# A LONG TERM EVALUATION OF THE CURVE OF SPEE STABILITY FOLLOWING ORTHODONTIC LEVELING

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A dissertation submitted in partial fulfillment of the requirements for the degree of

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FACULTY OF GRADUATE STUDIES

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# A Long Term Evaluation of the Curve of Spee Stability Following Orthodontic Leveling

BY

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MASTER OF SCIENCE

# ABSTRACT

The objectives of this study were to establish whether there is an association between pre-treatment facial morphology and initial magnitude of the curve of Spee and to determine whether vertical facial morphology influences curve of Spee relapse. This retrospective cephalometric study consisted of analyzing the records of 44 Angle Class I and II subjects obtained from the archives of a University Graduate Orthodontic Clinic. To be included in the study subjects had to be treated non-extraction with full fixed edgewise appliances. Subjects required complete pre-treatment, post-treatment and minimum five years post-retention cephalometric and plaster model records. Patients were grouped according to vertical facial type based on five cephalometric measurements. Nine brachycephalic, 10 dolicocephalic and 25 mesocephalic facial types were identified using the defined parameters. Plaster study models corresponding to pre-treatment, post-treatment and a minimum of five years post-treatment were reproducibly photographed using a digital camera. Calibrated curve of Spee measurements were obtained for each time point and compared statistically. No significant differences were found in pre-treatment curve of Spee depth between male and female subjects and right and left sides. The brachycephalic facial type demonstrated an increased initial curve of Spee depth; however the difference was not statistically significant. The hypodivergent phenotype was shown to exhibit a higher probability of re-establishing the initial curve of Spee following orthodontic leveling compared to other vertical facial types. ($p<0.05$) Orthodontic treatment biomechanics can successfully level the curve of Spee in all three vertical facial types. The magnitude of the pre-treatment curve of Spee depth does not seem to be associated with specific vertical facial patterns. Great variability exists for pre-treatment curve of Spee depth in all facial types. The hypodivergent facial type seems to demonstrate a statistically significant increase in post-treatment relapse ($p<0.05$) compared to other vertical facial types; although, the clinical significance of this association is uncertain.

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- My parents for not stopping after two children
- My wife Pam and daughter Emily for filling my life with happiness

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# CHAPTER 1

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# CHAPTER 1

# INTRODUCTION

## 1.1 FOREWORD

Relapse of orthodontic results is a fundamental concern of all orthodontic practitioners. Seemingly good occlusion and tooth position at the end of active orthodontic therapy may often deteriorate toward pre-treatment arrangements. Unfortunately, in some cases this can occur to a great extent.

Many researchers have identified various aspects involved in orthodontic therapy that increases the likelihood of relapse. However, little attention has been paid to the possible interaction of curve of Spee relapse and facial morphology.

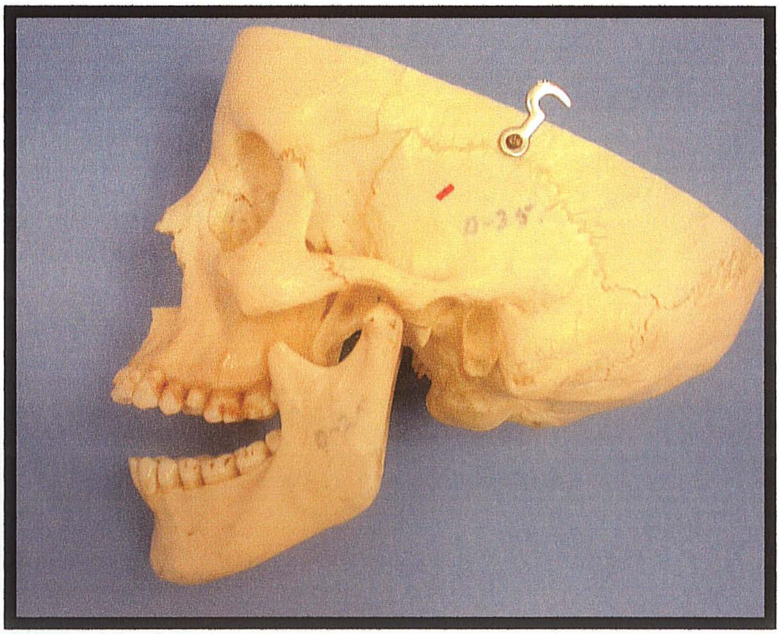
One of the customary goals of orthodontic treatment is to level a deep curve of Spee. The stability of such a goal has not been extensively studied in the literature. In addition, no recent study has identified whether patients with different vertical facial patterns are at an increased risk of re-establishing the curve of Spee following orthodontic leveling.

## 1.2 DEFINITIONS

**1.2.1 Leveling** – The term leveling will be used to describe the process of bringing the incisal edges of the anterior teeth and the buccal cusp tips of the posterior teeth into the same horizontal plane (Baldridge, 1969)

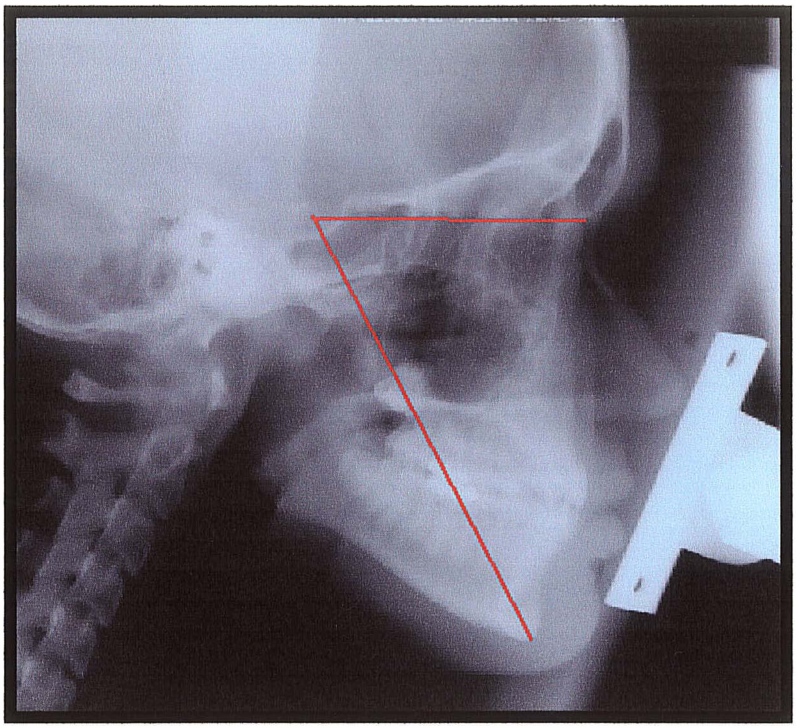
**1.2.2 Curve of Spee** – Several different definitions have been proposed to characterize the curve of Spee. For the purposes of this paper the curve of Spee shall be defined as the curve of the mandibular dentition when observed from the lateral view. (Figure 1.1) A superior boundary or reference is formed through establishing a horizontal reference line between the mandibular incisor tips and the distobuccal cusp of the mandibular second molar. The cusp tips of the mandibular canine, first and second bicuspid and the molar cusp tips represent the inferior boundaries of the curve.

**Figure 1.1 Lateral aspect of human skull representing mandibular dental curvature.**



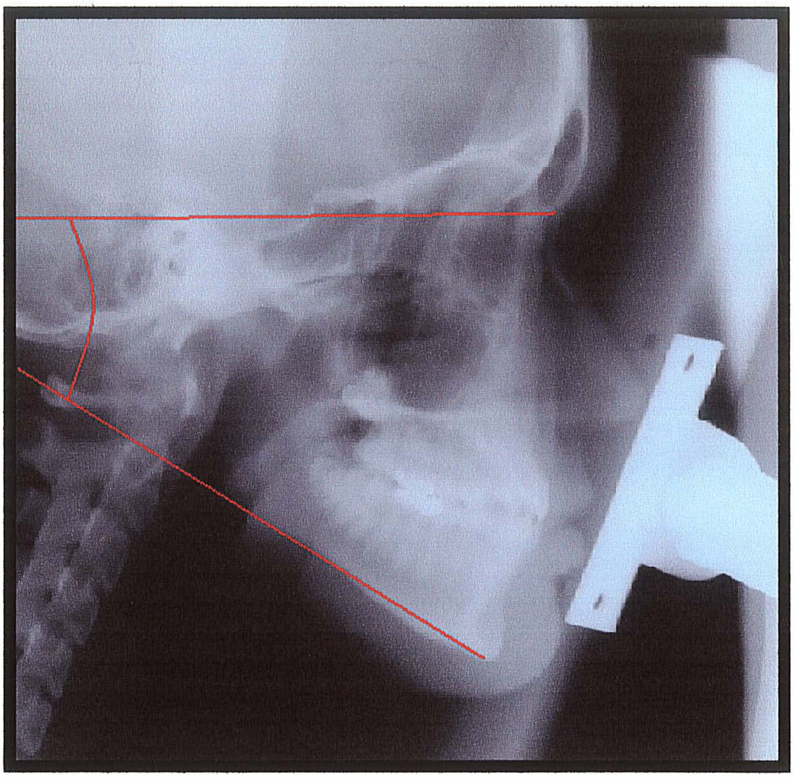
**1.2.3 Y-Axis** (Sella-Nasion to Sella-Gnathion) – Defined cephalometrically as the angle formed by the intersecting planes Sella - Gnathion to Sella - Nasion. (Figure 1.2) The norm value has been established at 67 +/- 5.5 degrees (Chung et al., 2002)

