowell and Baker, 1991). Although all of these subjects exhibited "orthognathic" facial types with normal mandibular plane angles, the fate of subjects outside the norm and are primarily horizontal or vertical growers, remained obscure.

Nanda et al. (1992) suggested that post-treatment retention devices should be differentiated on the basis of dentofacial morphology and the anticipated magnitude and direction of growth. For example he recommended the use of an anterior biteplate (Figure 2.21) during the retention phase of "short-face syndrome" patients and high-pull headgears (Figure 2.22) in the retention phase of "long-face syndrome" patients.

Figure 2.21 Anterior biteplate

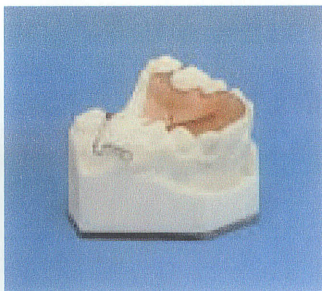
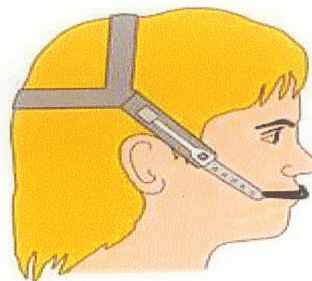


Figure 2.22 High-pull headgear



Evaluation of the occlusal changes in patients with varied vertical facial patterns post-treatment therefore remain obscure, in addition to the lack of a general consensus on what cephalometric parameters reliably identify patients' vertical craniofacial patterns.

2.3 Identification of Facial Pattern

Orthodontists continue to struggle with the complex and multifactorial vertical dimensions of vertical facial growth patterns. No consensus has yet to emerge on the cephalometric measurement(s) or variable(s) that accurately classify a patient as a vertical or horizontal grower (Vaden, 2002). Based on Björk's (1969) classic implant studies, 7 variables most strongly delineate acute forward growth rotators

1. The Intermolar and premolar angle
2. The Interincisor angle
3. Lower anterior face height
4. Size of the antegonial notch, a smaller notch
5. Lingual inclination of the mental symphysis
6. Inclination of the condyle as an indication of its growth direction, vertical condylar growth
7. Excess curvature of the mandibular canal

In a subsequent study, Skieller, Björk, and Linde-Hansen (1984) attempted to quantify this prediction approach. Their study demonstrated that four combined variables gave the best prognostic estimate of future mandibular growth direction, (ie. (1) mandibular

inclination (2) intermolar angle, (3) the shape of the lower boarder of the mandible measured as a tangent to the lower boarder and the angle between Go-Me, (4) the inclination of the symphysis measured as a tangent to the anterior border of the symphysis and SN. These variables predicted 86% of mandibular growth rotation. This study was based on a sample of children with extremely divergent facial patterns, and the authors suggested that the accuracy of prediction would be much less reliable if these predictors were employed on subjects with normal facial patterns. A more recent study casts doubt on the ability of this method to predict mandibular rotation (Leslie et al., 1998). Using the same four variables on 40 subjects, Leslie et al. found only 5.6% of the variability in mandibular growth rotation could be accounted for using the variables individually, and only 9% when used in combination. In addition, a study by Kolodziej et al. (2002) found that antegonial notch depth fails to provide adequate indication of future facial growth to justify its application as a growth predictor in a "normal" population.

It has been suggested that extreme values of the mandibular plane angle are prognostic criteria for predicting the proportions, and direction of growth (Schendel, 1976 and Opdebeeck, 1978). Bishara and Jakobsen (1985) utilized the mandibular plane angle and the ratio of posterior to anterior face height to categorize 35 subjects into groups of long, average, and short facial types in their study on longitudinal changes in facial types. However, Baumrind et al. (1984) and Skieller and Björk (1984) suggest that mandibular plane angle is not a good predictor of facial growth, since values of the mandibular plane are secondary to the spatial orientations of the palatal plane. Their studies suggest persons with a high mandibular plane angle may exhibit both clockwise and counter-

clockwise mandibular rotation. Nanda (1990) states that the constant remodelling of the inferior border of the mandible makes it an unreliable reference plane. Björk (1969) also found the angle of the mandible was an area that could have very pronounced deposition or resorption. Nanda (1990), Janson et al. (1994), and Blanchette et al. (1996) categorized growth patterns on the basis of lower face height, defined as the distance between Anterior Nasal Spine and Menton over the total face height, defined as the distance from Nasion to Menton (ANS-Me/N-Me). Fields and Proffit et al. (1984) found facial pattern differences in 84 patients using MP-SN, gonial angle, and the angle of the Mandibular Plane to the Palatal Plane (MP-PP). Cornforth (1980) studying 108 patients found a relationship between the original morphology of the mandible, as measured by Ricketts Mandibular Arch, and the propensity to open during treatment and close after treatment.

Some investigators have suggested that large cranial base angles (nasion-sella-articulare) are associated with mandibles that are rotated down and back, hyperdivergent facial types, and open-bites (Sasouni & Nanda, 1964; Sassouni, 1969), whereas others have failed to find this association. Subtelny and Sakuda (1964) found no difference in cranial base angles between 30 normal and 25 open-bite subjects. Nanda (1990) also found no correlation between cranial base angle and vertical dysplasia in a study of 32 patients, but found a sexually related difference in the magnitude of the cranial base angle.

It is recognized that skeletal differences correlate with varying degrees of overbite. For example, the horizontal facial planes tend to be steeper and more divergent in persons

with large lower face height and minimal overbite, than in deep-bite subjects with small lower face height whose facial planes tend to be more parallel (Sassouni, 1964; Sassouni, 1969; Isaacson et al., 1977; Naumann et al., 2000).

Figure 2.31 Divergent Facial Planes – minimal overbite

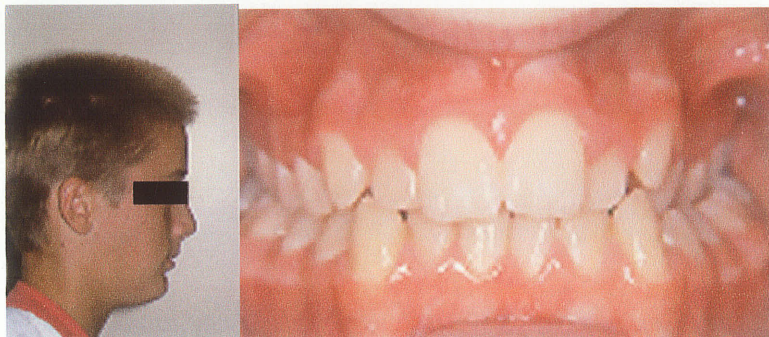


Figure 2.32 Parallel Facial Planes – deep-bite



Several investigators have found large palatomandibular plane angles (PP-MP) associated with open-bite malocclusions and large lower anterior face heights (Subtelny et al., 1964; Sassouni, 1969; Nanda, 1990). An excellent review of the literature by Buschang et al. (2002) summarizes the morphologic characteristics of the typical hyperdivergent patient, where most of the dysmorphology occurs in the mandible. The most constant mandibular characteristics include the following: steeper MP-SN angles; increased lower anterior

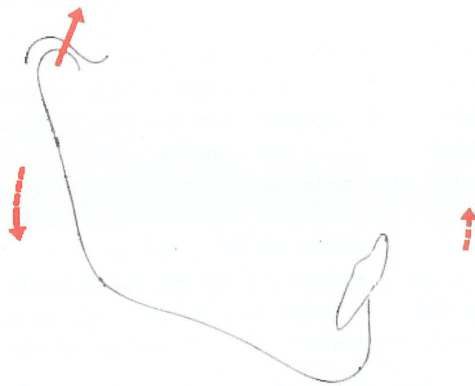
facial heights; larger gonial angles; increased lower to total and lower to upper anterior facial height ratios. Mandibular dentoalveolar heights were reported to be excessive. Decreased posterior facial heights caused by shorter ramus heights were consistently reported. With regard to the maxilla, the most consistent findings were excessive anterior and posterior dentoalveolar heights, in addition to flatter palatal plane angles from decreased anterior upper facial heights.

Despite a lack of consensus on the cephalometric parameters that characterize a person's facial growth pattern, the literature seems to agree that the different patterns of short- and long-face patients may react differently to bite-opening mechanics. In addition, horizontal and vertical growers probably experience distinct neuromuscular maturation following orthodontic changes in their vertical dimensions, which may lead to different patterns of overbite relapse.

2.4 Jaw Growth and Rotation

Numerous implant studies have demonstrated that the most common direction of condylar growth is superior and anterior (Björk, 1955; Björk, 1963; Björk, 1966; Björk, 1968; Björk & Skieller, 1972; Björk & Skieller, 1983); ie. eighty percent of people are “forwards” or anterior rotators.

Figure 2.41 Forwards Rotator



Patients with a short lower anterior face height generally demonstrate upward and forward condylar growth. For example, with the patient facing the right, the mandible exhibits a counter-clockwise rotation, with an average 15° of “true” forward rotation from 4 years of age to adulthood. However, remodelling of the lower border of the mandible masks 50% of the “true” forward rotation. Rotation apparent from the conventional lateral cephalometric radiograph on average equals 7° . These people tend to have a deep overbite, a deep mentolabial sulcus, and an overclosed appearance (Vaden & Pearson, 2002), whereas “backwards rotators” tend to have a “long-face appearance” and their condylar growth directed more posterior. These patients tend to have minimal overbite and a long lower anterior face height.

The predominance of forward mandibular growth/rotation has been confirmed in subjects with normal facial patterns (Sinclair and Little, 1985) and in subjects with divergent facial patterns (Nanda, 1990.) A study of normal untreated subjects found significant counter-clockwise, bite-closing, mandibular rotation with overall decreases in MP-SN

angle, Y-Axis, and gonial angle (Sinclair and Little, 1985). "Late mandibular growth" was determined to be a forward "bite-closing" rotation of the mandible that followed the cessation of maxillary growth. Males demonstrated these changes between 9 to 20 years of age, females between 12 to 20 years.

It would be natural to assume that this late bite-closing rotation would occur in patients with normal and horizontal growth patterns and not in the patients identified as predominantly vertical growers. However the MP-SN and gonial angles of both hypo- and hyperdivergent facial types decrease with age (Nanda, 1990). These bite-closing changes occurred progressively throughout the period of study (4 to 18 years of age). This decrease in MP-SN and gonial angles has specific affects on patients with a vertical dysplasia. In dolicephalic patients the magnitude of the dysplasia will decrease, in brachycephalic patients the dysplasia will be intensified.

However, evidence on subjects with various vertical craniofacial patterns suggests these subjects tend to maintain their original pattern of growth (ie. vertical growers tend to continue to display a predominantly vertical growth pattern and horizontal growers a strong horizontal growth). Also the hypo- or hyperdivergent growth patterns are developed early, before the eruption of the first permanent molars, and maintained throughout growth (Nanda, 1988). Longitudinal studies of patients with varied craniofacial patterns show a tendency to maintain short, average and long facial types (Buschang et al.,2002). For example, one study suggests 77% of individuals will maintain their facial type from 5 to 25.5 years of age (Bishara and Jakobsen, 1985).

Patients with excessive or deficient vertical facial dimensions, however, often present with either anterior open-bites or deep-bites, due to their vertical dysplasia (see Figures 2.31 & 2.32). Alterations in a patient's vertical dimension may occur intentionally or unintentionally through growth modification, dental intrusion, extrusion or surgical intervention (Braun, 2002). Changes in a patient's vertical dimension may then result in the mandible rotating either open or closed with analogous changes in facial esthetics, dental relationships, lip and tongue function and a corresponding change in functional masticatory status of the patient (Widmer, 2002). In an actively growing patient, the mandible may be rotated open while reducing a deep overbite with reverse curve of Spee mechanics. Also, supereruption of the mandibular posterior teeth causes the mandible to rotate clockwise, increasing the anterior facial height, the mandibular plane angle, and facial convexity (Braun, 2002). Clockwise rotation of the mandible and a corresponding increase in lower face height can also be caused by the use of cervical pull headgear, Class II or III elastics, bite plates, and many other appliances (Braun, 2002).

It is the stability of these changes in a patient's vertical dimension that provide the focus of this study (ie. are patients with a brachycephalic facial type necessarily going to have more vertical relapse following bite opening mechanics than a patient with a vertical facial pattern?).

2.5 Facial Pattern and Musculature

The relationships of the muscles of mastication to maxillomandibular growth patterns cannot be overemphasized; the jaw musculature is the key to the lower face height or vertical dimensions (Proffit et al., 1996). It is assumed that vertical relapse reflects increased active and passive forces generated by the muscles and associated connective tissue (Widmer, 2002). This was emphasized by Houston (1988), who stated "In adults, or in children where the treatment induced increase in anterior face height exceeds that which would normally have occurred with growth, there will often be a gradual anterior rotation associated with intrusion of the teeth under the influence of occlusal forces. The incisor occlusion will not usually be sufficiently stable to prevent a deepening of the overbite as the buccal teeth intrude."

There is considerable evidence to support the hypothesis that dolicocephalic patients tend to have less active, smaller masticatory muscles, with weaker bite forces (Buschang et al., 2002). Patients with divergent craniofacial patterns will also tend to have lower maximal bite forces and inferior mechanical advantages than their brachycephalic counterparts (Proffit and Fields, 1983; Garcia-Morales et al., 2003). Divergent skeletal patterns have been related to lower muscle volume and decreased muscle thickness (Gionhake, 1989). Indeed, theoretical models suggest an inverse relationship between divergent craniofacial morphology and mechanical advantage. This has been supported in adult patients (Throckmorton, 1980), where decreased bite force in adults with divergent craniofacial patterns has been well established, although such relationships remain controversial in

children. For example, normal facial-type adults have twice the bite force of long-face adults, but no differences in the bite forces have been reported between normal and long-face children (Proffit and Fields, 1983). A post-hoc power analysis suggests Proffit's sample was too small to identify a significant difference that may have been present (Garcia-Morales et al., 2003), whereas a more recent study found significant inverse relationships, between bite force, muscle strength and skeletal divergence, similar to those reported for adults (Garcia-Morales et al., 2003). This later study therefore suggests that a divergent skeletal pattern is associated with an inferior mechanical advantage and a lower maximal bite force in children.

Although such relationships are generally recognized, the contentious issues remain whether reduced occlusal forces in dolicocephalic patients produce hyperdivergence or whether lower occlusal forces result from the poorer biomechanical systems in dolicocephalic patients (Throckmorton et al., 1980; Proffit et al., 1983; Garcia-Morales et al., 2003). Moller (1966) and Thilander and Ingervall (1974) proposed that excessive maxillary posterior dentoalveolar development is associated with high-angle patients that tend to have weaker masticatory musculature, whereas low-angle patients tend to have a strong musculature. Comparative dentoalveolar development in three groups showed that, patients with: large anterior face height, average anterior face height and short anterior face height. The amount of maxillary posterior alveolar development was found to decrease at the same rate as the MP-SN decreased (Isaacson et al., 1971). This has been verified in subjects with short lower anterior face heights, which tended to have

significantly shorter dentoalveolar heights than subjects in the normal lower anterior face height group (Jansen et al., 1994).