**Figure 1.2 Lateral cephalogram with Y-Axis indicated in red.**



**1.2.4 Mandibular Plane to Sella-Nasion Angle (MP-SN)** – Defined cephalometrically as the angle formed through the intersection of the mandibular plane to Sella-Nasion. (Figure 1.3) The norm has been established as 33+/- 6 degrees. (Fields et al., 1984; Bishara et al., 1985; Bushang et al., 2002)

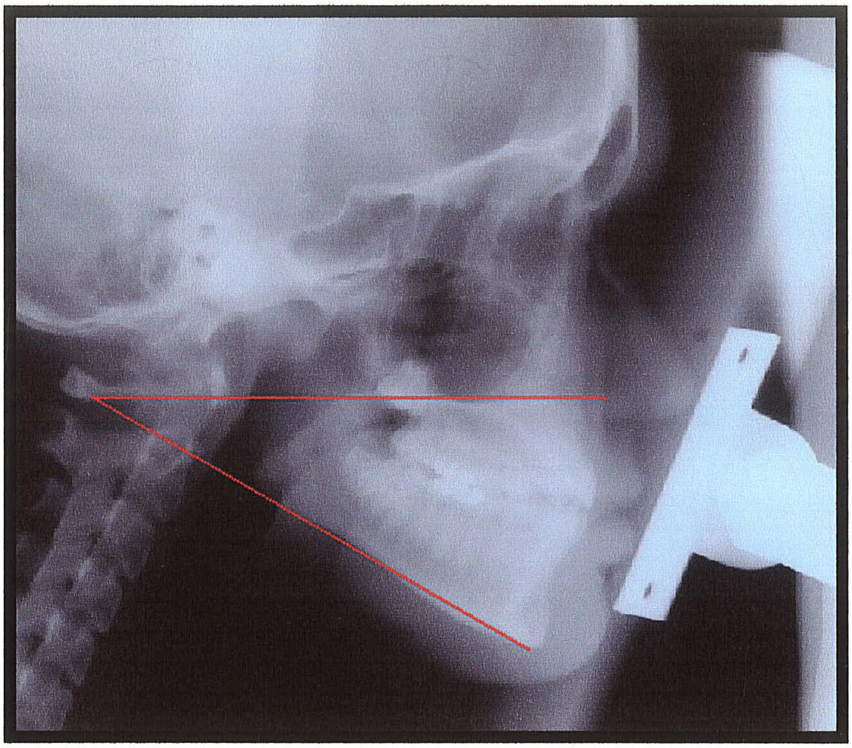
**Figure 1.3 Lateral cephalogram with mandibular plane to Sella Nasion angle (MP-SN) indicated in red.**



**1.2.5 Palatal Plane to Mandibular Plane Angle (PP-MP)** – Defined cephalometrically as the angle formed through the intersection of the palatal plane (ANS-PNS) and the mandibular plane. (Figure 1.4) The established norm is 25+/-6 degrees.

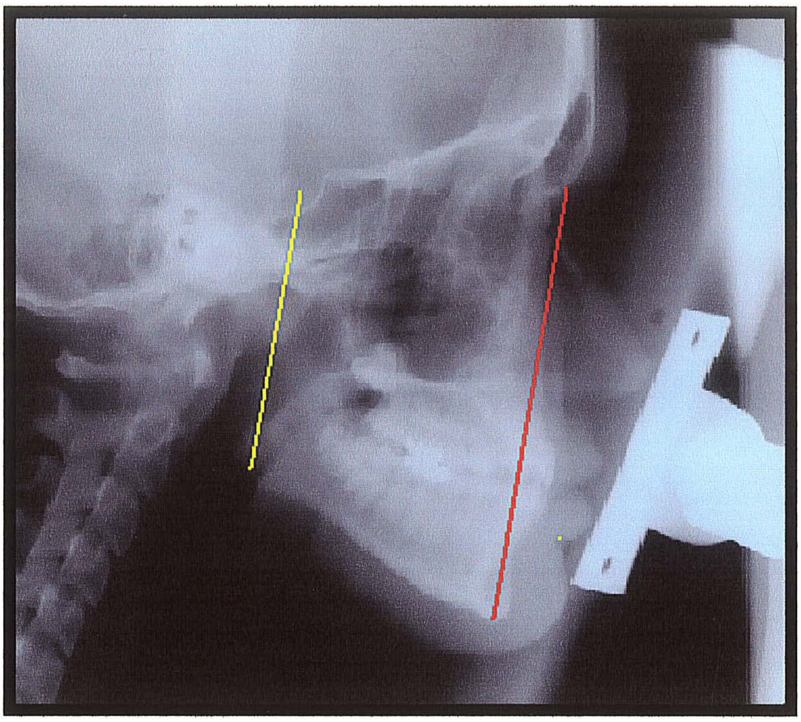
(Subtelny et al., 1964; Fields et al., 1984; Nanda, 1990)

**Figure 1.4 Lateral cephalogram with palatal plane-mandibular plane angle (PP-MP) indicated in red.**



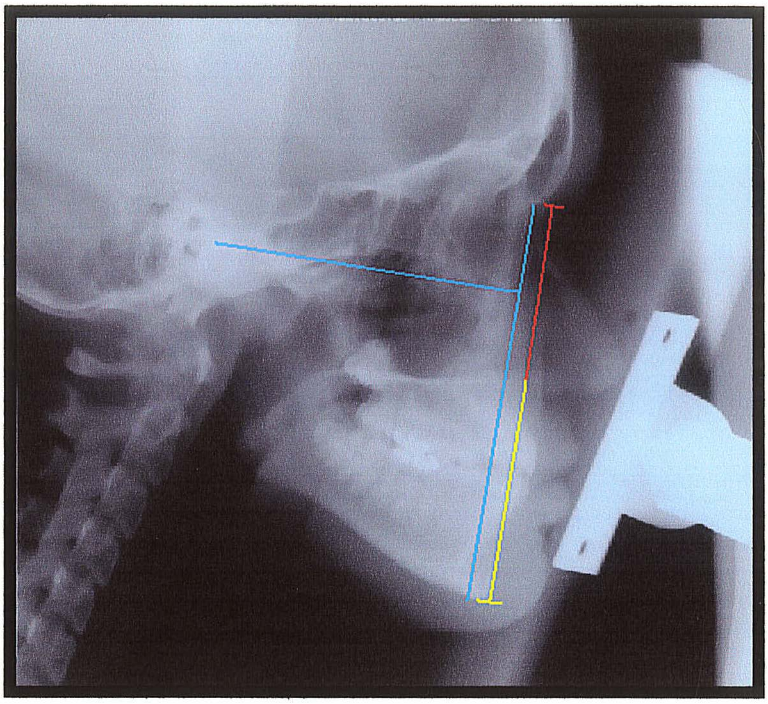
**1.2.6 P-A Face Ht (Sella to Gonion/Nasion to Menton % (S-Go/N-Me%)**– Defined cephalometrically as the ratio value obtained through division of the posterior face height by the anterior face height. (Figure 1.5) The established norm for this parameter is 65+/- 4% (Bishara et al., 1985; Bushang et al., 2002)

**Figure 1.5 Lateral cephalogram denoting ratio posterior face height to anterior face height (P-A%). Posterior face height and anterior face height represented by yellow and red lines respectively.**



**1.2.7 Ratio of UAFH to LAFH (N-ANS/ANS-Me %)** - Defined cephalometrically as the ratio of nasion to anterior nasal spine/anterior nasal spine to menton expressed as a percentage. (Figure 1.6) The established norm for this parameter is 80 +/- 7% (Sassouni, 1969; Isaacson et al., 1977; Nanda, 1990; Blanchette et al., 1996)

Figure 1.6 Lateral cephalogram indicating ratio of upper anterior face height (UAFH) to lower anterior face height (LAFH). UAFH and LAFH represented by red and yellow lines respectively. Blue line denotes constructed perpendicular to Frankfort horizontal (FH).



## 1.3 SIGNIFICANCE OF THE PROBLEM

One of, if not the most important problems facing orthodontic practitioners is post treatment instability. Many patients are found to demonstrate a tendency to relapse in the direction of pre-treatment values. It is self-evident why researchers have attempted to elucidate features common to patients who experience the greatest degree of relapse.

The vast majority of relapse studies are unable to provide useful clinical predictors of orthodontic relapse. Many of the studies evaluate relapse tendencies associated with dental parameters such as inter-canine width, inter-molar width, arch length and tooth dimensions and ignore the possible skeletal or soft tissue influences. (Little et al., 1988; Kahl-Nieke et al., 1995; Artun et al., 1996) In addition, many of the studies are comprised of inhomogeneous samples (Kahl-Nieke et al., 1995; Artun et al., 1996) and have post-treatment re-evaluation periods that are far too short in duration to draw significant conclusions. (Miyazaki et al, 1997)

One of Andrews "Six Keys to Occlusion," involves a flat or slightly pronounced curve of Spee. (Andrews, 1972) It is therefore a common objective in the majority of patients to level exaggerated curves. It is surprising that little attention has been paid to investigating the long-term stability of such a common treatment objective.

The formation and significance of the curve of Spee in humans is largely unknown; although, several hypotheses have been suggested. (Wheeler, 1970; DuBrul, 1980;

DuBrul, Osborn, 1982; Barager and Osborn, 1987; Enlow, 1990; Osborn, 1993; Ash and Ramfjord, 1995). The vast majority of these hypotheses share common themes of the curve of Spee resulting from adaptational or morphological processes. It is therefore possible that a patient's skeletal pattern may have an influence on the development of the curve of Spee and more importantly to orthodontists, may influence the relapse propensity following orthodontic leveling.

It is also generally accepted that leveling an exaggerated curve of Spee requires additional arch length. (Baldridge, 1969, Proffit, 1986, Garcia 1986, Germane et al., 1989) It could be argued that curve of Spee relapse could either beneficially or detrimentally affect the stability of an orthodontic result. A curve of Spee that is level at the end of orthodontic treatment may allow for the greatest relapse accommodation. Instead of manifesting as lower incisor crowding, arch length changes may be expressed as deepening of the curve of Spee over time.

## 1.4 PURPOSE OF THE STUDY

The aim of the present study is the following:

1. Determine whether a relationship exists between vertical facial pattern and initial magnitude of the curve of Spee
2. Determine the long term stability of the curve of Spee following orthodontic leveling
3. Determine whether a relationship exists between curve of Spee relapse and vertical facial pattern
4. Evaluate the applicability of a novel approach to measuring the curve of Spee

## 1.5 NULL HYPOTHESES

**Null Hypothesis #1** There is no relationship between initial curve of Spee depth and vertical facial pattern

**Null Hypothesis #2** The curve of Spee will not change when leveled through orthodontic treatment

**Null Hypothesis #3** There is no association between vertical facial pattern and re-establishment of the curve of Spee following orthodontic leveling

**Null Hypothesis #4** There is no difference between the measurement characteristics of conventional curve of Spee measurements with a novel measurement

# CHAPTER 2

## LITERATURE REVIEW

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 WHAT IS THE CURVE OF SPEE?

The curve of Spee was first described by Fendinand Graf Spee in 1890. Spee examined skulls with abraded teeth viewed from the lateral aspect and observed that the occlusal surfaces of the dentition are arranged in a downward convex curve. Based on his studies, Spee introduced three propositions. (Table 2.1)

**Table 2.1 Initial propositions suggested by Ferdinand Graf Spee in 1890.**

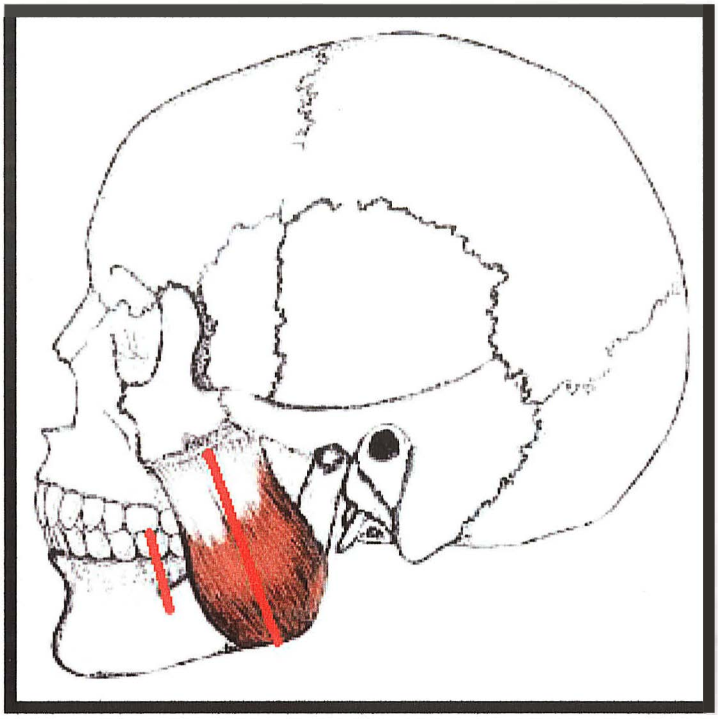
| | |
|---|---|
| **Proposition 1** | *When viewed from the profile the occlusal surfaces of the molars lie on the arc of a circle. When this arc is extended posteriorly, the anterior surface of the condyle is intersected. When both sides of the dentition are considered, a cylinder is formed. The central axis of the cylinder is located somewhere posterior to the midorbital plane posterior to the "crista lacrimalis posterior." The radius of the cylinder was determined to be approximately 6.5-7.0 cm.* |
| **Proposition 2** | *The curve is more readily apparent in well-worn dentitions. Although the curve is demonstrable in dentitions with intact cusp tips, the curve is more readily discernable in dentitions subjected to heavy dental attrition.* |
| **Proposition 3** | *In addition to the molars, the curve will intersect the occlusal surfaces of other teeth in the dentition as well as the condyle.* |

Hitchcock conducted a study in 1983 to test the propositions set forth by Spee. To satisfy Spee's second proposition, the study involved taking lateral cephalograms of 39 prehistoric skulls from the Shell Mound Indian tribe that were found to exhibit moderate amounts of dental attrition. Hitchcock traced four arcs of different radii and location on the skull lateral cephalograms and found that Spee's propositions could be verified when an arc was formed whereby, the mesial aspect of the mandibular condyle was contacted along with the distal cusp tip of the second molar and the mesial cusp tip of the mandibular first molar. This manufactured arc was the closest to satisfying Spee's propositions; however, a common exception was found in that the mandibular incisor often fell outside of the formed arc.

Several hypotheses have been put forth to explain the significance of the curve of Spee. For example, Enlow (1990) suggested that this morphological arrangement serves as an adjustment during facial growth that provides intrinsic compensations for discrepancies in the antero-posterior plane of space. Wheeler (1970) suggested that a curved arrangement of teeth is necessary to establish several simultaneous tooth-to-tooth contacts during the process of mastication. In addition, it has been argued that an antagonistic curved arrangement of teeth in the maxillary arch allows uniform separation during excursive mandibular movements. Ash and Ramfjord (1995) suggest that there is a relationship between the curve of Spee, molar cusp height and the angle of the eminentia. The relationship of the occlusal plane to the angle of the eminentia is suggested to be an important determinant in posterior cusp height. As the angle of the eminentia more closely approximates the plane of occlusion, posterior cusp height should correspondingly become reduced to eliminate to interferences during protrusive mandibular movements. In addition, as the radius of the curve of Spee becomes smaller a corresponding decrease in posterior cusp heights should be seen to eliminate protrusive interferences.

Several authors suggest that the curve of Spee offers significant functional biomechanical advantages. DuBrul (1980) contends that the curve of Spee is an adaptation process to the forces placed on the teeth. As a result, the mesial inclination of the molar teeth provides the maximum resistance to forces generated by the elevator muscles. Osborn (1982) suggests that the morphologic arrangement of teeth in the curve of Spee is more physiologically appropriate than their arrangement along a single plane since the latter could compromise masticatory function during excursive mandibular movements. Similar to DuBrul, Osborn (1982) suggests that the curvature allows masticatory forces to be more suitably directed down the long axis of the posterior teeth leading to more stable dental arches. Barager and Osborn (1987) using mathematical models, found a relationship between the curve of Spee and the muscles of mastication. They demonstrated that mastication is most efficient when the bite force is directed down the long axis of teeth and suggested that this is most readily achieved when the mandibular teeth are arranged on a slight curve. Osborn (1993) further investigated the biomechanical relationship between the orientation of muscles of mastication and the curve of Spee. He found that the angulation of the mandibular molars closely approximated the orientation of the superficial fibers of the masseter muscle in a number of species including humans. (Figure 2.1)

**Figure 2.1 Diagram representing relationship of mandibular molar angulation with angulation of superficial fibers of the masseter muscle in humans. (Adapted from diagram found at www.is.wayne.edu/mnissani/ bruxnet/Effects)**

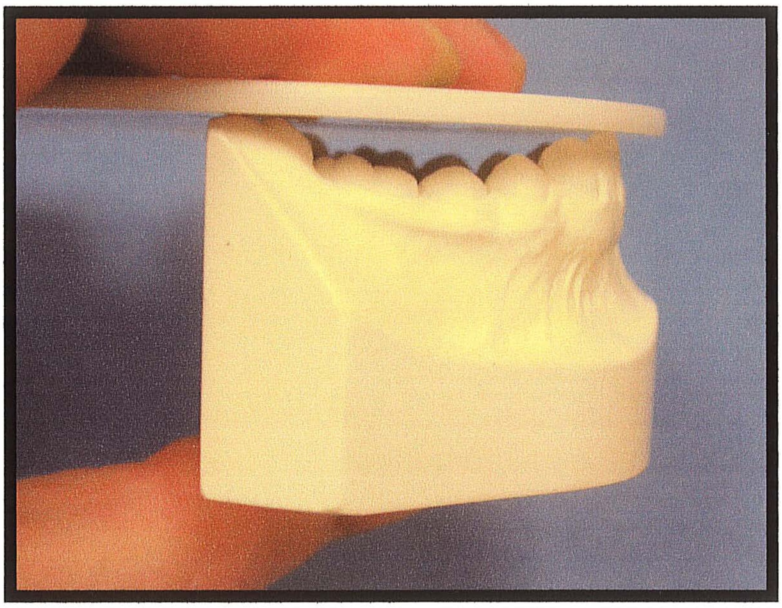


## 2.2 MEASUREMENT OF THE CURVE OF SPEE

When originally described by Spee in 1890, the curve of Spee involved both the maxillary and mandibular arches. The term has been modified over time in orthodontics to represent only the organization of the occlusal surfaces of the teeth in the mandibular arch when viewed from the midsaggital plane.

Clinically, the curve of Spee is often observed through placement of a flat plane on top of the mandibular study model and visualizing the curve from the lateral perspective. (Figure 2.2) Identification of deep curves of Spee are also customarily performed during a routine examination through unilateral placement of a mirror handle such that it contacts the most distal molar cusp tip posteriorly and the mandibular incisor teeth anteriorly.