Based on the statement that “Orthodontic extrusion of posterior teeth in persons who manifest a skeletal type of deep bite associated with heavy, strong jaw muscles may be difficult and time consuming because the extrusive mechanics must work against large occlusal forces” (Bell, 1984). It would seem logical that the greater bite force and mechanical advantage of the brachycephalic patients would predispose them to increased vertical relapse following bite opening. However, the corresponding weaker bite force and mechanical disadvantage of dolicocephalic patients would be expected to decrease the amount of overbite relapse following bite opening. Patients with a brachycephalic facial type have been reported to experience the greatest amount of overbite relapse (McAlpine, 1980). Subjects with a short lower face height and a low mandibular plane angle also showed the greatest amount of overbite relapse, whereas those with a normal or dolicocephalic facial type showed no significant overbite relapse. Unfortunately, the amount of overbite relapse, the method of overbite measurement, and the method of categorizing patients facial types are not described, so the study cannot withstand critical scientific scrutiny, due to the lack of a complete description of the protocol.

Based on the cumulative evidence, this study is designed to evaluate overbite relapse following treatment completion in patients with distinct craniofacial vertical patterns. This is based on the anticipation that patients with brachycephalic facial patterns may experience increased overbite relapse relative to dolicocephalic facial types. The

literature suggests increased vertical relapse could stem from increased counter-clockwise rotation of the mandible, excessive vertical muscular forces counteracting extrusive mechanics, or both (Björk, 1955; Björk, 1963; Björk, 1966; Moller, 1966; Björk, 1968; Isaacson, 1971; Björk & Skieller, 1972; Thilander and Ingervall, 1974; Mc Alpine, 1980; Björk & Skieller, 1983; Proffit and Fields, 1983; Bell, 1984; Sinclair and Little, 1985; Houston, 1988; Nanda, 1992; Jansen, 1994; Proffit et al., 1996; Vaden & Pearson, 2002; Widmer, 2002; Garcia-Morales, 2003). It is assumed that a more comprehensive understanding of orthodontic relapse, relative to vertical dysplasia, may indicate “active retention”, that is, adjustment of the dentition to late growth changes and maturation of neuromuscular balance.

2.6 Null Hypothesis

The purpose of this study is to test the following null hypothesis:

- “There is no statistically significant difference in overbite relapse in persons with various vertical dysplasias.”

This hypothesis will be rejected if the overbite relapse is different in persons with long, normal and short facial patterns.

To assist in testing the hypothesis this study proposes:

1. To determine whether there is a difference in overbite relapse in the subgroup samples of long, normal and short facial patterns
2. To establish population standards for overbite relapse in persons with long, normal and short facial types.

Chapter 3 Methods and Materials

3.1 Patient Selection

The subjects used in this study were selected at random by two investigators from the University of Manitoba Division of Orthodontics, Winnipeg, Manitoba, where archives uniquely contain records, study casts and lateral cephalograms from before orthodontic treatment (T1), after orthodontic treatment (T2), and 5 years post treatment (T3). The subjects in the archives were all treated by graduate students of the department, under close supervision of faculty members.

The subjects were selected on the following criteria:

1. Class I or II malocclusions – based on Angle’s molar classification and a minimum ANB angle of 0°
2. Started treatment between the ages of 12 to 17 years
3. Treated non-extraction and non-surgically
4. No missing permanent teeth
5. No labial or palatal cleft, or history of serious disease that could have affected growth
6. Treated with “edgewise type” biomechanics
7. Complete pre-treatment, post-treatment, and 5 years post-treatment records

From the archives of approximately 350 records, 20 subjects were selected that appeared to have either horizontal (10) or vertical facial patterns (10), without considering the

subjects occlusion. 24 additional subjects were selected that appeared to have “normal” facial patterns, without considering the subjects occlusion. In total 44 were selected, 14 males and 30 females. Lateral cephalograms were evaluated at three stages: pre-treatment, post-treatment, and 5 years post-treatment. The cephalograms were scanned with a HP 3400 Deskscan scanner (Hewlett-Packard Company, Palo Alto CA) and digitized with Dolphin™ treatment planning software (Dolphin Imaging and Management Systems, Chatsworth CA). Two calibrated operators digitized and analyzed the lateral cephalograms. Each operator digitized 66 lateral cephalograms, being half of the total requiring digitizing (132). Two weeks later each operator digitized the other half and re-digitized 66 of his own previously digitized cephalograms to obtain inter- and intra-operator calibration. From an analysis of the literature (Sassouni & Nanda, 1964; Subtelny & Sakuda, 1964; Björk, 1969; Schendel et al., 1976; Opdebeeck & Bell, 1978; Sassouni, 1969; Isaacson et al. 1977; Cornforth, 1980 Baumrind et al., 1984; Fields and Proffit et al., 1984; Skieller et al., 1984; Bishara & Jakobsen, 1985; Nanda, 1990; Janson et al., 1994; Blanchette et al., 1996; Leslie et al., 1998; Chung et al., 2002; Kolodziej et al., 2002; Naumann et al., 2000; Buschang et al., 2002; Vaden, 2002), it was ascertained five angular and ratio measurements are commonly used to identify subjects with vertical dysplasia (see Figures 3.11-3.15). As there is no clear consensus on which cephalometric parameter accurately characterizes a person’s facial growth pattern, it was decided to use a combination of the five most common parameters. All five parameters were measured for each subject.

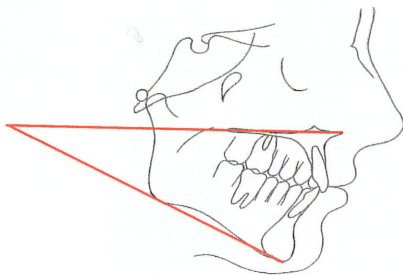
As illustrated in Figures 3.11-3.15, the following five measurements were recorded for each subject. The normal values and standard deviations used in categorizing the patients into the three facial types are the values built into the DolphinTM treatment planning software (Dolphin Imaging and Management Systems, Chatsworth CA).

1. Palatal plane to mandibular plane angle (PP-MP) norm = 25° SD +/- 6

- If lower than 1 SD then Horizontal tendency
- If higher than 1 SD then Vertical tendency

(Fields et al., 1984; Subtelny et al., 1964; Sassouni, 1969; Nanda, 1990)

Figure 3.11 PP-MP

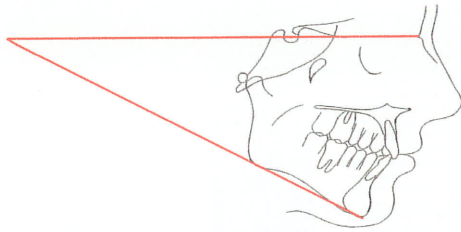


2. Mandibular plane to sella-nasion angle (MP-SN) norm = 33° SD +/- 6

- If lower than 1 SD then Horizontal tendency
- If higher than 1 SD then Vertical tendency

(Bishara et al., 1985; Fields et al., 1984; Bushang, 2002)

Figure 3.12 MP-SN

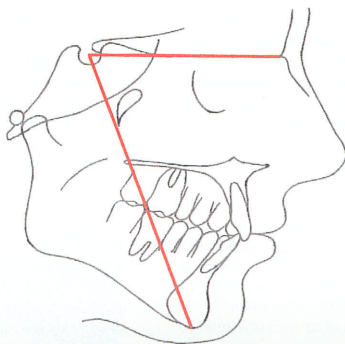


3. Y-axis – sella-nasion to sella-gnathion angle (SGn-SN) norm = 67° SD ± 5.5

- If lower than 1 SD then Horizontal tendency
- If higher than 1 SD then Vertical tendency

(Chung et al., 2002)

Figure 3.13 Y-Axis



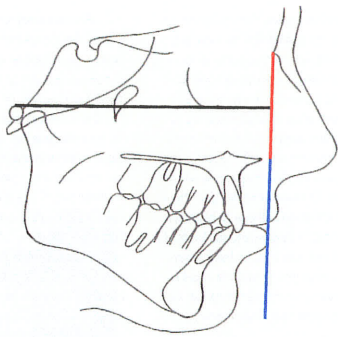
4. Upper anterior face height / lower anterior face height % - nasion to anterior nasal spine / anterior nasal spine to menton (N-ANS/ANS-ME %) norm = 80% SD +/-

7

- If lower than 1 SD then Vertical tendency
- If higher than 1 SD then Horizontal tendency

(Nanda, 1990; Janson et al., 1994; Blanchette et al., 1996; Sassouni, 1964; Sassouni, 1969; Isaacson et al., 1977; Naumann et al., 200)

Figure 3.14 UAFH/LAFH (%)



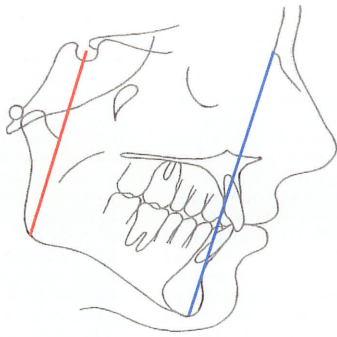
5. Posterior face height / anterior face height % - sella to gonion / nasion to menton

% (S-Go/N-Me %) norm = 65% SD +/- 4

- If lower than 1 SD then Vertical tendency
- If higher than 1 SD then Horizontal tendency

(Bishara et al., 1985; Buschang, 2002)

Figure 3.15 PA Face Height (%)



(The normal values and standard deviations used in categorizing the patients into the three facial types are the values built into the Dolphin Imaging software 3M corp.)

The sub-sample was partitioned into 3 groups according to vertical growth pattern at T1:

1. Brachycephalic – Horizontal growth pattern
2. Mesocephalic – Normal growth pattern
3. Dolicocephalic – Vertical growth pattern

Figure 3.16 Example - Brachycephalic at T1

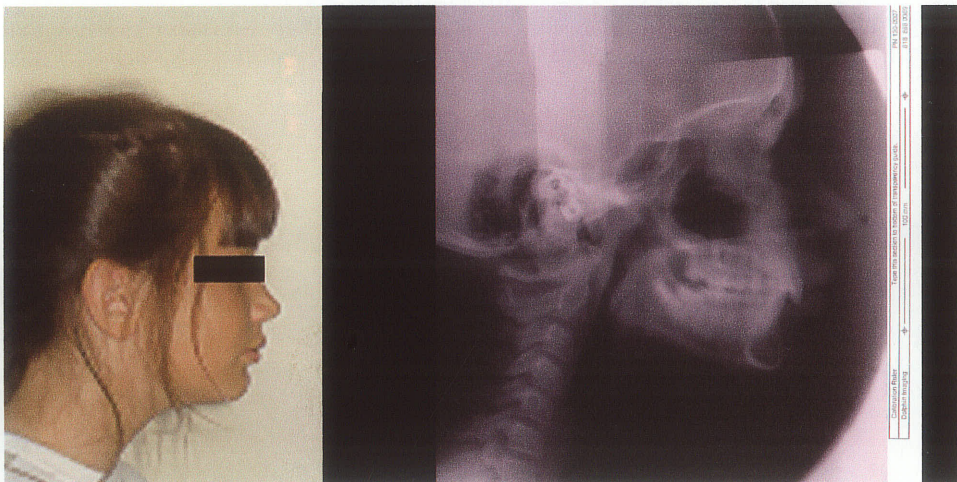


Figure 3.17 Example - Mesocephalic at T1

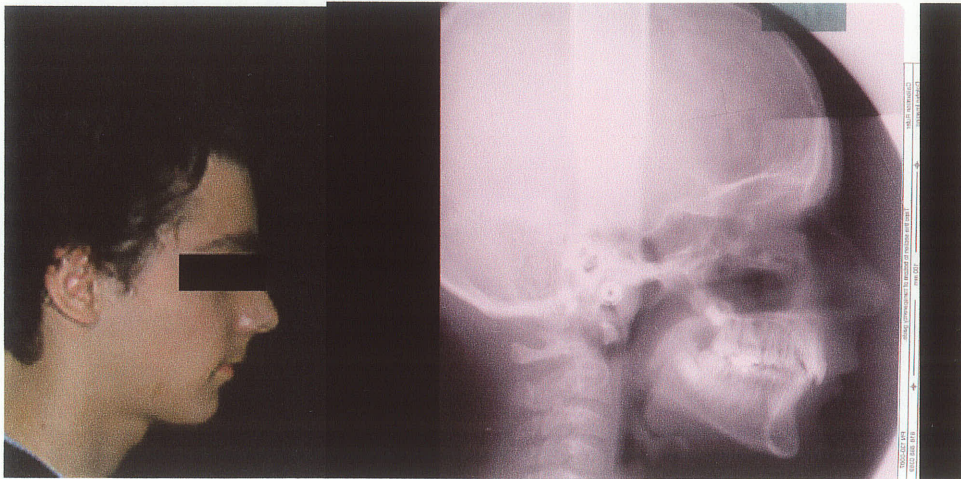
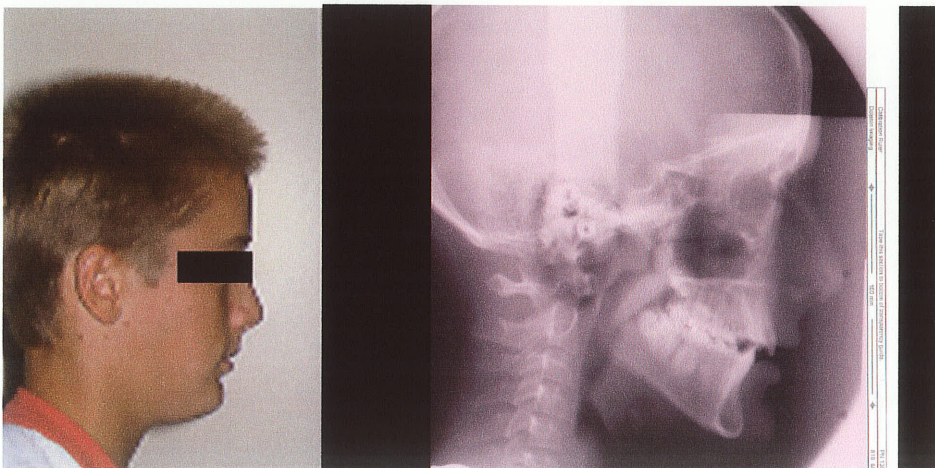


Figure 3.18 Example - Dolicocephalic at T1



The selection of these groups was based on skeletal measurements, without reference to clinical evaluation of their occlusion. The three groups were: Horizontal growers (brachycephalic), Normal growers (mesocephalic), and Vertical growers (dolicocephalic). To be categorized as brachycephalic or dolicocephalic 3 of the above mentioned

measurements had to be lower or higher than 1 standard deviation from normal values, the remaining subjects were considered normal growers.

Table 3.11 Age at T1 and Subject Sex

Group	Average Age at T1	Number of males	Number of females
Brachycephalic	12.6 years (SD1.636)	3	6
Mesocephalic	12.66 years (SD1.69)	6	19
Dolicocephalic	12.55 years (SD 1.82)	5	5
overall average age	12.6 years (SD1.636)		

Table 3.12 Mean Treatment Time

Group	Mean Treatment Time
Brachycephalic	22 months +/- 3 months
Mesocephalic	21 months +/- 4 months
Dolicocephalic	21 months +/- 3 months

3.2 Overbite Measurement

The study models were evaluated at three stages: pre-treatment, post-treatment, and 5 years post-treatment. Overbite was measured, by a single operator, with the casts in occlusion, the amount of greatest vertical overlap of right and left maxillary central incisors was marked on the corresponding mandibular central incisor parallel to the occlusal plane using a soft lead pencil (Kim et al., 1999). The distance between the mark and the incisal edge of the corresponding mandibular central incisor was measured to the nearest 0.01mm with a CE electronic digital calliper. Right and left measures were

averaged. Two weeks later 20% of the sample was re-measured to evaluate intra-operator error.

Figure 3.21 CE electronic digital calliper

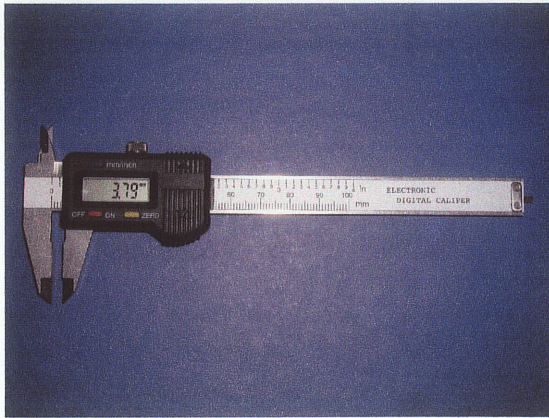
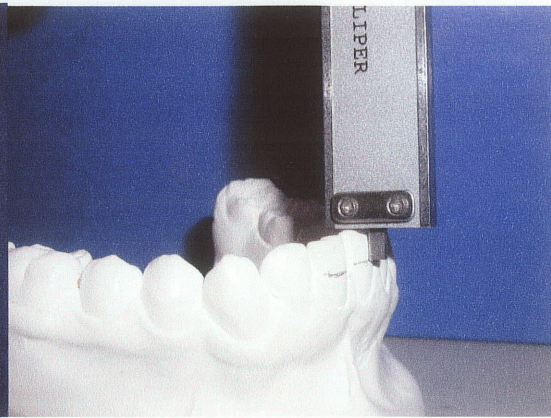


Figure 3.22 Overbite measurement on tooth #31



3.3 Investigator Error

The study contained 44 subjects each with three sets of records T1, T2, and T3 (pre-treatment, post-treatment, and 5 years post-treatment). Two calibrated operators each digitized half of the lateral cephalograms, 66. Two weeks later each operator digitized 66 of the other operator's cephalograms and re-digitized 66 of his own previously digitized cephalograms. These measurements were then statistically analysed to ensure inter- and intra-operator calibration. A single calibrated operator measured overbite, with the casts in occlusion. 20% of the sample was re-measured 2 weeks later to evaluate intra-operator error.

3.4 Statistical Analysis

Based on the advice of an experienced biostatistician (Dr. T. Hazzard) intra- and inter-operator calibrations for the measurements of the lateral cephalometric radiographs were verified through Intra- and Inter-Class Correlation Coefficients, whereas Intra-Class Correlation Coefficients were used to verify intra-operator calibration for overbite measurement from the dental casts. Subsequently a Two-Way Anova was used to determine if there were any significant differences in the 5 cephalometric measurements at T1, T2, and T3. A Two-Way Anova was also used to determine if there were any significant changes in overbite at T1, T2, and T3.

Chapter 4 Results

4.1 Cephalometric Calibration

Intra-examiner calibration for cephalometric measurements was verified by Intra-Class Correlation Coefficients (ICC). ICC values for cephalometric measurements by the operators (B. Douglas and I. Meldrum) are listed in the tables below (Table 4.11-4.12). All measurements demonstrated above 97% reliability and reproducibility. Upper (U) and Lower (L) 95% confidence limits are listed on either side.

Table 4.11 ICC Intra-Class Correlation Coefficients - Cephalometrics – B. Douglas

Measurement	L	ICC	U
PP-MP	0.990	0.995	0.998
Y-Axis	0.955	0.978	0.990
MP-SN	0.983	0.992	0.996
P-A Face H.	0.959	0.980	0.990
UAFH/LAFH	0.972	0.990	0.994

Table 4.12 ICC Intra-Class Correlation Coefficients - Cephalometrics – I. Meldrum

Measurement	L	ICC	U
PP-MP	0.990	0.995	0.998
Y-Axis	0.970	0.985	0.993
MP-SN	0.983	0.992	0.996
P-A Face H.	0.961	0.981	0.991
UAFH/LAFH	0.979	0.990	0.995

Inter-Class Correlation Coefficients for cephalometric measurements between operator I. Meldrum and B. Douglas are listed in the table below. All measurements demonstrated above 97% reliability and reproducibility. 95% confidence limits are listed on either side.

Table 4.13 ICC Inter-Class Correlation Coefficients - Cephalometrics – B. Douglas and I. Meldrum

Measurement	L	ICC	U
PP-MP	0.990	0.994	0.996
Y-Axis	0.978	0.987	0.992
MP-SN	0.989	0.993	0.996
P-A Face H.	0.965	0.979	0.987
UAFH/LAFH	0.987	0.992	0.995

The reproducibility of the error measurements was also assessed by analyzing the differences between double measurements using the Dahlberg (1940) equation $S_x = \sqrt{\sum D^2 / 2N}$. Intra-examiner error for B. Douglas was $<0.5^\circ$ and $<0.8\%$. Inter-examiner error for operator B. Douglas was $<0.5^\circ$ and $<0.7\%$ (Table 4.14). Intra-examiner error for operator I. Meldrum was $<0.5^\circ$ and $<0.8\%$. Inter-examiner error for operator I. Meldrum was $<0.5^\circ$ and $<0.6\%$.

Table 4.14 Dahlberg $S_x = \sqrt{\sum D^2 / 2N}$ for Operator B. Douglas

Intra-examiner Dahlberg – degrees	0.484	Intra-examiner Dahlberg – percent	0.778
Inter-examiner Dahlberg – degrees	0.482	Inter-examiner Dahlberg – percent	0.658

Table 4.15 Dahlberg $S_x = \sqrt{\sum D^2 / 2N}$ for Operator I. Meldrum

Intra-examiner Dahlberg – degrees	0.489	Intra-examiner Dahlberg – percent	0.780
Inter-examiner Dahlberg – degrees	0.486	Inter-examiner Dahlberg – percent	0.562

4.2 Overbite Calibration

Intra-Class Correlation Coefficients for overbite measurements for operator B. Douglas demonstrated above 99% reliability and reproducibility. 95% confidence limits are listed on either side.

Table 4.21 Intra-Class Correlation Coefficients - Overbite

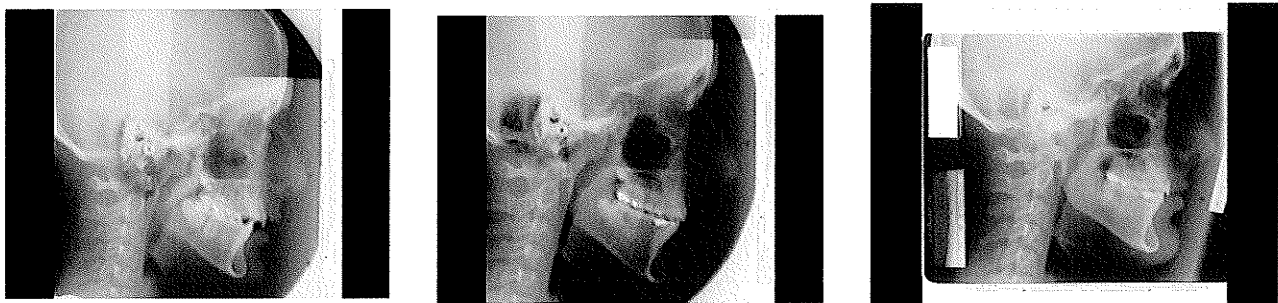
Measurement	L	ICC	U
T1 – average	0.997	0.999	1.000
T2- average	0.988	0.996	0.999
T3 – average	0.989	0.996	0.999

Using the Dahlberg (1940) equation $Sx = \sqrt{\sum D^2 / 2N}$, repeated measurements showed intra-examiner error to be $< 0.1\text{mm}$.

4.3 Cephalometrics

The skeletal patterns of the 44 subjects were evaluated from lateral cephalograms taken before treatment (T1), immediately post-treatment (T2), and 5 years after treatment (T3) (see Figure 4.31).

Figure 4.31 Lateral Cephalogram at T1, T2 and T3 – from left to right, respectively

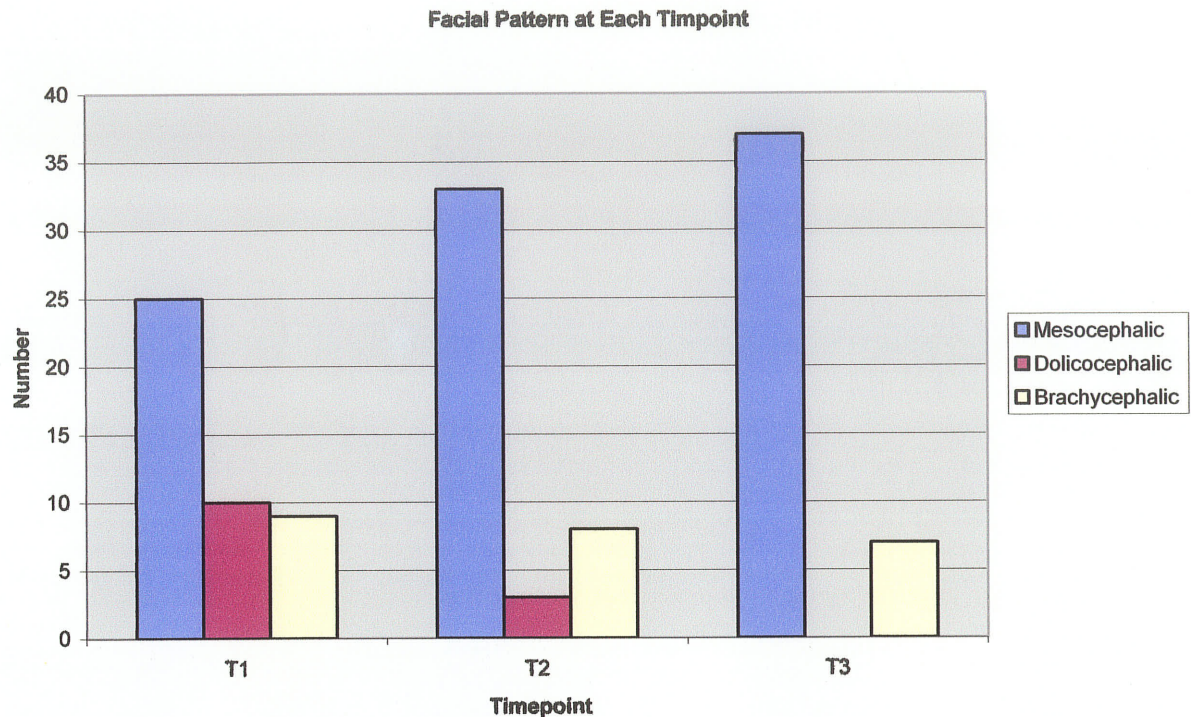


From T1 to T3 there was an overall decrease in the number of patients considered to have divergent facial types (based on the 5 cephalometric measurements: MP-SN, Y-Axis, UAFH/LAFH%, P-A face height – described in methods and materials). At T1 there were 10 dolicocephalic patients, at T2 there were 3 dolicocephalic patients, and by T3 there were 0 dolicocephalic patients. The brachycephalic patients also decreased, at T1 there were 9, at T2 there were 8, and at T3 there were 7. Only the mesocephalic group showed a steady increase in number from 25 at T1, 33 at T2 and 37 at T3. The craniofacial pattern of the subjects at each time point is listed below (see Table 4.31 and Graph 4.31).

Table 4.31 Number of patients with each Facial Pattern at each Timepoint and % total sample

Facial Pattern	T1 (pre-treatment)	T2 (post-treatment)	T3 (5-years post-treatment)
Mesocephalic	25 (56.8%)	33 (75%)	37 (84.1%)
Dolicocephalic	10 (22.7%)	3 (6.8%)	0 (0.0%)
Brachycephalic	9 (20.5%)	8 (18.2)	7 (15.9%)

Graph 4.31 Number of patients with each Facial Pattern at each Timepoint
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



A Two-Way Anova was completed to determine if there were any significant changes in the 5 cephalometric measurements from T1 to T3.

PP-MP

A Two-Way Anova revealed the only significant changes in PP-MP was in the dolicocephalic patients. PP-MP did not change significantly in the dolicocephalic patients from T1 to T2, but did change significantly ($p=0.006$) from T2 to T3 and from ($p<0.001$) T1 to T3. PP-MP decreased from 31.37° (SD 2.75) at T1, to 29.08° (SD 3.75) at T2, to 24.54° (SD 4.70) at T3, for an average decrease of 6.83° from T1 to T3. In the mesocephalic group there was a slight decrease from T1 to T2 and from T2 to T3. No

significant ($p>0.05$) changes were noted in the mesocephalic group with overall differences of 1.38° at most. In the brachycephalic group there was an increase from T1 to T2 and from T2 to T3. No significant changes ($p>0.05$) were noted in the brachycephalic group with overall differences of 2.37° at most (see Table 4.32 and Graph 4.32).