**Figure 2.2 Customary clinical evaluation of the curve of Spee using a flat plane.**



Studies to investigate the curve of Spee have used a variety of methods. This lack of consensus compromises comparative data on the curve of Spee. For example, Bishara (1989) used a plane formed between the distal cusp of the second molar and the incisal edges and averaged of the sum of the perpendicular distances to individual cusp tips on each side. Sondhi et al (1980) calculated the curve of Spee by summing the perpendicular distances of the cusp tips to a plane formed between the lower incisors and the first molar. Braun et al (1996) on the other hand used the sum of the maximum depth on both sides to a plane formed between the incisal edged and the distobuccal cusp of the second molar. De Praeter et al (2002) used a plane formed between the lower incisors and the distobuccal cusp of the second molar and summed the perpendicular distance between the canine, pre-molar and molar cusp tip to the constructed reference line on both sides.

## 2.3 THE CORRELATION BETWEEN ARCH LENGTH AND THE CURVE OF SPEE

Andrews (1972) characterized "The Six Keys to Normal Occlusion." In this outstanding contribution, Andrews outlined six significant characteristics observed in 120 non-orthodontic normal occlusions. Andrews (1972) indicated that the planes of occlusion found in normal occlusions ranged from flat to having slight curves of Spee. Andrews argued that the arrangement of teeth that allowed the best intercuspation, from a geometrical standpoint, was when the plane of occlusion is relatively flat. In contrast, a deep curve of Spee would result in a more contained area for maxillary arch alignment, making good intercuspation impossible.

Several investigators have studied the effect of leveling the curve of Spee on arch circumference. It is generally accepted that leveling a deep curve of Spee results in an increase in arch perimeter; however, there is little consensus as to the amount.

Proffit and Akerman (1986), suggests that a 1:1 relationship exists between depth of curve of Spee and arch circumference per side. An additional 2.0 mm of arch circumference is said to be required for each 1.0 mm of curve of Spee depth leveled.

In 1969, Baldridge examined thirty mandibular casts that showed initial exaggerated curves of Spee. The sample was also chosen to have all of the permanent teeth except for third molars and with good alignment of the dentition. Baldridge (1969) measured initial arch length and depth of the curve of Spee using an adapted ligature wire and a Boley gauge respectively. These initial arch circumference and curve of Spee measurements were compared to those obtained from models with teeth reset in wax to eliminate the curve and create an ideal occlusion. In addition, Baldridge (1969) eliminated other arch circumference influences by not allowing expansion or anterior labial tipping during the re-setting of the model teeth. From his comparisons he calculated a linear relationship between arch circumference and leveling the curve of Spee. The relationship was found to be $Y=0.488X-0.51$, where Y represents the arch length differential in millimeters and X represents the sum of the right and left side maximum depths of curve of Spee in millimeters.

Garcia (1985) also attempted to elucidate the relationship between arch circumference and leveling the curve of Spee. Garcia (1985) examined 100 patients with complete dentitions including the third molars, all second molars in good occlusion, absence of occlusal attrition and absence of ectopic eruptions. Similar to Baldridge (1969), Garcia (1985) found a linear relationship between increase in arch circumference and leveling of a curve of Spee represented by the regression formula $Y=1.34+0.657X$, where $X$ represents the summed total of the maximum depth in each quadrant. Garcia (1985) also found no sexual dimorphism pertaining to the curve of Spee measurements.

Germane et al (1992) investigated the effects of leveling the curve of Spee on arch circumference of two different arch forms, a catenary curve and a Bonwill Hawley arch form. In their study, Germane et al (1992) used inter-molar and average mesio-distal tooth dimensions provided by Moyer's (1974) to construct a mathematical model relating depth of curve of Spee to arch circumference. The group found that mathematically the two arch forms behaved very differently when leveled. The Catenary arch form required less arch length to level when compared to the Bonwill-Hawley arch form although the results were not significant. Unlike previous investigators, the group found that the relationship was non-linear and was consistently less than a 1:1 relationship for curves of Spee less than 9.0mm. Curve of Spee depths of 9.0mm or 10.0mm were found to require greater than a 1:1 relationship to level.

Braun et al (1996) examined twenty-seven casts of untreated patients to determine the relationship between arch circumference and leveling the curve of Spee. He argued that previous studies involved a significant degree of measurement error as well as inaccurate assumptions when determining the relationship. Braun (1996) included only casts with fully developed dentitions and no absent teeth excluding the third molars. Casts with ectopically erupted teeth or severe attrition were excluded. The curve of Spee was measured bilaterally using the mandibular incisors and the distal cusp tips of the second molars as the superior plane. The cusp tips of each cast were subsequently measured using a precision co-ordinate machine and the three dimensional point locations recorded. From this data arch circumferences of the 27 subjects were also calculated. Braun et al (1996) then calculated the amount of additional arch space required to level of the curve of Spee by comparing the three dimensional arch circumference to a constructed horizontal planar projection arch circumference. The investigators calculated a linear regression formula similar to Baldridge (1969) and Garcia (1985); however, the magnitude was much smaller. The regression equation calculated from the data was $Y=0.2462\ X-0.1723$ where Y represents the arch circumference differential in millimeters and X the sum of the right and left side curve of Spee in millimeters. Braun et al (1996) suggest that the arch circumference loss related to curve of Spee leveling is not as important as previously suggested if adequate treatment mechanics are employed. He argued that lower incisor proclination is the most important factor in arch circumference leveling and segmental mechanics should be employed in situations where arch circumference changes are critical.

## 2.4 LEVELING THE CURVE OF SPEE THROUGH ORTHODONTICS

The importance of leveling the curve of Spee as a treatment goal is well documented in the orthodontic literature. (Baldridge, 1969; Andrews, 1972; Germane et al., 1992; Orthlieb, 1997) Unfortunately however, there is no consensus as to the most appropriate and stable means of leveling a deep curve of Spee. Vertical movement of the dentition to allow the cusp tips and incisal edges to lie on a flat plane may be accomplished in one of several ways. According to Proffit (2000) there are three possible ways of leveling a lower arch with an excessive curve of Spee: (1) absolute intrusion of incisors (2) relative intrusion of incisors and (3) posterior eruption.

Absolute lower incisor intrusion involves moving the teeth inferiorly independent of the posterior segments. Burstone (1977) suggested using a segmental arch technique to accomplish this goal. According to Burstone (1977) apically directed forces in the range of 12.5 grams through the center of resistance of the lower teeth are required to move the incisor teeth inferiorly while maintaining the posterior anchorage segment.

The process of relative intrusion involves maintaining vertical incisor position while allowing vertical dentoalveolar development of the posterior dentition. This has an obvious limitation in that it may only be accomplished in the growing orthodontic patient. Conversely, posterior eruption involves maintaining or limiting the vertical position of the incisors while the posterior segments are orthodontically extruded.

Dake and Sinclair (1989) evaluated the long term-stability of subjects who underwent two different overbite reduction procedures. Sixty matched Class I, deep bite low angle non-extraction cases had curves of Spee leveled using either posterior tooth eruption as in Tweed type mechanics utilizing reverse curve of Spee wires or through the use of utility intrusion arches similar to those commonly used in the Bioprogressive technique. (Ricketts, 1969) Dake and Sinclair (1989) found that both techniques were effective in reducing overbite and that the changes remained stable after an average post-treatment period of 4 years 6 months. The theory however that utility arches may produce absolute intrusion was not validated. The group found that incisor intrusion measured cephalometrically was not significantly different from the group treated with reverse curve of Spee mechanics.

Weiland et al. (1996) evaluated the efficacy of overbite reduction in 50 adult low-angle deep-bite malocclusions achieved through reverse curve of Spee mechanics and the segmented arch technique recommended by Burstone (1966). The group used cephalometrics to determine that patients with overbite reduced using the segmental arch technique is superior when absolute intrusion of lower incisors is indicated. Unfortunately, neither of the previously mentioned studies assessed relapse tendencies of curve of Spee and study models were not used to identify changes.

## 2.5 CURVE OF SPEE RELAPSE FOLLOWING ORTHODONTIC TREATMENT

Numerous studies have quantified the amount and type of relapse that often occurs following orthodontic treatment. (Fidler et al., 1956; Little, 1975; Sinclair, 1983; Williams, 1985; Glenn et al., 1987, Little et al., 1988, Bishara et al., 1989; Dake et al., 1989). These studies are often limited to changes in arch dimension, overjet, overbite and mandibular incisor crowding. Very little research to date has been focused on the changes in the curve of Spee following orthodontic leveling.

One of the early goals of orthodontic treatment is leveling a deep curve of Spee. Andrews (1972) recommended that the curve of Spee be leveled as a form of over-treatment due to the natural tendency for the curve to partially re-establish following orthodontics. Koyama (1979) studied the relapse propensity in sixty patients treated orthodontically with four first pre-molar extractions. He found that the curve of Spee generally became deeper during the post-orthodontic phase. Similarly, Kim et al. 1999 when examining the relapse of Class II division 2 patients found that the curve of Spee decreased through treatment but increased significantly during the post-retention period. Carcara et al. (2001) investigated the long-term stability of leveling the curve of Spee using the Alexander Discipline. The sample consisted of 31 patients records selected from the private practice of Dr. R.G. Alexander. Subjects were selected according to the following inclusion criteria; treated non-extraction, ANB>4°, a least on half cusp Class II molar relationship, overbite of 50% or greater and a curve of Spee 2.0mm or greater.