Figure 4.32 - T1 lateral cephalograms from a mesocephalic, a dolicocephalic, and a brachycephalic subject, from left to right respectively

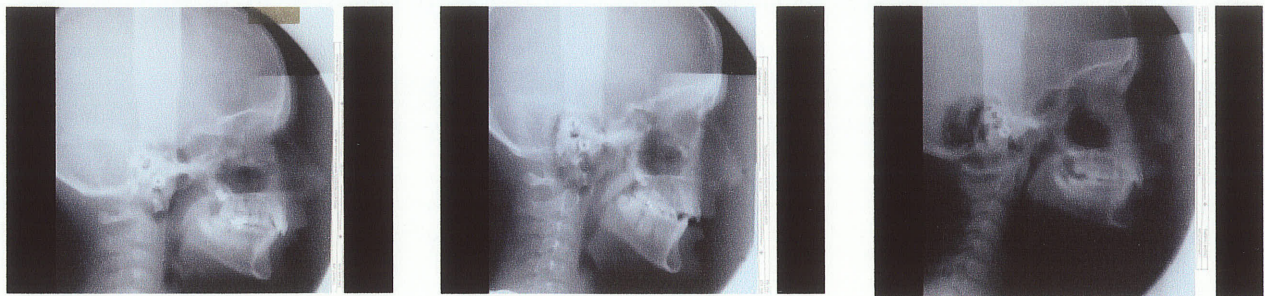
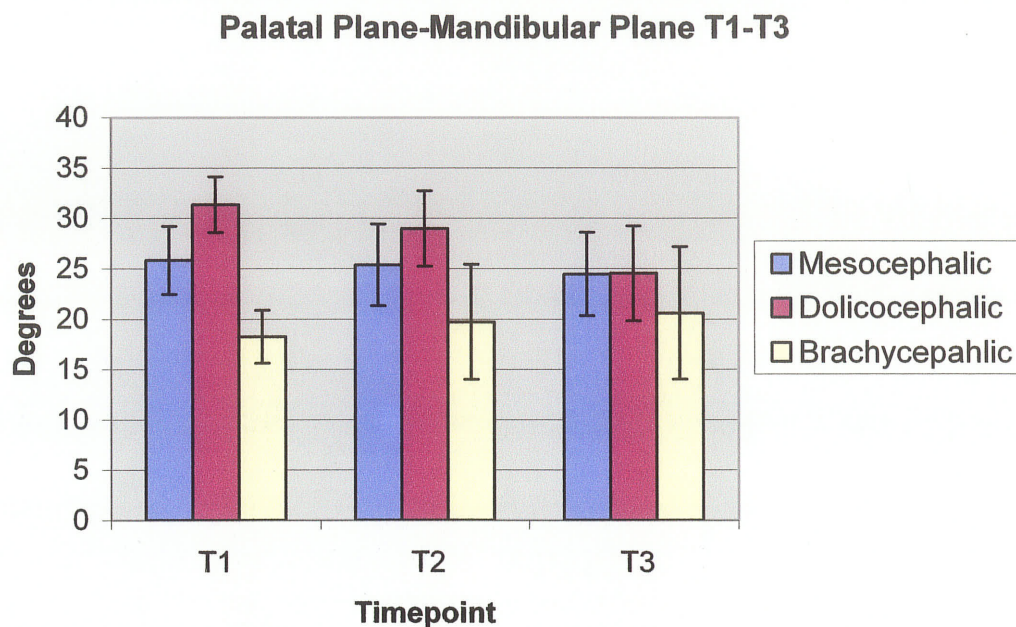


Table 4.32 Palatal Plane-Mandibular Plane at each Timepoint

PP-MP (degrees)		
	Mean	Std dev (SD)
Mesocephalic T1	25.84	3.37
Mesocephalic T2	25.38	4.05
Mesocephalic T3	24.46	4.14
Dolicocephalic T1	31.37	2.75
Dolicocephalic T2	29.00	3.75
Dolicocephalic T3	24.54	4.70
Brachycephalic T1	18.23	2.63
Brachycephalic T2	19.71	5.73
Brachycephalic T3	20.60	6.58

Graph 4.32 Palatal Plane-Mandibular Plane at each Timepoint
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



MP-SN

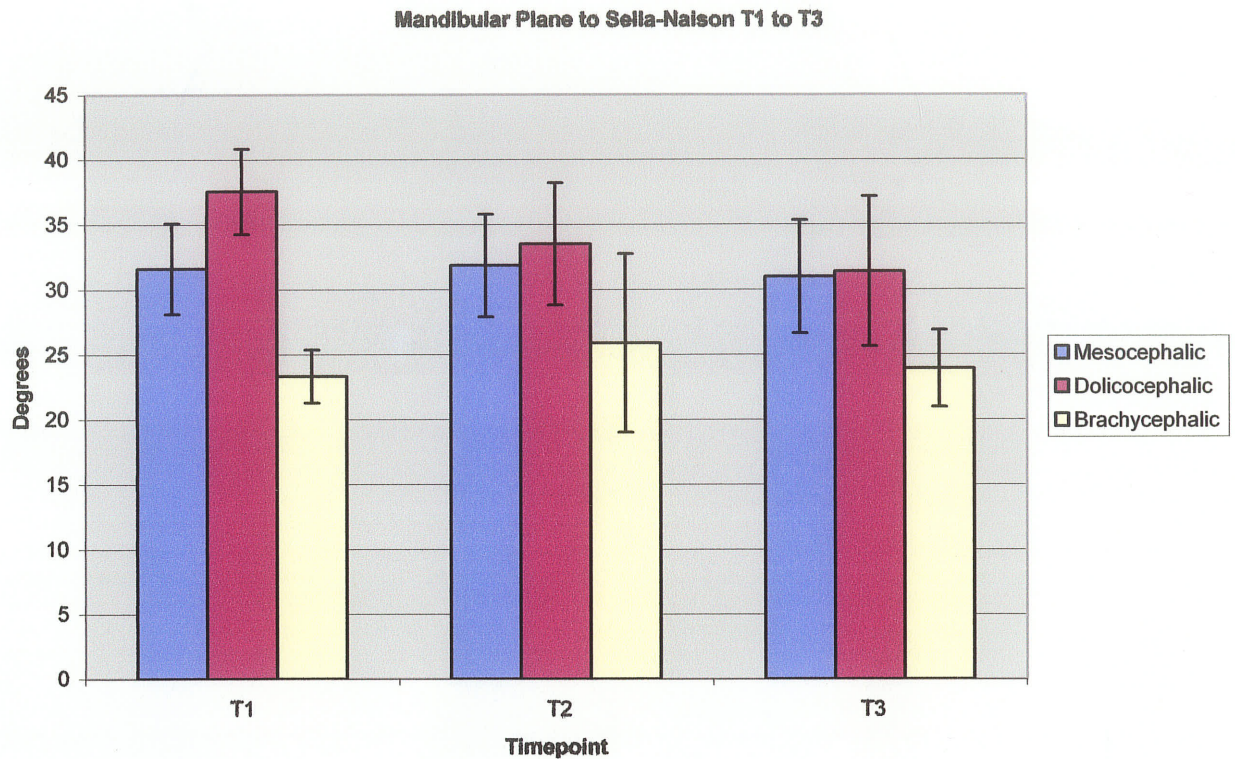
MP-SN showed a steady decrease from T1 to T3 in the dolicocephalic group. The dolicocephalic group demonstrated a significant ($p=0.0288$) decrease from T1 to T2, and ($p=0.0011$) from T1 to T3, but not from T2 to T3. MP-SN decreased approximately 6° from T1 to T3. In the dolicocephalic group MP-SN at T1 was 37.56° (SD 3.28), 33.51° (SD 4.71) at T2, and 31.38° (SD 5.80) at T3. In the mesocephalic group there was a slight increase from T1 to T2 and a slight decrease from T1 and T2 to T3. No significant ($p>0.05$) changes were noted in the mesocephalic group with overall differences of 0.87° at most. In the brachycephalic group there was a slight increase from T1 to T2 and a decrease from T2 to T3. No significant changes ($p>0.05$) were noted in the

brachycephalic group with overall differences of 2.56° at most (see Table 4.33 and Graph 4.33).

Table 4.33 Mandibular Plane to Sella-Nasion at each Timepoint

Mandibular Plane to Sella-Nasion T1 to T3 (degrees)		
	Mean	Std dev (SD)
Mesocephalic T1	31.62	3.49
Mesocephalic T2	31.85	3.95
Mesocephalic T3	30.98	4.36
Dolicocephalic T1	37.56	3.28
Dolicocephalic T2	33.51	4.71
Dolicocephalic T3	31.38	5.76
Brachycephalic T1	23.33	2.04
Brachycephalic T2	25.89	6.86
Brachycephalic T3	23.91	2.95

Graph 4.33 Mandibular Plane to Sella-Nasion each Timepoint
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



Y-Axis

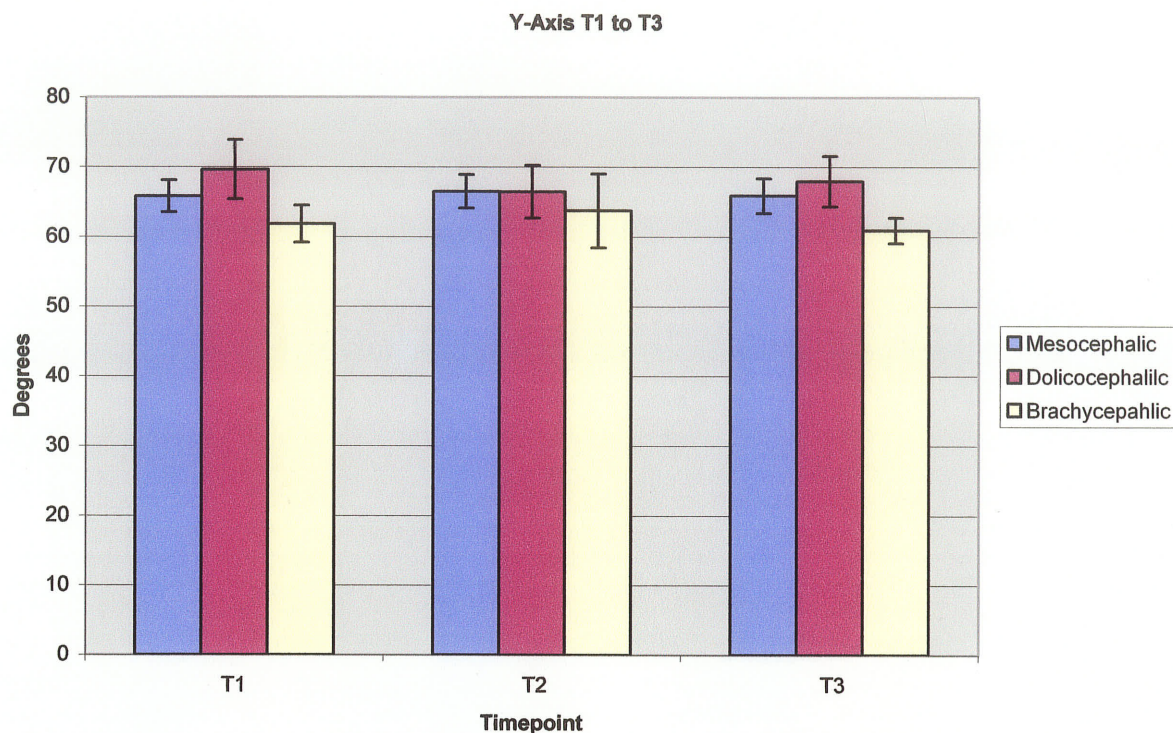
Y-Axis also only showed significant changes in the dolicocephalic patients. The only significant ($p=0.0235$) change was from T1 to T2. Y-Axis for the dolicocephalic patients dropped from 69.62° (SD 4.23) at T1, to 66.45° (SD 3.79) at T2, and then increased to 67.94° (SD 3.62) by T3. In the mesocephalic group there was a slight increase from T1 to T2 and a decrease from T2 to T3. No significant changes ($p>0.05$) were observed in the mesocephalic group with overall differences of 0.7° at most. In the brachycephalic group there was a slight increase from T1 to T2, follow by a decrease from T2 to T3. No

significant changes ($p>0.05$) were observed in the brachycephalic group with overall differences of 2.82° at most (see Table 4.34 and Graph 4.34).

Table 4.34 Y-Axis at each Timepoint

Y-Axis (degrees)		
	Mean	Std dev (SD)
Mesocephalic T1	65.79	2.29
Mesocephalic T2	66.49	2.41
Mesocephalic T3	65.87	2.49
Dolicocephalic T1	69.62	4.23
Dolicocephalic T2	66.45	3.79
Dolicocephalic T3	67.94	3.62
Brachycephalic T1	61.82	2.66
Brachycephalic T2	63.72	5.30
Brachycephalic T3	60.90	1.84

Graph 4.34 Y-Axis at each Timepoint
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



P-A Face H.

P-A Face Height also only showed significant changes in the dolicocephalic patients.

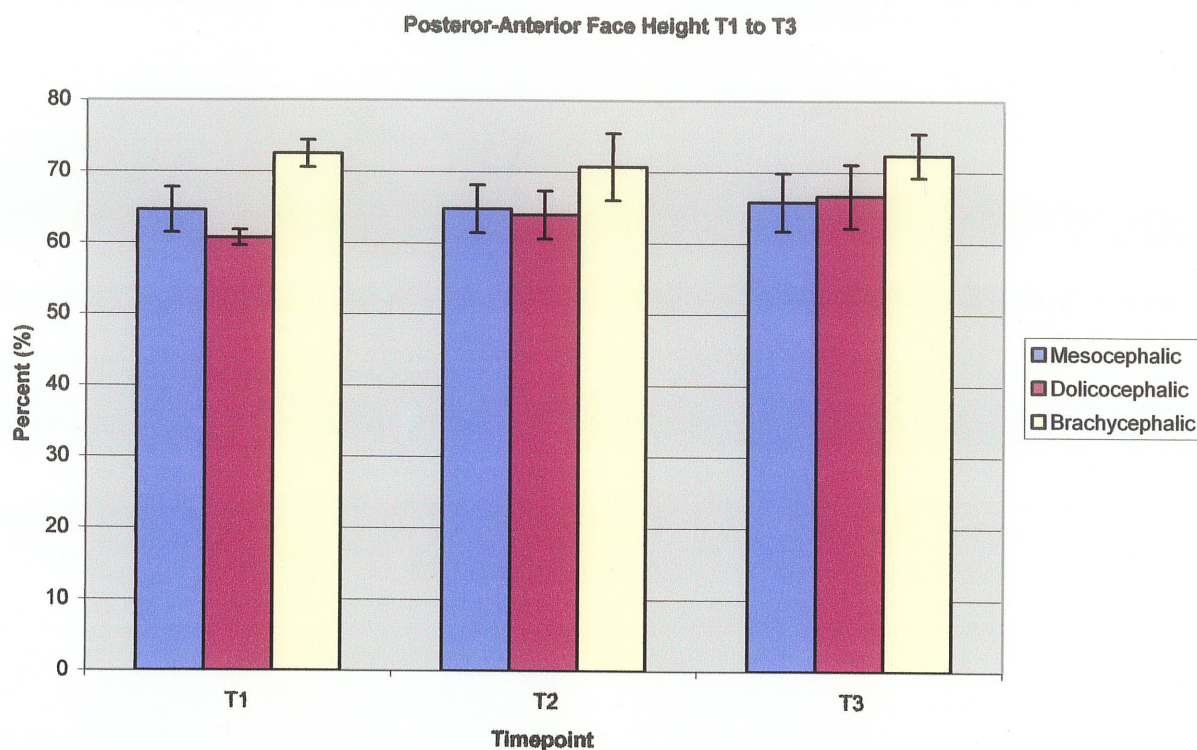
The change in P-A Face Height was significant ($p=0.0406$) from T1 to T2, and from ($p=0.003$) T1 to T3, but not from T2 to T3. There was a steady increase from T1 to T3 in the dolicocephalic patients. In the dolicocephalic group P-A Face Height increased from 60.72% (SD 1.09) at T1, to 63.98% (SD 3.35) at T2, to 66.64% (SD 4.47) at T3. In the mesocephalic group P-A Face Height increased slightly from T1 to T2 and from T2 to T3. No statistically significant changes ($p>0.05$) were observed in the mesocephalic group with overall differences of 1.21° at most. In the brachycephalic group P-A Face Height dropped from T1 to T2 and increased from T2 to T3. No statistically significant

changes ($p>0.05$) were observed in the brachycephalic group with overall changes of 1.79° at most (see Table 4.35 and Graph 4.35).