Records consisted of pre-treatment, post-treatment and post-retention dental models with the average post-retention period being 7 years 5 months after the removal of fixed retention. The curve of Spee was measured at all time points bilaterally using the procedure adapted from Koyama (1979) and compared. The group found that for pre-treatment curves of 2.0-4.0mm the curve of Spee reestablishes to a lesser extent than was present prior to orthodontic treatment. For patients with curves of Spee of 2.0-4.0mm where the curve of Spee was not completely leveled during orthodontic treatment, the re-establishment of the curve of Spee increased significantly. 88.9% of subjects relapsed when the curve of Spee was incompletely leveled compared to 50% in the leveled subpopulation.

Kuitert et al. (2000) investigated the changes of form and depth of the curve of Spee during and after orthodontic treatment. The study involved 115 subjects selected based on complete sets of records and good treatment results. Photographs of orthodontic models taken at pre-treatment, post-treatment and post-retention were used to measure the deepest linear dimension of the curve of Spee and compared. Kuitert et al. (2000) found that during treatment 72% of the deep curves were corrected to normal curves. Of the subjects deemed to have normal curve of Spee measurements at the end of treatment, 10% changed with most of these once again becoming deep. Interestingly, of the patients categorized as having abnormal curves at the end of treatment, 50% changed to a normal curve. In addition, at post-retention, 58% of subjects with deep curves had pre-treatment measurements in the deep or normal range. It was concluded from the study that the original depth of the curve of Spee is not predicative for post-retention depth. Also, some other factors may be responsible in terms of stability of the curve of Spee as 50% of the abnormal curves improve and 25% of the normal curves deteriorate with time.

## 2.6 CLASSIFICATION OF VERTICAL GROWTH

Recognizing characteristics associated with various vertical growth patterns has been attempted by both researchers and clinicians and have generated inconclusive results. There is an obvious advantage to the orthodontic practitioner in elucidating characteristics that allow identification of extremes of vertical facial growth. With the development of the lateral cephalogram by Broadbent in 1931, orthodontics has focused a great deal of attention on cephalometric measurements that may be used to describe and predict various facial patterns.

In a review article by Buschang et al. (2002) on vertical facial patterning, it was suggested that various morphologic characteristics could be associated with patients with extreme vertical growth capacity. Buschang et al. (2002) found that increased MP-SN angles, increased LAFH measurements, more obtuse gonial angles, increased LAFH: UAFH ratios, decreased posterior to anterior face heights and excessive dentoalveolar heights were indicative of the hyper-divergent facial type. It has also been suggested that the angulation of the mandibular plane to the anterior cranial base may be used in identification of vertical facial growth. Schendel et al. (1976) and Opendebeeck et al. (1978) suggest that as the mandibular plane angulation increases there is a subsequent increase in vertical facial growth potential. MP-SN has also been used in combination with other cephalometric measurements to classify patients into hyper-divergent, hypo-divergent and normal facial types. Bishara and Jakobsen (1985) used MP-SN in addition to ratios of posterior to anterior face height to classify patients in their longitudinal study. Skieller and Björk (1984) through longitudinal implant studies, however, suggest that the angulation of the mandibular plane with the anterior cranial base is not a good predictor of future facial growth. Nanda (1990) further suggests that the inferior border of the mandible is in a constant state of remodeling during growth and is inadequate for growth prediction. Other investigators have found an association between increased palato-mandibular angles (PP-MP) and the dolicocephalic facial type with associated open-bite malocclusions. (Sassouni, 1969; Nanda, 1990) As well, some researchers use lower anterior face height as a predictor of vertical facial growth. (Nanda, 1990; Blanchette et al., 1996)

Due to the complexity of growth of the craniofacial complex solitary cephalometric measurements may not be satisfactory in identifying vertical facial types. Rather, a constellation approach may be used to classify growth patterns outside the range of normal.

# CHAPTER 3

## MATERIALS AND METHODS

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3.2.1 Area Measurement 36-37

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 SAMPLE SELECTION

The sample was chosen from the archives of the University of Manitoba Graduate Orthodontic Clinic. The archived subjects were treated by graduate students of the department of orthodontics, under direct supervision of faculty. The records of approximately 350 patients were searched on the basis of the inclusion criteria presented in Table 3.1. The stringent inclusion criteria were used to identify a homogeneous sample and minimize other possible influencing factors.

**Table 3.1 Inclusion Criteria for Subjects Selected for the Study**

1. Complete cephalometric and plaster model records including pre-treatment, post-treatment and minimum five years post-treatment
2. Angle Class I, Class II division 1 or 2 malocclusions
3. Non-extraction orthodontic treatment
4. All teeth excluding the third molars were present and fully erupted at the start of treatment
5. Non-extraction orthodontic treatment
6. Non-surgical orthodontic treatment
7. Treatment initiated between the ages of 12 to 17 years
8. Treated with an edgewise approach

A total of 44 subjects were selected, 14 males (31.88%) and 30 females (68.12%).

Pre-treatment lateral cephalograms for the 44 subjects were scanned by two calibrated operators using a HP 3400 Deskscan scanner (Hewlett-Packard Company, Palo Alto CA) and subjected to cephalometric analysis using the Dolphin$^{TM}$ treatment planning software (Dolphin Imaging and Management Systems, Chatsworth CA).

Each operator scanned and digitized 66 lateral cephalograms corresponding to half of the total cephalograms from pre-treatment, post-treatment and a minimum of 5-years post-treatment time periods. Two weeks later each operator digitized 132 records comprised of the 66 previously digitized cephalograms and 66 cephalograms digitized by the other operator. Intra-operator and inter-operator calibration coefficients were obtained.

Using defined angular and ratio pre-treatment cephalometric values the subjects were partitioned into three groups based on vertical facial pattern. Measurement criteria were selected from the literature that are commonly used to identify patients with vertical dysplasia. (Table 3.2) (Sassouni, 1969; Schendel et al., 1976; Opendebeeck et al., 1978; Skieller and Björk, 1984; Bishara and Jakobsen, 1985; Nanda, 1990; Blanchette et al., 1996; Buschang et al., 2002) The three groups identified were brachycephalic or horizontal growers (Figure 3.1), mesocephalic or normal growers (Figure 3.2) and dolicocephalic or vertical growers. (Figure 3.3)

Figure 1.1 Typical brachycephalic facial type. Clinical photograph (left) and corresponding lateral cephalogram (right)

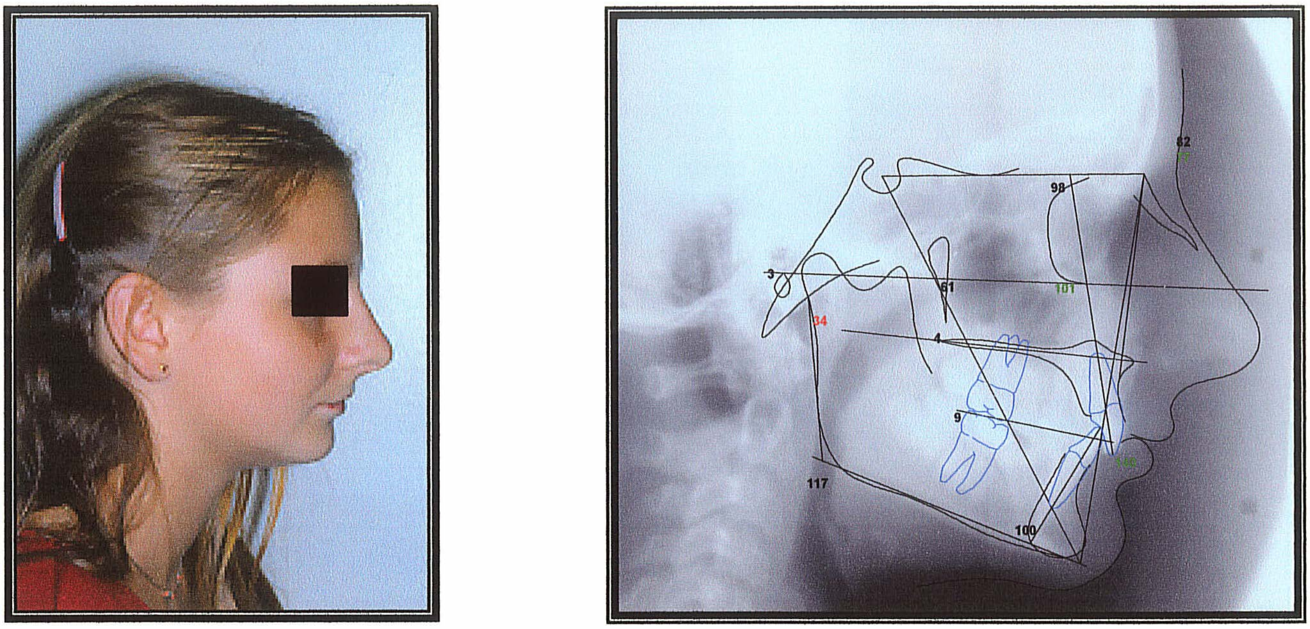


Figure 3.2 Typical mesocephalic facial type. Clinical photo (left) and corresponding lateral cephalogram (right).

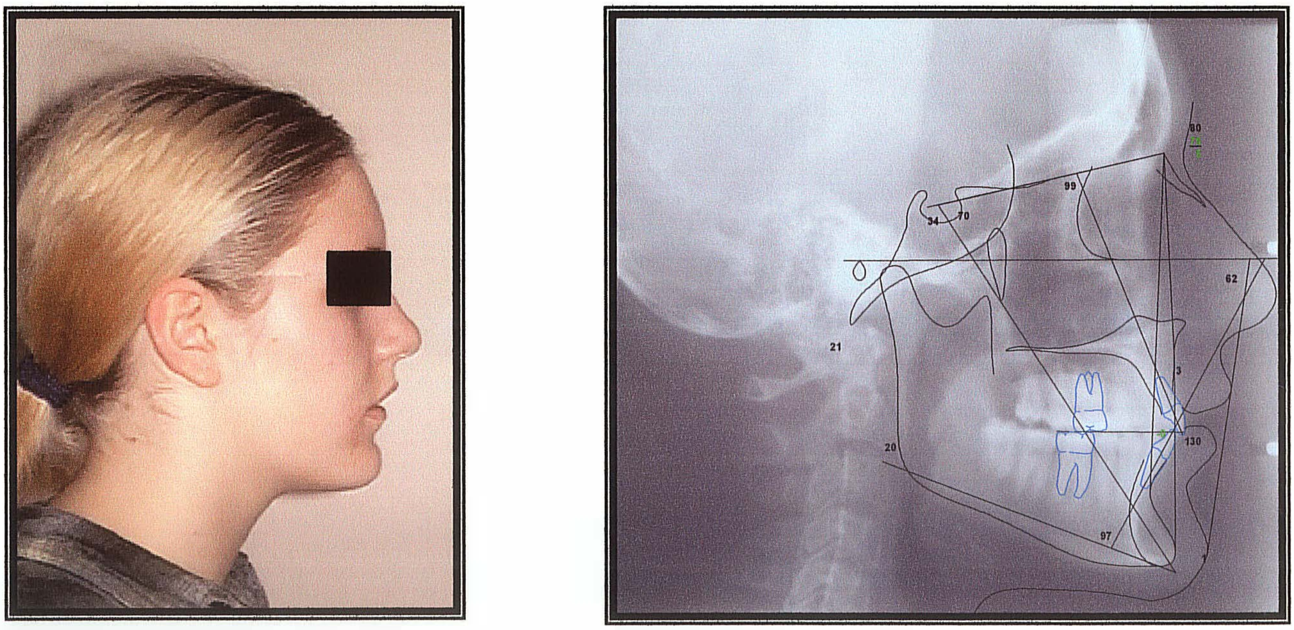
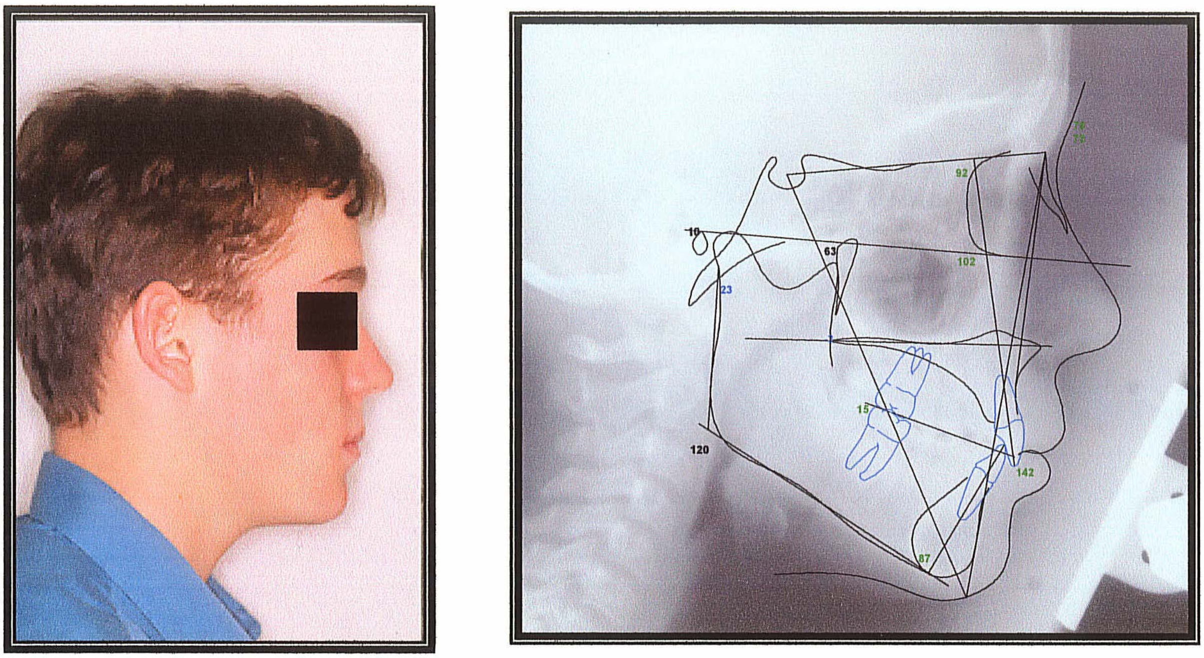


**Figure 3.3 Typical dolicocephalic facial type. Clinical photograph (left) and corresponding lateral cephalogram (right).**



To be categorized as either brachycephalic or dolicocephalic it was necessary for the subject to have a minimum of three of the five measured parameters fall outside one standard deviation from the accepted norm. The remaining subjects were considered to be normal growers and were placed in the mesocephalic category.

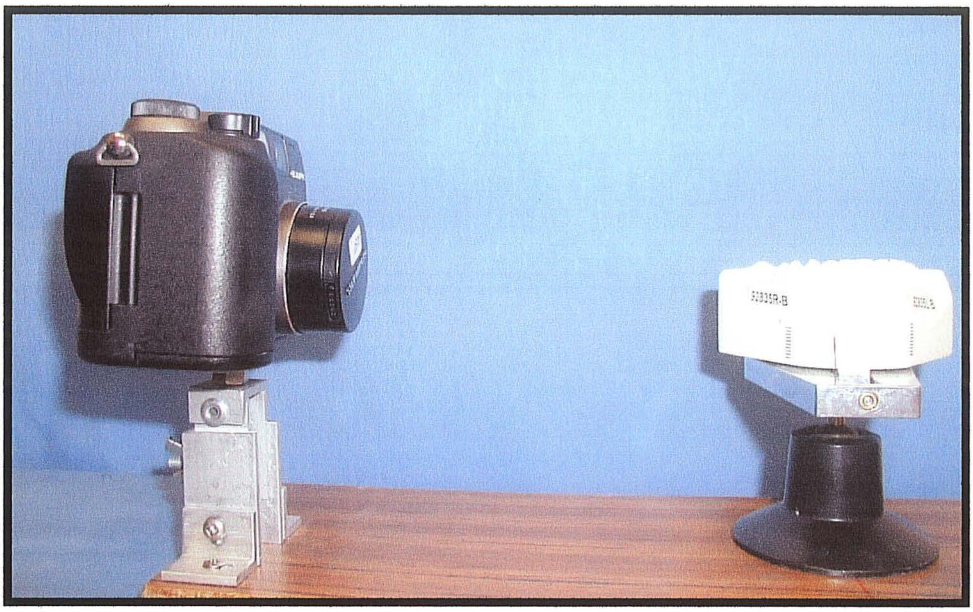
**Table 3.2 Cephalometric Variables Used to define Vertical Facial Pattern.**

1. Mandibular plane to Sella-Nasion angle (MP-SN)
   Norm = 33° S.D. +/- 6
2. Palatal plane to Mandibular plane angle (PP-MP)
   Norm = 25° S.D. +/- 6
3. Y-axis – Sella-Nasion to Sella-Gonion angle (SGn-SN)
   Norm = 67° S.D. +/- 5.5
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% S.D. +/- 7
5. Posterior Face Height / Anterior Face Height % - Sella to Gonion / Nasion to Menton % (S-Go/N-Me %)
   Norm = 65% S.D. +/- 4

## 3.2 CURVE OF SPEE MEASUREMENT

Study models corresponding to pre-treatment, post-treatment and minimum 5-years post-treatment were photographed bilaterally using a mounted digital camera (Olympus Camedia C3000 Zoom 3.3 Megapixel; Melville, NY) The camera was mounted on a fully adjustable apparatus to permit proper alignment with the study model. (Figure 3.4) Lateral photographs were taken for both right and left sides at a distance of 15cm to the midsaggital plane. Using a carpenter's level the camera was oriented so that the focal plane was parallel and level with the cast. A ruler was included in the photograph to identify the degree of magnification. Scion Image Beta 4.02$^{TM}$ software (Scion Corporation, Frederick Maryland) was used to calculate the magnification and measure the curve of Spee. Photographs were downloaded onto a desktop computer and analyzed for image quality and sharpness. Two measurements related to the curve of Spee were recorded: linear and area.

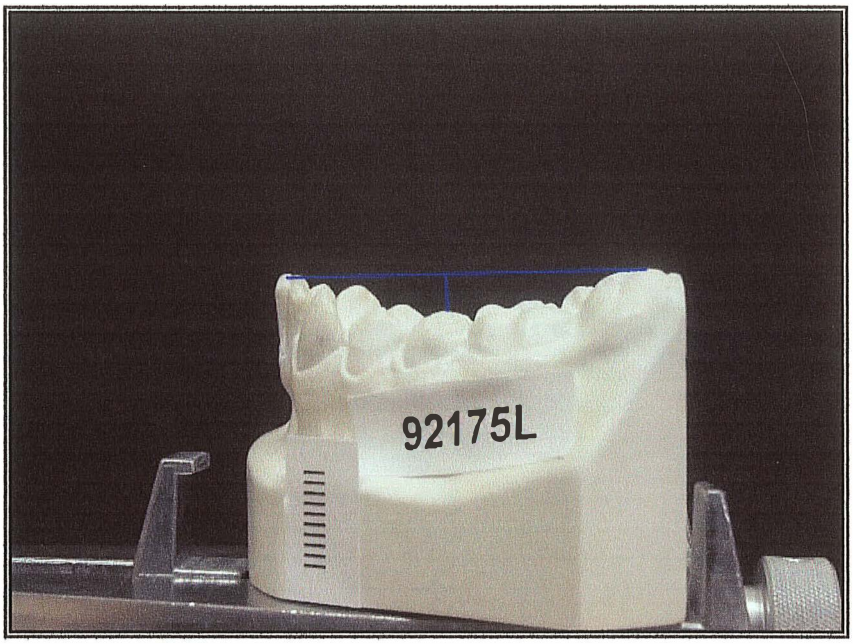
**Figure 3.4 Adjustable photographic apparatus used to digitally record right and left curve of Spee from plaster study models.**



## 3.2.1 LINEAR CURVE OF SPEE MEASUREMENT

The linear measurement of the curve of Spee used was identical to that used by Braun and Schmidt (1956) and Braun et al (1996) and is depicted in Figure 3.5. A reference line was constructed connecting the incisal tips of the mandibular incisors with the distobuccal cusp tip of the mandibular second molar. A perpendicular line was constructed from the reference line to the point of maximum depth determined visually. These measurements were individually recorded and for both right and left sides, corrected for magnification error and averaged.