Table 4.35 Posterior-Anterior Face Height (%) at each Timepoint

Posterior-Anterior Face Height (%)		
	Mean	Std dev (SD)
Mesocephalic T1	64.60	3.20
Mesocephalic T2	64.82	3.34
Mesocephalic T3	65.81	4.09
Dolicocephalic T1	60.72	1.09
Dolicocephalic T2	63.98	3.35
Dolicocephalic T3	66.64	4.47
Brachycephalic T1	72.51	1.91
Brachycephalic T2	70.72	4.70
Brachycephalic T3	72.34	3.09

Graph 4.35 P-A Face Height (%) at each Timepoint
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



UAFH/LAFH

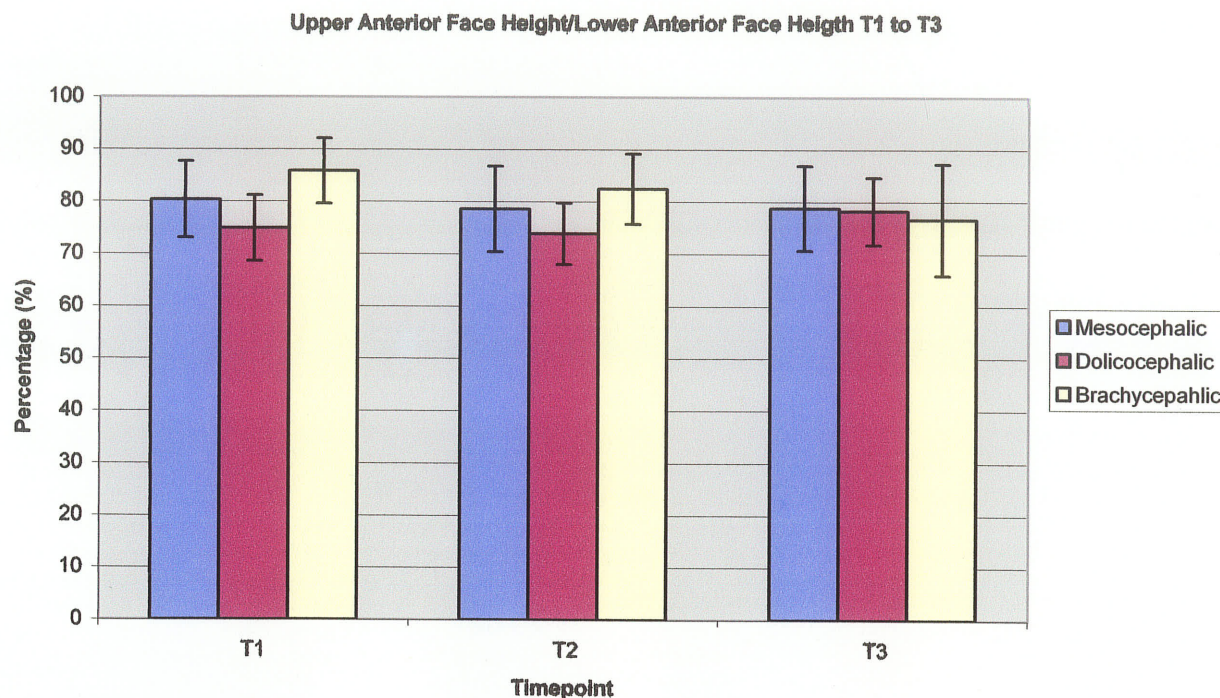
UAFH/LAFH was the only measurement that demonstrated a significant change only in the brachycephalic patients. There was a significant ($p=0.0066$) decrease in UAFH/LAFH from T1 to T3. From T1 to T2 there was a decrease in UAFH/LAFH, this decrease was borderline, but not significant ($p=0.0803$). In the brachycephalic group UAFH/LAFH dropped from 85.83% (SD 6.24) at T1, to 82.47% (SD 6.71) at T2, to 76.59% (SD 10.61) at T3. In the mesocephalic group there was a decrease from T1 to T2 and a slight increase from T2 to T3. No significant changes ($P>0.05$) were noted in the mesocephalic group with overall differences of 1.21° at most. In the dolicocephalic group there was a slight decrease from T1 to T2 and an increase from T2 to T3. No

significant changes ($p > 0.05$) were noted in the dolicocephalic group with overall differences of 4.33° at most (see Table 4.36 and Graph 4.36).

Table 4.36 Upper Anterior Face Height/Lower Anterior Face Height (%) at each Timepoint

Upper Anterior Face Height/Lower Anterior Face Height (%)		
	Mean	Std dev (SD)
Mesocephalic T1	80.35	7.29
Mesocephalic T2	78.64	8.18
Mesocephalic T3	78.79	8.14
Dolicocephalic T1	74.90	6.31
Dolicocephalic T2	73.90	5.87
Dolicocephalic T3	78.23	6.43
Brachycephalic T1	85.83	6.24
Brachycephalic T2	82.47	6.72
Brachycephalic T3	76.59	10.61

Graph 4.36 Upper Anterior Face Height/Lower Anterior Face Height (%) at each Timepoint T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



4.4 Overbite

A Two-Way Anova was completed to determine if there were any significant changes in overbite between the three groups. See Tables 4.41-4.44 and Graphs 4.41-4.44.

At T1 there was a significant ($p=0.0138$) difference in overbite between the three facial types, there was no gender difference found, and there was no interaction between facial type and gender found. At T1, Brachycephalic patients had the deepest overbite followed by mesocephalic and then dolicephalic patients. The mean overbites for the three facial

types at T1 were: 5.31mm (SD 1.69) brachycephalic, 4.54mm (SD 1.56) mesocephalic, and 3.16mm (SD 1.94) dolicephalic (see Table 4.41 and Graph 4.41). Although there was no significant difference in overbite levels between the sexes ($p=0.1081$), the males tended to have deeper initial overbites. The T1 overbites of the subjects were: brachycephalic males = 6.18mm (SD 1.70), brachycephalic females = 4.88mm (SD 1.66), dolicocephalic males = 3.67mm (SD 2.27), dolicocephalic females = 2.65mm (SD 1.64), mesocephalic males = 5.01mm (SD 1.47), mesocephalic females = 4.39mm (SD 1.67) (see Table 4.41, 4.43 and Graph 4.41, 4.43).

From T1 to T2 there was a significant ($p=0.0105$) group effect and gender effect ($p=0.0302$) but no interaction between group and gender. The overbites of the male patients were reduced more than the females in all of the facial types. The deep overbites of the brachycephalic patients were reduced an average of 3.11mm (SD 1.55) for the females and 4.98mm (SD 2.12) for the males. The mean reduction in overbites for the female mesocephalic patients was 3.02mm (SD 1.76) and the males were reduced 3.85mm (SD 1.30). The female dolicocephalics overbites were reduced 0.66mm (SD 1.55) and the males were reduced 2.34mm (SD 2.90), on average (see Table 4.42, 4.44 and Graph 4.42, 4.44).

At T2 there was a significant ($p=0.0332$) gender difference in overbites, but there was no group difference. The male patients in all the groups had, on average, a larger reduction in overbite than the females. At T2 the average brachycephalic subject had an overbite of 1.77mm (SD 0.69) and 1.19mm (SD 0.42), female and male respectively. The average

mesocephalic female subject had an overbite of 1.37mm (SD 0.69), and the average mesocephalic male subject had an overbite of 1.15mm (SD 0.40). The average dolicocephalic had an overbite of 1.99mm (SD 0.14) and 1.33mm (SD 0.82), female and male respectively (see Table 4.41, 4.43 and Graph 4.41, 4.43).

From T2 to T3 there was no significant difference ($p>0.46$) in overbite change between the different groups or genders. On average all of the groups experienced an increase in overbite from post-treatment (T2) to 5 years post-treatment (T3). The average change in overbite for a brachycephalic subject was 0.92mm (SD 0.68) for a female and 1.42mm (SD 0.46) for a male. The average change in overbite for a mesocephalic female patient was 1.28mm (SD 1.023) and 1.12mm (SD 1.00) for a male. The average change in overbite for a dolicocephalic female patient was 0.65mm (SD 0.74) and 1.09mm (SD 1.53) for a male. The group with the least amount of overbite relapse was the dolicocephalic females with 0.65mm, and the group with the greatest overbite relapse was the brachycephalic males with 1.42mm. However, these differences were not statistically significant ($p=0.2977$) (see Tables 4.42, 4.44 and Graphs 4.42, 4.44).

The brachycephalic subjects had, on average, an overbite correction (T1-T2) of -3.74mm (SD 1.87) of which 1.09mm (SD 0.63) 29.06% relapsed in the post-treatment period (T2-T3). The dolicocephalic subjects showed an overbite correction of -1.50mm (SD 2.37) of which 0.87mm (SD 1.15), 58.13%, relapsed in the post-treatment period. The mesocephalic subjects showed an overbite correction of -3.22mm (SD 1.67) of which 1.24mm (SD 1.00), 38.53%, relapsed in the post-treatment period.

At T3 there was no significant difference ($p>0.40$) in overbite between any of the groups or sexes. The brachycephalic females had an average overbite of 2.69mm (SD 0.53) and males had an overbite of 2.61mm (SD 0.41). The average overbite at T3 for a mesocephalic female patient was 2.65mm (SD 0.74) and 2.27mm (SD 0.94) for a male. The average dolicocephalic female patient had an overbite of 2.64mm (SD 0.78) and the average dolicocephalic male had an overbite of 2.42mm (SD 0.73).

From T1 to T3 there was no significant difference in overbite change between the groups or genders ($p>0.26$). On average all of the groups experienced a reduction in overbite from T1 to T3. Brachycephalic male subjects maintained an average overbite reduction (T1-T3) of 3.56mm (SD 0.69), 71.50% of their initial (T1-T2) 4.98mm (SD 2.12) overbite correction. Brachycephalic female subjects maintained an average overbite reduction of 2.19mm (SD 1.86), 70.48% of their initial 3.11mm (SD 1.55) overbite correction. Dolicocephalic male subjects maintained an average overbite reduction of 1.24mm (SD 1.52), 53.25% of their initial 2.34mm (SD 2.91) overbite reduction. Dolicocephalic female subjects maintained an average overbite reduction of 0.01mm (SD 1.57), 1.52% of their initial 0.66mm (SD 1.55) overbite reduction. Mesocephalic male subjects maintained an average overbite reduction of 2.73mm (SD 1.18), 70.93% of their initial 3.85mm (SD 1.30) overbite reduction. Mesocephalic female subjects maintained an average overbite reduction of 1.74mm (SD 1.65), 57.66% of their initial 3.02mm (SD 1.76) overbite reduction.

Table 4.41 Overbite at each Timepoint - Mean and Standard Deviation (SD)

Group	Number	T1 Mean	T1 SD	T2 Mean	T2 SD	T3 Mean	T3 SD
Brachy	9	5.313	1.69	1.58	0.65	2.66	0.47
Doli	10	3.16	1.94	1.66	0.65	2.55	0.72
Meso	25	4.54	1.56	1.32	0.62	2.56	0.79

Graph 4.41 Mean Overbite at each Timepoint

T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)

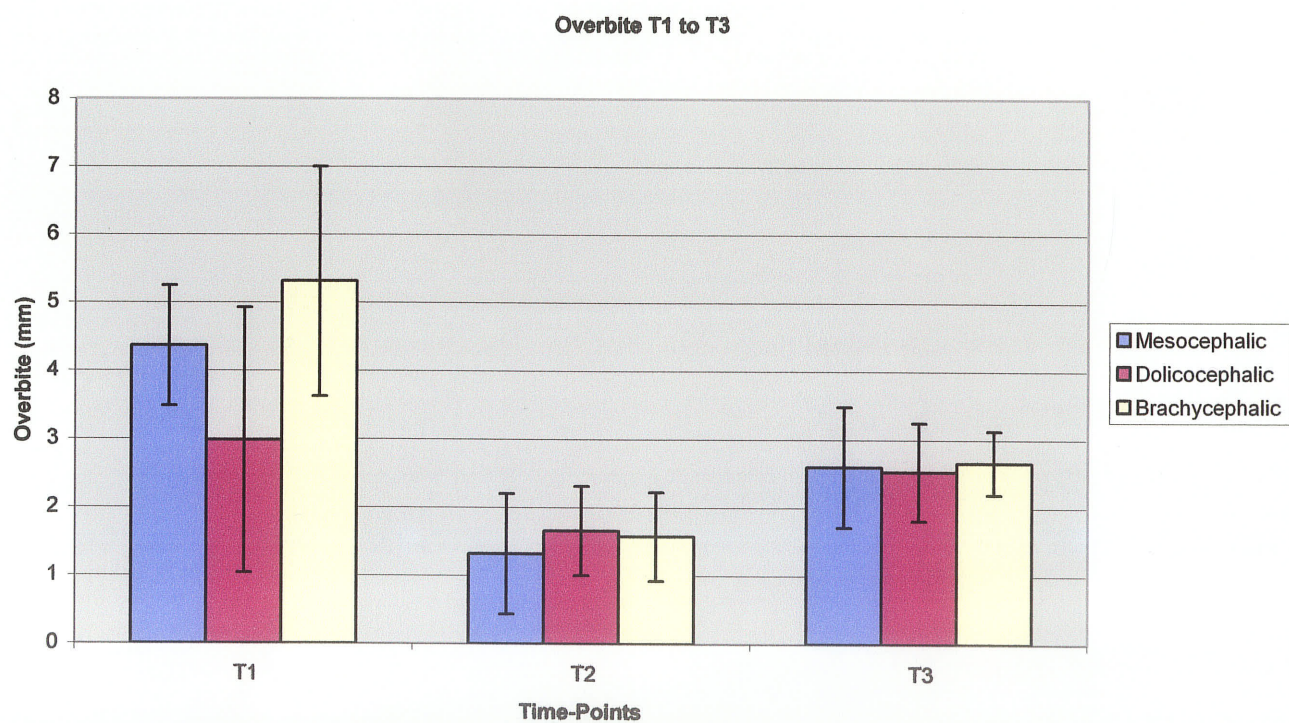


Table 4.42 Mean Overbite change between Timepoints

Overbite change between timepoints - Mean and Standard Deviation (SD)

Group	Number	T1-T2 MEAN	SD	T2-T3 Mean	SD	T1-T3 Mean	SD
Brachy	9	-3.74	1.87	1.09	0.63	-2.36	1.62
Doli	10	-1.5	2.37	0.87	1.15	-1.47	1.46
Meso	25	-3.22	1.67	1.24	1	-1.75	1.59

Graph 4.42 Mean Overbite change between Timepoints
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)

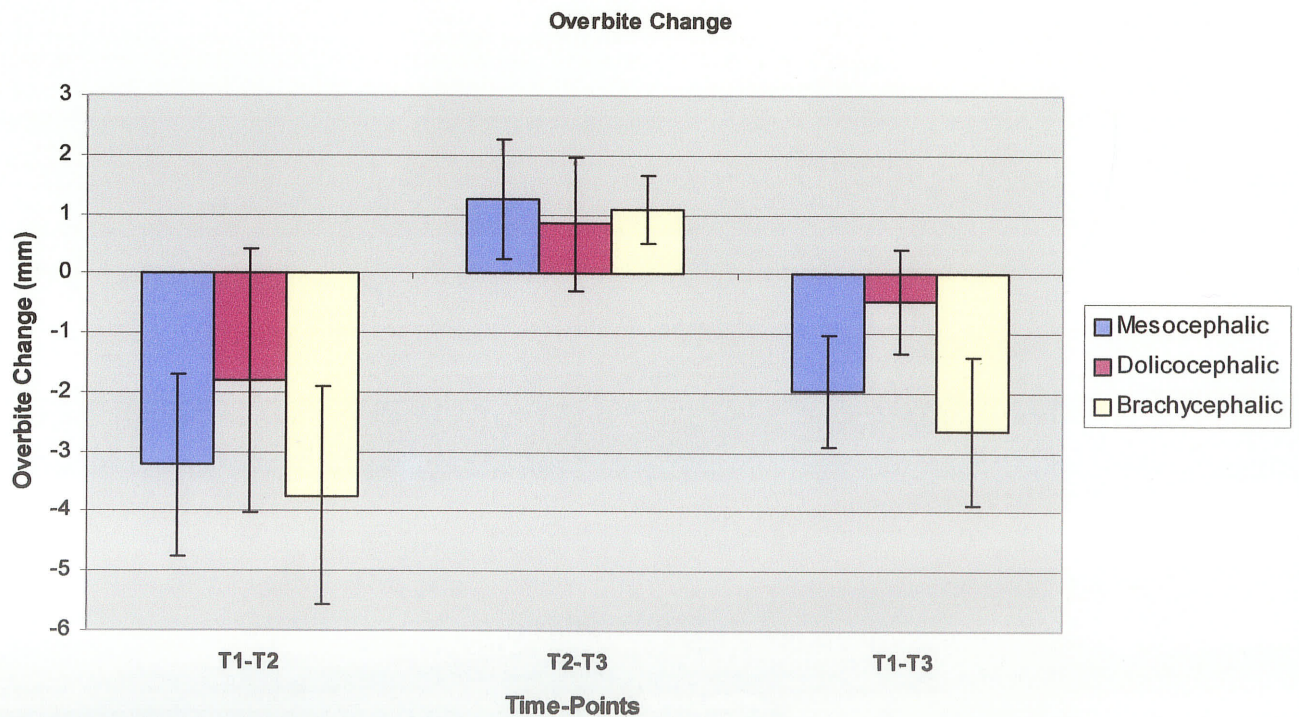


Table 4.43 Mean Overbite at each Timepoint – separated by facial type and sex

Overbite at each timepoint - Mean and Standard Deviation

Group	Sex	Number	T1 Mean	T1 SD	T2 Mean	T2 SD	T3 Mean	T3 SD
Brachy	F	6	4.88	1.66	1.77	0.69	2.69	0.53
Brachy	M	3	6.18	1.7	1.19	0.423	2.61	0.41
Doli	F	5	2.65	1.64	1.99	0.14	2.64	0.78
Doli	M	5	3.67	2.27	1.33	0.82	2.42	0.73
Meso	F	19	4.39	1.67	1.37	0.68	2.65	0.74
Meso	M	6	5.01	1.15	1.15	0.4	2.27	0.94

Graph 4.43 Mean Overbite at each Timepoint – separated by facial type and sex
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)

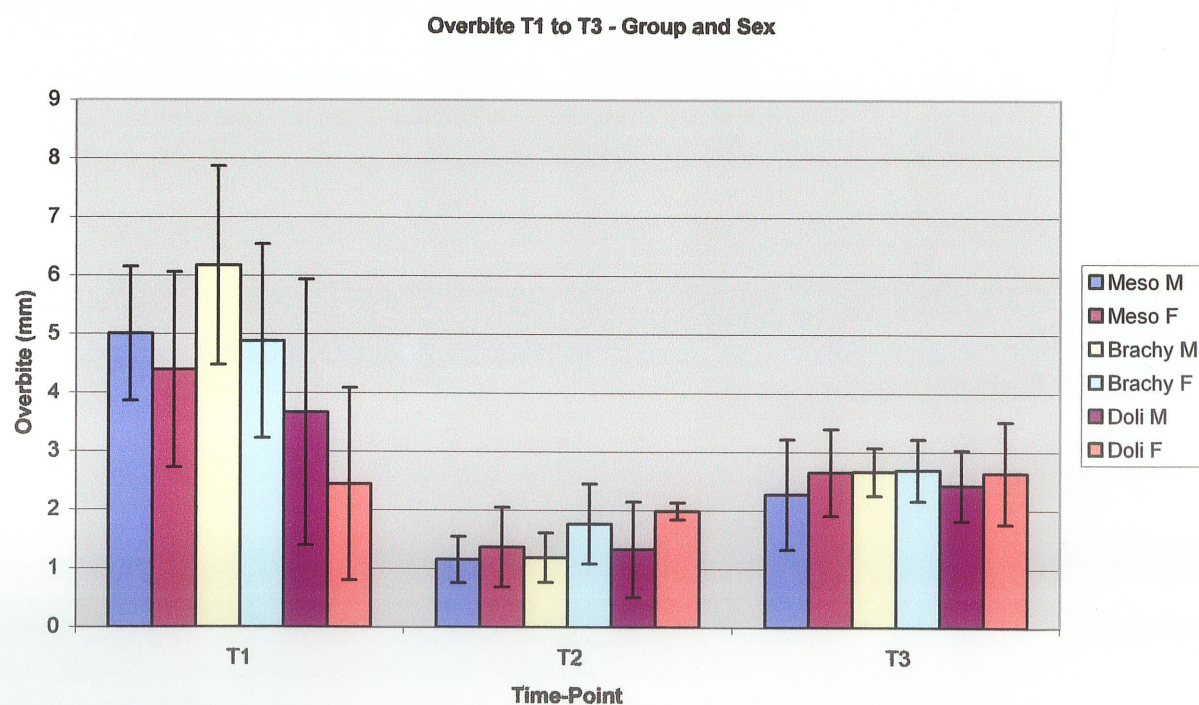
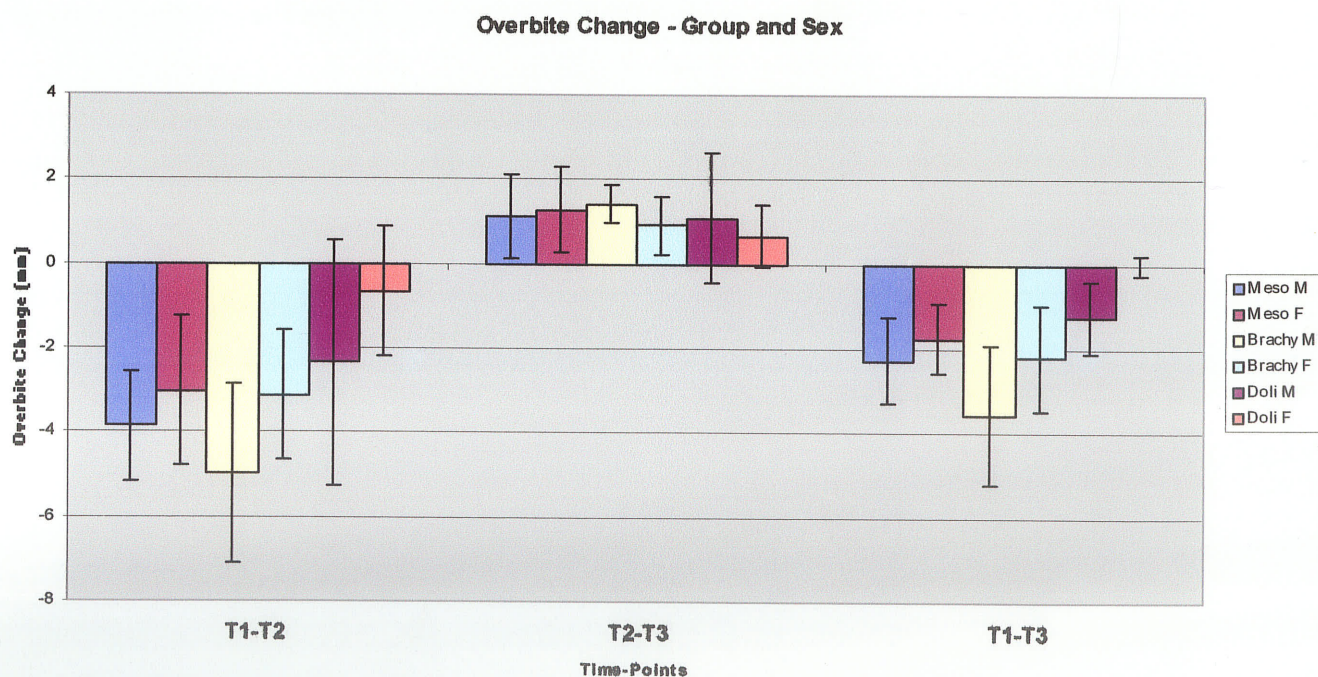


Table 4.44 Mean Overbite change between Timepoints – separated by facial type and sex

Overbite change between timepoints - Mean and Standard Deviation

Group	Sex	Number	T1-T2 Mean	SD	T2-T3 Mean	SD	T1-T3 Mean	SD
Brachy	F	6	-3.11	1.55	0.92	0.68	-2.74	1.86
Brachy	M	3	-4.98	2.12	1.42	0.46	-1.6	0.69
Doli	F	5	-0.66	1.55	0.65	0.74	-1.46	1.57
Doli	M	5	-2.34	2.91	1.09	1.53	-1.48	1.52
Meso	F	19	-3.02	1.76	1.28	1.02	-1.5	1.64
Meso	M	6	-3.86	1.3	1.12	1	-2.53	1.17

Graph 4.44 Mean Overbite change between Timepoints – separated by facial type and sex
T1 (pre-treatment), T2 (post-treatment), T3 (5-years post-treatment)



Chapter 5 Discussion

This discussion is divided into two sections: Cephalometrics and Overbite. The sections are designed to evaluate the findings of this study relative to the evidence contained in the literature.

5.1 Cephalometrics

From pre-treatment to five years post-treatment (T1- T3), the number of patients considered to have “vertical” or “horizontal” facial patterns was shown to decrease from 19 (43.2%) to 7 (15.9%), and the number of “normals” increased from 25 (56.8%) to 37 (84.1%). In addition, the number of dolicocephalic patients decreased from 10 (22.7%) at T1, to 3 (6.8%) at T2, to 0 at T3. The brachycephalic patients decreased from 9 (20.5%) patients at T1 to 7 (15.9%) patients at T3. The disappearance of the dolicocephalic group by T3 suggests the majority of the subjects seemed to be forward, counter-clockwise mandibular rotators, confirming the results of numerous implant studies that have demonstrated condylar growth is most commonly in a superior and anterior direction (Björk, 1955; Björk, 1963; Björk, 1966; Björk, 1968; Björk & Skieller, 1972; Björk & Skieller, 1983). According to these studies 80% of people are “forwards” or anterior rotators and the number of “forward rotators” in the current study would support this conclusion. Overall, the number of patients with divergent facial patterns decreased by T3, and the only increase was in the mesocephalic group, which increased

from 25 (56.8%) patients at T1 to 37 (84.1%) patients at T3. The subjects in Björk's (1955,1963,1966,1968) and Björk & Skieller's (1972,1983) studies were untreated subjects, whereas the patients in the current study underwent full fixed edge-wise treatment. It can be assumed that patients with vertical facial growth patterns were treated with mechanics to control the vertical, and promote counter-clockwise rotation. Conversely, patients with horizontal facial patterns were most likely treated with bite opening mechanics, to promote clockwise rotation. The effect of treatment on the subjects' facial patterns may then have contributed to the "normalization" of the patients with divergent facial types (see Figures 5.11 & 5.12). The mesocephalic subjects stayed in the "normal" range of facial patterns.

Figure 5.11 – T1, T2, and T3 profiles of the same dolicocephalic subject - left to right respectively - by T2 the subject was mesocephalic



Figure 5.12 – T1, T2, and T3 profiles of the same brachycephalic subject - left to right respectively - by T2 the subject was mesocephalic



PP-MP significantly decreased in the dolicocephalic subjects from T1 to T3 and T2 to T3. In the dolicocephalic group there was a 2° decrease in PP-MP during treatment (T1-T2), this change was not significant ($p > 0.05$). During the retention period (T2-T3) there was a significant ($p = 0.006$) 4.5° decrease in PP-MP. The significant decrease in PP-MP in the dolicocephalic group from T1-T3 suggests good vertical control during treatment, and a counter-clockwise rotation of the mandible during treatment and the retention period. PP-MP changes in the mesocephalic and brachycephalic group were not significant.

MP-SN decreased significantly in the dolicocephalic patients from T1 to T2 and T1 to T3. The 4° decrease from T1 to T2 suggests good vertical control during treatment and the 6° decrease from T1 to T3 suggests counter-clockwise rotation of the mandible

continued during the retention period. MP-SN changes in the brachycephalic and mesocephalic groups were not significant.

Y-Axis decreased significantly during from T1 to T2 in the dolicocephalic patients. This 3° decrease during treatment suggests good vertical control during treatment and favourable growth pattern. There was a slight increase in the Y-Axis form T2 to T3, suggesting a bite-opening rotation, but this 1.5° increase was not statistically significant. In the mesocephalic and brachycephalic groups no significant changes in Y-Axis were observed.

P-A face height increased significantly from T1 to T2 and T1 to T3 in dolicocephalic patients. As with the previous measurements, this suggests good vertical control during treatment and favourable pattern of growth, helping to normalize a divergent facial pattern. In the mesocephalic and brachycephalic groups no significant changes in P-A face height were observed.