**Figure 3.5 Linear curve of Spee measurement**



## 3.2.2 AREA CURVE OF SPEE MEASUREMENT

The area measurement of the curve of Spee is depicted in Figure 3.6. The measurement calculated by constructing a superior reference line connecting the incisal tips of the mandibular incisors with the distobuccal cusp tip the second molar in a similar manner to that of the linear measurement. The inferior border of the curve of Spee area was defined by the cusp tips of the mandibular canine, first and second premolar, mesiobuccal and distobuccal cusp tips of the mandibular first molar and the mesiobuccal cusp tip of the mandibular second molar.

The defined area was calculated using the Scion Image Beta 4.02 ™ software (Scion Corporation, Frederick Maryland). These values were individually recorded for both right and left sides, corrected for magnification error and averaged.

**Figure 3.6 Area curve of Spee measurement.**

# CHAPTER 4

# STATISICAL ANALYSIS

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# CHAPTER 4

## STATISICAL ANALYSIS

### 4.1 INVESTIGATOR ERROR

The study involved 44 subjects each with three sets of complete records corresponding to pre-treatment (T1), post-treatment (T2) and minimum 5 years post-treatment (T3). Two calibrated operators each digitized 66 lateral cephalograms. Two weeks following the initial digitization, each operator digitized the remaining 66 cephalograms and re-digitized 66 of the other operator's cephalograms. The measurements were subjected to statistical analysis to ensure intra-operator and inter-operator reliability.

A single operator performed the curve of Spee linear and area measurements. 20 percent of the sample was re-measured and recorded two weeks following the initial measurements to establish intra-operator reliability.

### 4.2 STATISTICAL ANALYSIS

Following consultation with an experienced statistician (Dr. T. Hassard), cephalometric and curve of Spee data were entered into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond WA) and descriptive statistics including means, standard deviations, minimum and maximum values and confidence intervals were calculated for all variables at pre-treatment, post-treatment and minimum 5-years post-treatment. Intra-group and inter-group correlations were calculated for the measurement of the lateral cephalometric radiographs and intra-group correlations were calculated for linear and area curve of Spee measurements.

A paired t-test was performed to identify any differences between right and left curve of Spee measurements. A Two-way analysis of variance (ANOVA) was performed to test whether the initial curve of Spee at pre-treatment was statistically different among the three facial patterns. ANOVA was also used to discern any possible gender effects or facial pattern effects between the three time periods.

# CHAPTER 5

# RESULTS

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# CHAPTER 5

# RESULTS

## 5.1 CALIBRATION

Reproducibility of measurements was assessed by statistically analyzing the difference between the initial measurements and measurements taken two weeks later. Intra-group, inter-group and Dahlberg's method of reliability were established for the cephalometric variables used for classifying subjects based on vertical facial pattern. The results of the intra-examiner and inter-examiner Dahlberg reliability test are given in Table 5.1. The intra-examiner and inter-examiner Dahlberg for Operator 1 was found to be 0.4893 and 0.4863 for the angular measurements respectively. The intra-examiner and inter-examiner Dahlberg for Operator 2 was found to be 0.4836 and 0.4823 for the angular measurements respectively. For ratio measurements, Operator 1 was found to have intra-examiner and inter-examiner Dahlberg reliability scores of 0.780 and 0.562 respectively. Similarly, Operator 2 was found to have scores of 0.778 and 0.658 for intra-examiner and inter-examiner Dahlberg reliability. Intra-group and inter-group differences were found to be well below one degree for angular measurements and one percent for ratio measurements.

Intra-group and inter-group reliability for the cephalometric parameters used to classify vertical facial pattern is given in Table 5.2. Intra-group reliability for Operator 1 was found to be 0.995, 0.985, 0.992, 0.981 and 0.989 for the PP-MP, Y-Axis, SN-MP, Ratio P-A Face Ht and Ratio UAFH/LAFH respectively. Intra-group reliability for Operator 2 was found to be 0.995, 0.978, 0.992, 0.980 and 0.986 for PP-MP, Y-Axis, SN-MP, Ratio P-A Face Ht and Ratio UAFH/LAFH respectively. Inter-examiner reliability between Operator 1 and Operator 2 was found to be 0.994, 0.987, 0.993, 0.978 and 0.992 for PP-MP, Y-Axis, SN-MP, Ratio P-A Face Ht and Ratio UAFH/LAFH respectively. The results indicate a high degree of intra-group and inter-group reliability in respect to measurement of the cephalometric parameters used to define vertical facial type.

**Table 5.1 Intra-group and inter-group cephalometric reliability using Dahlberg's method.**

| Operator | Calibration | Cephalometric Variables | |
|---|---|---|---|
| | | PP-MP°/Y-Axis°/ MP-SN° | P-A Face Height%/UAFH-LAFH% |
| Operator 1 | Intra-examiner Dahlberg | 0.489 | 0.780 |
| | Inter-examiner Dahlberg | 0.486 | 0.562 |
| Operator 2 | Intra-examiner Dahlberg | 0.484 | 0.778 |
| | Inter-examiner Dahlberg | 0.482 | 0.658 |

**Table 5.2 Intra-group and inter-group reliability for cephalometric measurements used in classifying facial types.**

| Operator | Reliability | Cephalometric Parameter | | | | |
|---|---|---|---|---|---|---|
| | | PP-MP° | Y-Axis° | MP-SN° | P-A Face Ht% | UAFH/LAFH% |
| 1 | Intra-group | 0.995 | 0.985 | 0.992 | 0.981 | 0.989 |
| 2 | Intra-group | 0.995 | 0.978 | 0.992 | 0.980 | 0.986 |
| 1 and 2 | Inter-group | 0.994 | 0.987 | 0.993 | .0978 | 0.992 |

Intra-class coefficients and Dahlberg's method of reliability for area and linear curve of Spee measurements are shown in Table 5.3. Intra-examiner Dahlberg for area and linear curve of Spee measurements was found to be 0.245 and 0.105 respectively. Intra-group reliability was found to be 0.997 and 0.971 for area and linear curve of Spee measurements respectively. Both intra-examiner Dalhberg and intra-group reliability measurements were found to have minimal differences.

**Table 5.3 Intra-group and Dahlberg's method to test reliability of curve of Spee measurements**

| | Area COS Measurement | Linear COS Measurement |
|---|---|---|
| Intra-examiner Dahlberg | 0.245 | 0.105 |
| Intra-group Reliability | 0.997 | 0.971 |

## 5.2 VERTICAL CLASSIFICATION

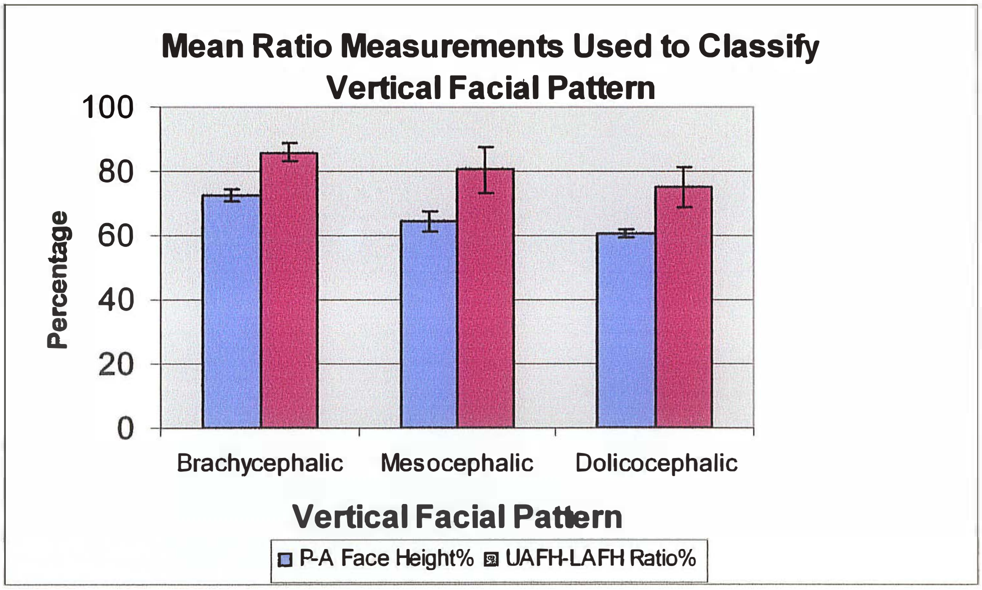
Using five cephalometric indicators of vertical facial pattern (PP-MP, Y-Axis, SN-MP, P-A Face Ht, UAFH/LAFH) patients were partitioned into three vertical facial categories. A minimum of three of the five variables was to be one standard deviation from the established norm to be included in the group. Mean cephalometric values for the three facial types are given in Table 5.4 and are represented graphically in Figures 5.1 and 5.2. Brachycephalic facial types were found to have mean cephalometric measurements of 18.23°, 61.82°, 23.33°, 72.51% and 85.83% for PP-MP, Y-Axis, MP-SN, P-A Face Height and UAFH/LAFH respectively. The mesocephalic group was found to have means of 25.84°, 65.79°, 31.21°, 64.60% and 80.35% for PP-MP, Y-Axis, MP-SN, P-A Face Height and Ratio UAFH/LAFH respectively. The dolicocephalic 31.37°, 69.62°, 37.56°, 60.72% and 74.90% for PP-MP, Y-Axis, MP-SN, P-A Face Height and UAFH/LAFH respectively.