UAFH/LAFH was the only measurement that demonstrated a significant ($p=0.0066$) change, only in the brachycephalic patients. A decrease occurred in UAFH/LAFH from T1 to T3, 85.83% to 76.59% respectively. It is assumed that extrusive mechanics were used in these patients to reduce overbite and increase LAFH. The UAFH/LAFH ratio continued to decrease in the retention period (T2-T3), but this decrease was not significant. The changes in UAFH/LAFH observed in the dolicocephalic and mesocephalic groups were not significant.

PP-MP, MP-SN, Y-Axis, and P-A face height all demonstrated significant ($p<0.05$) changes consistent with counter-clockwise rotation of the maxillomandibular complex, or bite closing rotation, in the dolicocephalic subjects only. These changes would be constant with excellent vertical control during treatment, and continued bite-closing rotation in the post-orthodontic period. This rotation is consistent with implant studies that suggest 80% of people are “forwards” or anterior rotators (Björk, 1955; Björk, 1963; Björk, 1966; Björk, 1968; Björk & Skieller, 1972; Björk & Skieller, 1983).

It would be natural to assume that this late bite-closing rotation would occur in patients with normal and horizontal growth patterns and not in the patients identified as predominantly vertical growers. However, the predominance of forward mandibular growth/rotation has been confirmed in subjects with divergent facial patterns. The MP-SN and gonial angles of both hypo- and hyperdivergent facial types decrease with age (Nanda, 1990). These bite-closing changes occurred progressively throughout the period of study (4 to 18 years of age). This decrease in MP-SN and gonial angles has specific affects on patients with a vertical dysplasia. In dolicocephalic patients the magnitude of the dysplasia will decrease, in brachycephalic patients the dysplasia will be intensified.

What is interesting about this study is the clockwise maxillomandibular rotation seen in the brachycephalic patients, as a significant decrease in the UAFH/LAFH ratio.

This rotation was most likely caused by bite opening mechanics. Pretreatment the brachycephalic patients had significantly ($P<0.05$) deeper overbites than the other groups,

and demonstrated the largest reduction in overbite during treatment (T1-T2). In an actively growing patient the mandible may be rotated open while reducing a deep overbite with reverse curve of Spee mechanics. Orthodontists commonly utilize cervical pull headgear, bite plates, Class II or III elastics and many other appliances: all of which can cause supereruption of the mandibular posterior teeth causing the mandible to rotate clockwise, increasing the anterior facial height, the mandibular plane angle, and facial convexity (Braun, 2002).

5.2 Overbite

Before the start of treatment (T1) there was a significant difference ($p=0.0138$) in overbite between the three facial types, there was no gender effect and there was no interaction between facial type and gender. At T1 patients with a horizontal facial pattern, brachycephalics, tended to have the deepest overbite with a mean of 5.31mm (SD 1.69). Patients with an average facial pattern tended to have an overbite between the other two groups with a mean of 4.54mm (SD 1.56). Dolicocephalic patients, or patients with a vertical facial pattern, tended to have the lowest amount of overbite with a mean of 3.16mm (SD 1.94). It is recognized that skeletal differences exist among persons with varying degrees of overbite. The horizontal facial planes tend to be steeper and more divergent in persons with large lower face height and minimal overbite, than in deep-bite subjects with small lower face height whose facial planes tend to be more parallel

(Sassouni 1964, Sassouni 1969, Isaacson et al. 1977, Naumann et al. 2000). The initial differences in overbite levels between the groups' supports these historical studies.

During treatment, from T1 to T2, there was a significant ($p < 0.05$) group effect and gender effect but not an interaction. The overbites of the male patients were reduced more than the females in all the facial types. The deep overbites of the brachycephalic patients were reduced an average of 3.11mm (SD 1.55) for the females and 4.98mm (SD 2.12) for the males. The mean reduction in overbite for the female mesocephalic patients was 3.02mm (SD 1.76), and 3.85mm (SD 1.30) for the males. The female dolicocephalics' overbites were reduced 0.66mm (SD 1.55) and the males were reduced 2.34mm (SD 2.90), on average. It is understandable that the patients with the deepest bites, the brachycephalics, experienced more bite opening than the other two groups, followed by the mesocephalics, and the dolicocephalics. The effect of the bite opening mechanics is also reflected cephalometrically by the significant ($p < 0.05$) decrease in the UAFH/LAFH ratio in the brachycephalic subjects. It is interesting that the males in all the groups had a significantly larger ($p = 0.0302$) amount of overbite reduction than the females, considering the pre-treatment overbite was not significantly different between the sexes. Perhaps overbite was reduced more in male patients in anticipation of increased overbite relapse in males. Or possibly, overbite was reduced less in female patients in order to ensure a greater amount of incisor display at rest, that is often desired in female patients. It should be noted that the male patients did tend to have deeper overbites at T1, but this difference was not significant ($p = 0.1081$).

At the completion of treatment (T2) there was a significant gender difference in the overbites, but there was no group difference and no interaction. The male patients had significantly lower ($p=0.0332$) overbites than the female patients. At T2 the average brachycephalic had an overbite of 1.77mm (SD 0.69) and 1.19mm (SD 0.42), female and male respectively. The average mesocephalic female patient had an overbite of 1.37mm (SD 0.69), and the average mesocephalic male patient had an overbite of 1.15mm (SD 0.40). The average dolicocephalic had an overbite of 1.99mm (SD 0.14) and 1.33mm (SD 0.82), female and male respectively. Overbite was reduced to a greater extent in the male patients. It seems logical that the clinicians may have opened the bite of male patients to a greater extent in anticipation of greater vertical relapse due to stronger facial musculature (Proffit and Fields, 1983; Ueda et al., 2002). Another possibility is that the less bite opening was performed in the female patients to ensure a greater amount of upper incisor display at rest.

During the 5-year post-treatment period (T2-T3) there was no significant difference ($p>0.46$) in overbite change between the different groups or genders. All of the groups experienced an increase in overbite from T2-T3. The average increase in overbite for a brachycephalic subject was 0.92mm (SD 0.68) for a female and 1.42mm (SD 0.46) for a male. The average increase in overbite for a mesocephalic female patient was 1.28mm (SD 1.023) and 1.12mm (SD 1.00) for a male. The average increase in overbite for a dolicocephalic female patient was 0.65mm (SD 0.74) and 1.09mm (SD 1.53) for a male. The group with the least amount of overbite relapse was the dolicocephalic females with

0.65mm, and the group with the greatest overbite relapse was the brachycephalic males with 1.42mm. However, these differences were not statistically significant.

It is interesting to note that the dolicocephalic subjects had the least amount of overbite correction (-1.5mm) and had the least amount of total overbite relapse (0.87mm), but had the greatest amount of overbite relapse when viewed as a percentage of the amount of total overbite correction $(0.87/1.5) \times 100 = 58.13\%$. The mesocephalic subjects had, the median amount of overbite correction (-3.22mm) and had the most overbite relapse (1.24mm), but had the median amount of overbite relapse when viewed as a percentage of the amount of overbite correction $(1.24/3.22) \times 100 = 38.53\%$. The brachycephalic patients had the largest amount of overbite correction (-3.74mm) and had the median amount of overbite relapse (1.09mm), however they had the least amount of overbite relapse when viewed as a percentage of the amount of overbite correction $(1.09/3.74) \times 100 = 29.06\%$.

At T3 there was no significant difference in overbite between any of the groups or sexes. The brachycephalic females had an average overbite of 2.69mm (SD 0.53) and males had an overbite of 2.61mm (SD 0.41). The average overbite at T3 for a mesocephalic female patient was 2.65mm (SD 0.74) and 2.27mm (SD 0.94) for a male. The average dolicocephalic female patient had an overbite of 2.64mm (SD 0.78) and the average dolicocephalic male had an overbite of 2.42mm (SD 0.73). It is interesting that despite such large group differences in overbite pre-treatment, 5 years posttreatment the groups had very similar average overbites.

From T1 to T3 there was no significant difference in overbite change between the groups or genders ($p>0.26$). On average all of the groups experienced a reduction in overbite from T1 to T3. Brachycephalic male subjects maintained an average overbite reduction (T1-T3) of 3.56mm (SD 0.69), 71.50% of their initial (T1-T2) 4.98mm (SD 2.12) overbite correction. Similarly, brachycephalic females maintained an average overbite reduction of 2.19mm (SD 1.86), 70.48% of their initial 3.11mm (SD 1.55) overbite reduction. Dolicocephalic male subjects maintained 1.24mm (SD 1.52), 53.25% of their initial 2.34mm (SD 2.91) overbite correction. However, dolicocephalic female subjects maintained an average overbite reduction of only 0.01mm (SD 1.57), only 1.52% of their initial 0.66mm (SD 1.55) overbite correction. Mesocephalic male subjects maintained an average overbite reduction of 2.73mm (SD 1.18), 70.93% of their initial 3.85mm (SD 1.30) overbite correction. Mesocephalic female subjects maintained an average overbite reduction of 1.74mm (SD 1.65), 57.66% of their initial 3.02mm (1.76) overbite reduction.

When viewed as a percentage of overbite correction, the amount of overbite relapse found in this study is as variable as that found in other studies (Berg, 1983; Drake et al., 1989; Sadowsky et al., 1994; Fidler, 1995). Fidler's (1995) subjects had a 60% relapse in overbite correction, after being out of retention 14 years. Sadowsky et al. (1994) found 26% of overbite correction relapsed in the post-retention period: with a long retention period, 8.4 years on average. The study by Drake and Sinclair (1989) found 20-34% of overbite correction relapsed; their subjects were out of treatment approximately 4 years, with an estimated 2 year retention period. Simons et al. (1973) found that patients that

had a deep overbite prior to treatment maintained the greatest amount of correction or percent decrease in overbite, although they also had the most overbite relapse. Berg's (1983) study reported one of the lowest percentages of overbite relapse, 20%. This is interesting as Berg's (1983) sample consisted of only patients with deep impinging overbites. The current study's results are similar to the studies by Berg (1983) and Simons et al. (1973), subjects with deep bites were found to maintain the greatest correction or percent decrease in overbite. Patients with deeper initial overbites (brachycephalic patients) experienced a greater amount of overbite relapse, but experienced a lower percentage relapse than dolicocephalic patients that started with a lower initial overbite, 29.06% and 58.13% respectively. Perhaps with a larger sample size this result may have been significant.

This study began with the question: "are patients with a brachycephalic facial type necessarily going to have more vertical relapse following bite opening mechanics than a patient with a vertical facial pattern?" The pattern that appeared in the current study was that dolicocephalic patients had less total overbite relapse than brachycephalic and mesocephalic patients: 0.87mm (SD 1.15), 1.09mm (SD 0.63), and 1.24mm (SD 1.00) respectively. However when viewed as a percentage of overbite correction the dolicocephalic patients had 58.13% overbite relapse, compared to 38.53% for the mesocephalic and 29.06% for the brachycephalic subjects. However, these differences were not significant. As a result, the null hypothesis cannot be rejected. Although the patients with long facial patterns appeared to experience less overbite relapse than subjects with normal and short facial patterns, the differences were too small to be

considered significant. Perhaps, as suggested by Bishara et al. (1998) and Ceylan et al. (2001) the potential growth of the alveolar process may be more influential in determining the amount of overbite for an individual, than the vertical parameters of the craniofacial skeleton.

The results of the current study do not demonstrate a significant association between overbite relapse and various vertical growth patterns. Therefore, this study cannot suggest a specific treatment or retention protocol based on a craniofacial pattern.

There were no significant differences in overbite relapse between the groups of patients with vertical, horizontal or normal facial growth patterns. Therefore the null hypothesis cannot be rejected and a specific treatment or retention protocol, based on craniofacial pattern, cannot be suggested. Possibly, if the sample size employed in this study was larger differences in overbite relapse could have been detected. Or perhaps, another factor such as potential growth of the alveolar process, as suggested by Bishara et al. (1998) and Ceylan et al. (2001), may be more influential in determining the amount of overbite for an individual, than the vertical parameters of the craniofacial skeleton.

Many studies on the assessment of post-treatment results in orthodontics have indicated that relapse occurs in most cases. As of yet, no variable has been found to be predictive of stability or relapse (Little, 1981, 1988, 1989; Shields, 1985).

Chapter 6 Conclusion & Future Research

6.1 Conclusion

The following conclusions are supported by the present study:

- 1) Facial growth pattern does not influence overbite relapse.
- 2) Growth of the alveolar process may be an important factor influencing overbite.
- 3) It is not possible to predict overbite relapse or stability at present.

6.2 Future Research

A limitation of any study that examines subjects with facial patterns that fall outside the “norm” is sample size; the same can be said of this study. Hundreds and hundreds of records were examined to find the 19 patients considered to have divergent facial patterns. Patients with atypical facial patterns are by definition are rare. Once adequate selection criterion and the need for complete records are added, the ability to obtain a large sample becomes incredibly difficult. Future studies should concentrate on larger sample sizes. Perhaps a larger sample size would reveal a significant association.

In the current study the sample was partitioned into vertical growth pattern at T1 based on having three cephalometric of five measurements (PP-MP, MP-SN, Y-Axis, UAGH/LAFH %, P-A Face Height) that were greater or less than one standard deviation (SD) from normal values. However, at the current time no consensus has yet emerged on the cephalometric measurement(s) or variable(s) that accurately classify a patient as a

vertical or horizontal grower (Sassouni & Nanda, 1964; Subtelny & Sakuda, 1964; Björk, 1969; Schendel et al., 1976; Opdebeeck & Bell, 1978; Sassouni, 1969; Isaacson et al. 1977; Cornforth, 1980 Baumrind et al., 1984; Fields and Proffit et al., 1984; Skieller et al., 1984; Bishara & Jakobsen, 1985; Nanda, 1990; Janson et al., 1994; Blanchette et al., 1996; Leslie et al., 1998; Kolodziej et al., 2002; Naumann et al., 2000; Buschang et al., 2002; Vaden, 2002). Perhaps using an alternate method to classify a patient's vertical growth pattern would yield more conclusive results. However, it seems unlikely that a consensus on the accurate diagnosis of vertical craniofacial pattern will be reached any time soon.

Ideally, an implant study (Björk, 1969) would allow analysis of a subject's response to orthodontic treatment and subsequent relapse, to be determined from stable landmarks. This would allow a more comprehensive understanding of growth rotations, and local dentoalveolar development during and after orthodontic treatment. However, due to ethical limitations it is unlikely an implant study will ever be possible again.

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Chapter 8.0 Appendix

T1 Cephalometric Values

Patient	PP-MP	Y-Axis	MP - SN (°)	P-A Face Height (S-Go/N-Me) (%)	UAFH/LAFH Ratio (N-ANS/ANS-Me) (%)	3 out of 5 variables
1	21.8		35	59.8	92.8	Meso
2	27.4		38.5	63.5	82.6	Meso
3	27.5		35.1	59.3	73.5	Meso
4	31.4	high	33.6	63.7	77.2	Meso
5	29.3		36.4	60.3	78.6	Meso
6	23		28.6	65.1	87.4	Meso
7	22.7		27.4	70.1	77.7	Meso
8	25.8		31.2	64.8	74.9	Meso
9	30.1		35.6	61.7	81.9	Meso
10	26.9		27.7	68.2	70.2	Meso
11	26.4		33.6	63.1	82.7	Meso
12	25.2	low	28	67.2	76.6	Meso
13	28		31.7	64.4	73.7	Meso
14	20.7		27.4	69.4	80.5	Meso
15	18.7	low	34.5	62.7	100.4	Meso
16	22.6		32.7	62.5	94.4	Meso
17	27.2		29.2	67.6	76.7	Meso
18	25.6		32.4	63	80	Meso
19	28.9		32.3	64.1	77.2	Meso
20	21.3		27.5	67.9	78.6	Meso
21	30.8		33.3	63	71.6	Meso
22	28.6		33.4	61.7	86.8	Meso
23	22.5		24.5	71	82.2	Meso
24	26.2		28.3	67.2	75.6	Meso
25	27.4		32.6	63.8	74.9	Meso
26	31.1	high	32.6	60.9	67.9	Doli
27	31.9	high	38.3	60.8	76.4	Doli
28	31	high	39	60.2	78.5	Doli
29	32.6	high	41.5	63	77.9	Doli
30	31	high	31.5	60.9	71.1	Doli
31	32.9	high	38.6	58.5	70.9	Doli
32	31.2	high	40.3	60.8	74	Doli
33	26.5	high	39.1	60.3	80.5	Doli
34	28.5	high	39.1	61	86.4	Doli
35	37	high	35.6	60.8	65.4	Doli
36	20.7		24.4	71.8	92.8	Brachy
37	18.9	low	24.8	72.5	75.5	Brachy
38	15.4	low	19.8	74.7	81.5	Brachy
39	15.5	low	21.2	74	85.9	Brachy
40	19	low	25.8	70	83.4	Brachy
41	22.7	low	25	70.2	79.6	Brachy
42	16.3	low	22.2	74.4	92.6	Brachy
43	19.9		24.6	70.7	91.4	Brachy
44	15.7	low	22.2	74.3	89.8	Brachy

T2 Cephalometric Values

Patient		UAFH/LAFH Ratio										3 out of 5 variables
PP-MP		Y-Axis		MP - SN (°)		P-A Face Height (N-ANS/ANS-Me) (S-Go/N-Me) (%)						
1	20		67.1		33		62.2		89.9	low	Meso	
2	29.8		72.1		40.8	high	60.9	high	81		Meso	
3	23.2		64.6		26	low	70.9	low	85.1		Meso	
4	28.2		66.7		35.6		58.1	high	74.2		Meso	
5	28.6		71.7		36.4		62.5		76.9		Meso	
6	28.6		65.3		30		66.9		74.5		Meso	
7	28.8		65.6		30		66.1		64.2	high	Meso	
8	27.7		63.5		35		64.5		74.4		Meso	
9	20.4		64.4		28		67.7		87.6	low	Meso	
10	20.9		62.1		28		67.2		82.2		Meso	
11	28.8		63.9		29.8		67.4		69.1	high	Meso	
12	33.9	high	68		37.2		60.3	high	75.5		Meso	
13	25.1		66.1		27.3		68.6		78.8		Meso	
14	26.7		67.1		28.5		63.7		66.5	high	Meso	
15	28		67.1		33.4		63.2		79.8		Meso	
16	26.2		66.3		32.4		64.1		79		Meso	
17	25.5		66.5		31.3		65.8		73.3		Meso	
18	19.4		64.4		28.1		67.9		84.4		Meso	
19	28.1		68.4		37.8		59.8	high	74.9		Meso	
20	16.1	low	67.8		31.4		66.4		99	low	Meso	
21	22.2		65.6		33.5		62.3		94.6	low	Meso	
22	25		63.7		27.4		68.4		74.2		Meso	
23	25.8		68.4		36.3		60.4	high	77		Meso	
24	26.2		69.7		31.5		67.3		71.2	high	Meso	
25	21.3		66.2		27.5		67.9		78.6		Meso	
26	26		68.3		33.8		63.7		74.4		Meso	
27	30.1		67.2		35.7		62.1		73	high	Meso	
28	24.6		63.8		27.2		69	low	74.8		Meso	
29	30.7		73.3	high	39	high	63.8		80.3		Meso	
30	27.3		65.6		33.8		62.8		79.6		Meso	
31	23		63.9		26.8	low	69.2	low	83.2		Meso	
32	34.4	high	64.3		31.4		66.7		66.4	high	Meso	
33	29.7		63.2		32.7		62.6		66.5	high	Meso	
34	31.8	high	62.6		32.6		60.9	high	67.9	high	Doli	
35	33.2	high	72.3		42.1	high	59	high	72.9	high	Doli	
36	34.2	high	75.4	high	43.4	high	59.2	high	71.3	high	Doli	
37	17.8	low	63.2		25.6	low	72	low	76.9		Brachy	
38	17.5	low	60.4	low	22.4	low	71.3	low	84.2		Brachy	
39	14.3	low	56.7	low	19.7	low	76.5	low	83.9		Brachy	
40	18.3	low	62.4		23	low	71.8	low	76.6		Brachy	
41	19.5		60.1	low	24.5	low	72.7	low	83		Brachy	
42	20.9		63.6		26.6	low	69.5	low	93.3	low	Brachy	
43	18.1	low	67.2		24.1	low	71.9	low	83.7		Brachy	
44	16.8	low	64.5		23.7	low	71.6	low	89.3	low	Brachy	

T3 Cephalometric Values

Patient										3 out of 5 variables
PP-MP		Y-Axis		MP - SN (°)		P-A Face Height (S-Go/N-Me) (%)		UAFH/LAFH Ratio (N-ANS/ANS-Me) (%)		
1	19.1		68.4		33.5		62.3		90.4	Meso
2	26.2		65		39.2	high	57.7	high	83.3	Meso
3	28.7		61.3	low	31.5		59.9	high	70.2	Meso
4	24		63.8		26	low	70.3	low	85	Meso
5	25.9		65.1		34		60.8	high	72.2	Meso
6	24.2		70.4		31.5		67.6		76.9	Meso
7	28.3		64.9		29.1		69.2	low	71.9	Meso
8	20.3		66.5		23.3	low	73.9	low	72	Meso
9	25.1		62.7		33.8		65.5		80.7	Meso
10	20.9		64.6		28.3		67.7		86.9	Meso
11	21.4		62.2		27.9		67.4		82.9	Meso
12	33	high	72.2		42.2	high	61.8		74.9	Meso
13	26.8		63.6		28.1		69.2	low	71.1	Meso
14	30.4		68.6		35		62.4		77.8	Meso
15	20.7		65.6		23.9	low	72.6	low	81.4	Meso
16	26.6		66.8		27.5		65.5		68.6	Meso
17	27.6		66.7		32.6		64.7		78.5	Meso
18	24.5		65		31.2		65.3		80.7	Meso
19	25.2		64.3		28		69.2	low	67.6	Meso
20	18.6	low	65.6		28.1		67		83.8	Meso
21	28.7		66.8		33.4		64.5		68.6	Meso
22	14.3	low	64.9		28.4		68.6		99.6	Meso
23	22.7		66		34.6		60.1	high	92.3	Meso
24	22.8		67		32.8		63.3		79.7	Meso
25	25.6		68.8		30.5		68.7		72.7	Meso
26	31.4	high	71.9		38.4		63		69.9	Meso
27	20.3		66.5		23.3	low	73.9	low	72	Meso
28	21.7		70.2		31.4		67.5		77.1	Meso
29	29.8		66.3		34.4		64.2		70.4	Meso
30	23		63.5		26	low	70.3	low	79.5	Meso
31	29.9		75	high	39.9	high	62.4		82.1	Meso
32	28.1		66.2		34.8		61.6		78.4	Meso
33	19.1		68.4		33.5		62.3		90.4	Meso
34	21.1		63.5		26.1	low	70.1	low	84.3	Meso
35	21		67.9		26	low	71.1	low	78.2	Meso
36	33.7	high	61	low	27.9		68.4		60.9	Meso
37	28.9		60.5	low	28.4		67.7		62.9	Meso
38	18.7	low	61.5	low	25.1	low	72.5	low	75.2	Brachy
39	14.7	low	62.4		23.5	low	70.6	low	90.6	Brachy
40	14.5	low	56.8	low	19.4	low	76.7	low	83.8	Brachy
41	21.2		61.4	low	22.6	low	74.3	low	68.7	Brachy
42	17.5	low	61.1	low	21.3	low	75.2	low	77.2	Brachy
43	20.1		60	low	24.7	low	71.3	low	82.4	Brachy
44	16.1	low	63.4		22.3	low	74.4	low	87.6	Brachy

Overbite Measurements

Patient	T1 right	T1 left	T1 Average	T2 right	T2 left	T2 Average
1	4.89	4.82	4.855	2.15	2.15	2.15
18	6.02	5.2	5.61	0.95	0.74	0.845
15	4.87	5.52	5.195	1.01	1.01	1.01
20	7.04	6.38	6.71	1.32	1.32	1.32
40	6.92	7.9	7.41	0.86	0.92	0.89
34	4.73	4.73	4.73	2	2	2
29	1.91	2.39	2.15	1.82	2.35	2.085
2	5.92	5.34	5.63	0.57	0.72	0.645
16	5.38	5.1	5.24	0.73	0.55	0.64
11	5.48	6.18	5.83	1.19	1.05	1.12
9	1.19	-0.69	0.25	0.51	0.92	0.715
3	3.27	3.68	3.475	2.67	2.67	2.67
31	3.47	4.12	3.795	2.15	2.15	2.15
7	5.63	5.15	5.39	1.6	1.6	1.6
25	4.13	4.01	4.07	0.71	0.71	0.71
33	7.26	6.57	6.915	0	0	0
5	4.27	4.24	4.255	1.73	1.4	1.565
22	2.2	2.75	2.475	1.64	1.92	1.78
13	4.1	3.69	3.895	0	0	0
44	5.96	5.66	5.81	1.78	1.89	1.835
37	4.24	4.24	4.24	1.56	1.79	1.675
32	3.29	3.09	3.19	2.12	2.13	2.125
36	7.35	6.99	7.17	1.72	1.66	1.69
24	5.96	5.43	5.695	0.9	0.9	0.9
39	4.64	4.87	4.755	2.78	3.05	2.915
4	5.62	5.61	5.615	0.87	0.87	0.87
38	4.43	3.83	4.13	2.07	1.76	1.915
35	1.87	2.18	2.025	1.72	2.11	1.915
21	5.72	5	5.36	2.25	1.81	2.03
19	3.31	3.29	3.3	1.94	1.94	1.94
23	5.59	5.82	5.705	1.45	1.76	1.605
42	3.24	1.26	2.25	0.91	0.72	0.815
26	0.43	0.9	0.665	1.14	1.69	1.415
41	4.84	5.53	5.185	1.45	1.45	1.45
17	3.93	3.63	3.78	1.72	1.51	1.615
30	3.17	3.13	3.15	1.86	1.85	1.855
8	0.84	1.17	1.005	0.51	0.97	0.74
14	5.48	5.46	5.47	1.65	1.28	1.465
12	6.16	6.48	6.32	1.2	1.46	1.33
43	6.88	6.87	6.875	1.01	1.01	1.01
27	4.27	4.56	4.415	1.38	1.14	1.26
10	4.12	4.13	4.125	2.28	2.28	2.28
28	0.23	0.83	0.53	1.88	1.69	1.785
6	4.57	3.86	4.215	1.41	1.4	1.405

Overbite Measurements

Patient	Change T1-T2	T3 right	T3 left	T3 Average	Change T2-T3	Change T1-T3
1	-2.705	2.33	2.72	2.525	0.375	-2.33
18	-4.765	2.18	1.68	1.93	1.085	-3.68
15	-4.184	4.03	4.46	4.245	3.235	-0.95
20	-5.39	2.78	2.5	2.64	1.32	-4.07
40	-6.52	2.78	2.91	2.845	1.955	-4.565
34	-2.73	2.66	2.67	2.665	0.665	-2.065
29	-0.065	2.93	2.5	2.715	0.63	0.565
2	-4.985	2.89	3.11	3	2.355	-2.63
16	-4.6	3.64	3.82	3.73	3.09	-1.51
11	-4.71	2.57	3.31	2.94	1.82	-2.89
9	0.465	1.32	1.51	1.415	0.7	1.165
3	-0.805	2.04	2.08	2.06	-0.61	-1.415
31	-1.645	3.8	3.19	3.495	1.345	-0.3
7	-3.79	2.26	2.54	2.4	0.8	-2.99
25	-3.36	1.68	1.68	1.68	0.97	-2.39
33	-6.915	3.39	3.95	3.67	3.67	-3.245
5	-2.69	3.18	3.87	3.525	1.96	-0.73
22	-0.695	2.19	2.51	2.35	0.57	-0.125
13	-3.895	2.15	2.07	2.11	2.11	-1.785
44	-3.975	3.44	3.37	3.405	1.57	-2.405
37	-2.565	2.99	2.71	2.85	1.175	-1.39
32	-1.065	1.8	1.8	1.8	-0.325	-1.39
36	-5.48	3.2	3.21	3.205	1.515	-3.965
24	-4.795	2.96	2.95	2.955	2.055	-2.74
39	-1.84	2.68	2.68	2.68	-0.235	-2.075
4	-4.745	2.68	3.21	2.945	2.075	-2.67
38	-2.215	2.66	2.41	2.535	0.62	-1.595
35	-0.11	1.37	1.37	1.37	-0.545	-0.655
21	-3.33	2.2	2.87	2.535	0.505	-2.825
19	-1.36	2.45	2.46	2.455	0.515	-0.845
23	-4.1	2.84	2.85	2.845	1.24	-2.86
42	-1.435	2.1	1.95	2.025	1.21	-0.225
26	0.75	2.29	1.85	2.07	0.655	1.405
41	-3.735	2.27	2.3	2.285	0.835	-2.9
17	-2.165	0.93	0.92	0.925	-0.69	-2.855
30	-1.295	2.14	2.4	2.27	0.415	-0.88
8	-0.265	1.17	0.71	0.94	0.2	-0.065
14	-4.005	2.87	2.71	2.79	1.325	-2.68
12	-4.99	2.99	3.17	3.08	1.75	-3.24
43	-5.865	2.14	2.14	2.14	1.13	-4.735
27	-3.155	2.17	2.44	2.305	1.045	-2.11
10	-1.845	2.74	2.73	2.735	0.455	-1.39
28	1.255	2.91	2.96	2.935	1.15	2.405
6	-2.81	3.4	3.04	3.22	1.815	-0.995