Mean PP-MP, Y-axis and MP-SN angles showed a general increase from hypodivergent to hyperdivergent facial types. Conversely, mean P-A Face height and UAFH/LAFH showed a general decrease in value from hypodivergent to hyperdivergent patients.

**Table 5.4 Mean cephalometric values used to classify vertical facial pattern groups**

| | Mean Cephalometric Value Pre-treatment | | | | |
|---|---|---|---|---|---|
| **Group** | PP-MP° | Y-Axis° | MP-SN° | P-A Face Height% | UAFH/LAFH Ratio |
| Brachycephalic | 18.23+/- 2.63 | 61.82+/- 2.65 | 23.33+/- 2.04 | 72.51+/- 1.91 | 85.83+/- 2.63 |
| Mesocephalic | 25.84+/- 3.37 | 65.79+/- 2.29 | 31.62+/- 3.49 | 64.60+/- 3.20 | 80.35+/- 7.29 |
| Dolicocephalic | 31.37+/- 2.75 | 69.62+/- 4.23 | 37.56+/- 3.28 | 60.72+/- 1.09 | 74.90+/- 6.31 |

**Figure 5.1 Mean ratio mesurements used to classify vertical facial pattern.**



The distribution of males to females, mean age at initiation of treatment and mean treatment time for the three vertical facial pattern groups are given in Table 5.5.

**Figure 5.2 Mean angular measurements used to classify vertical facial pattern.**

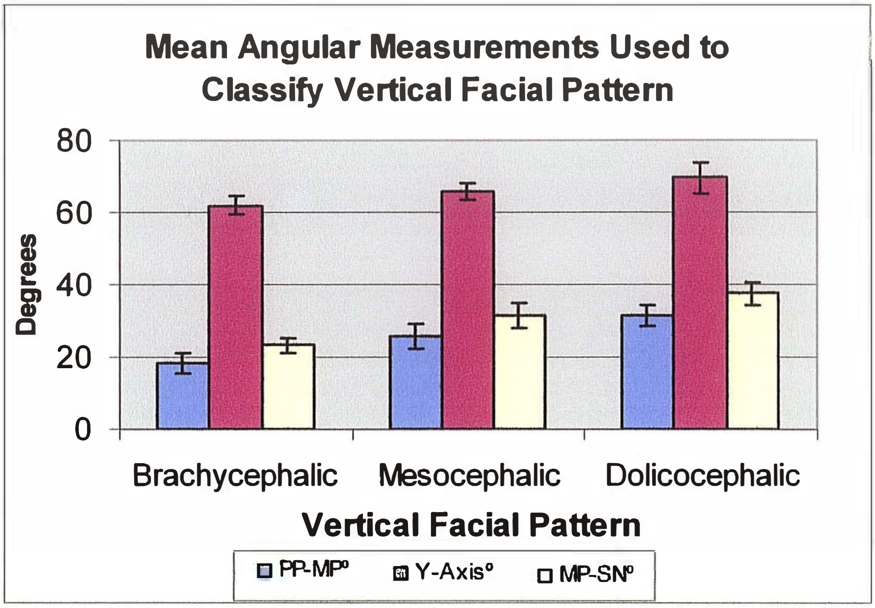


**Table 5.5 Male: Female distribution, mean age at initiation of treatment and mean treatment time for three vertical facial pattern groups**

| Group | Males | Females | Mean Age (Yrs) | Mean Treatment Time (Mos) | Total |
|---|---|---|---|---|---|
| Brachycephalic | 3 | 6 | 12.5 +/- 1.6 | 22+/-3 | 9 |
| Mesocephalic | 6 | 19 | 12.7 +/- 1.5 | 21+/-4 | 25 |
| Dolicocephalic | 5 | 5 | 12.6 +/- 1.8 | 21+/-3 | 10 |
| **TOTAL** | **14** | **30** | **12.6 +/- 1.6** | **21+/-4** | **44** |

The total sample was composed of 44 subjects. Vertical facial pattern groups were composed of 3 male and 6 female subjects in the brachyfacial group, 6 males and 19 females for the mesofacial group and 5 males and 5 females in the dolicofacial group. Mean age at the initiation of treatment was found to be similar between the groups with 12.5+/-1.6, 12.7+/-1.5 and 12.6+/-1.6 yrs for the brachyfacial, mesofacial and dolicofacial groups respectively. Mean treatment times were also similar between the groups with subjects having 22+/-3, 21+/-4, 21+/-3 and 21+/-4 months of treatment for the brachcephalic, mesocephalic and dolicocephalic facial types respectively.

## 5.3 COMPARISON OF CURVE OF SPEE RIGHT AND LEFT SIDES

The linear and area curve of Spee measurements were performed on both the left and right sides of the 44 subjects included in this study. The resulting 132 measurements for each linear and area curve of Spee measurements were compared statistically using a paired t-test. The results shown in Table 5.6 indicate that there were no significant statistical differences ($p>0.01$) between the right and left measurements. The right and left sides were therefore averaged for further statistical comparison

**Table 5.6 Paired t-test for curve of Spee differences between right and left sides. T1,T2,T3 represent pre-treatment, post-treatment and 5-year post-treatment respectively. *indicates statistical significance (p<0.05)**

| Group | Time Period | Area Curve of Spee Measurement | | Linear Curve of Spee Measurement | |
|---|---|---|---|---|---|
| | | t-value | p-value | t-Value | p-value |
| Brachycephalic | T1 | 0.37 | 0.359 | 0.99 | 0.173 |
| | T2 | 1.42 | 0.094 | 1.05 | 0.160 |
| | T3 | 0.69 | 0.251 | 1.63 | 0.068 |
| Mesocephalic | T1 | 1.63 | 0.060 | 0.72 | 0.238 |
| | T2 | -0.55 | 0.294 | -0.82 | 0.211 |
| | T3 | -0.27 | 0.396 | -1.07 | 0.147 |
| Dolicocephalic | T1 | -1.23 | 0.126 | 0.69 | 0.251 |
| | T2 | -1.21 | 0.128 | -0.26 | 0.399 |
| | T3 | 0.982 | 0.176 | 1.42 | 0.094 |

## 5.4 AREA CURVE OF SPEE MEASUREMENTS

Mean curve of Spee area and maximum and minimum values for pre-treatment, post-treatment and minimum 5-years post treatment are given in Table 5.7 and are represented graphically in Figures 5.3 and 5.4. Pre-treatment mean area curve of Spee values for the brachycephalic, mesocephalic and dolicocephalic sub-groups were found to be 107.62+/51.12mm$^2$, 85.41+/-23.56mm$^2$ and 74.38+/-26.81mm$^2$ respectively. Post-treatment mean area values were found to 16.57+/-13.86 mm$^2$, 33.64+/-22.43 mm$^2$ and 20.17+/-14.87 mm$^2$ for the brachycephalic, mesocephalic and dolicocephalic sub-groups respectively. In addition, minimum 5-year post-treatment mean area values were found to be 34.38+/-20.18 mm$^2$, 49.38+/-17.08 mm$^2$ and 30.85+/-18.18 mm$^2$ for the brachycephalic, mesocephalic and dolicocephalic sub-groups respectively. (Figure 5.3)

Maximum and minimum mean curve of Spee values for the brachycephalic sub-group were 198.90-39.99, 40.09-0.43 and 63.41-4.72 mm$^2$ for the pre-treatment, post-treatment and minimum 5-year post-treatment time intervals respectively. For the mesocephalic group the values were 130.05-30.25, 50.34-0.00 and 77.92-10.92 mm$^2$ for the three time periods. As well, the dolicocephalic maximum and minimum values were 115.81-37.73, 70.88-3.30 and 76.9-24.65 mm$^2$ for the three respective time intervals. (Figure 5.4)

**Table 5.7 Area curve of Spee measurements according to facial type. T1,T2,T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.**

| Group | Time Period | Mean Area (mm$^2$) | SD | Maximum (mm$^2$) | Minimum (mm$^2$) |
|---|---|---|---|---|---|
| Brachycephalic (n=9) | T1 | 107.62 | 51.12 | 198.90 | 39.99 |
| | T2 | 16.57 | 13.86 | 40.09 | 0.43 |
| | T3 | 34.38 | 20.18 | 63.41 | 4.72 |
| Mesocephalic (n=25) | T1 | 85.41 | 23.56 | 130.05 | 30.25 |
| | T2 | 33.64 | 22.43 | 50.34 | 0.00 |
| | T3 | 49.38 | 17.08 | 77.92 | 10.19 |
| Dolicocephalic (n=10) | T1 | 74.38 | 26.81 | 115.81 | 37.73 |
| | T2 | 20.17 | 14.87 | 70.88 | 3.30 |
| | T3 | 30.85 | 18.18 | 76.90 | 24.65 |

**Figure 5.3** Mean area curve of Spee measurements. T1, T2 and T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.

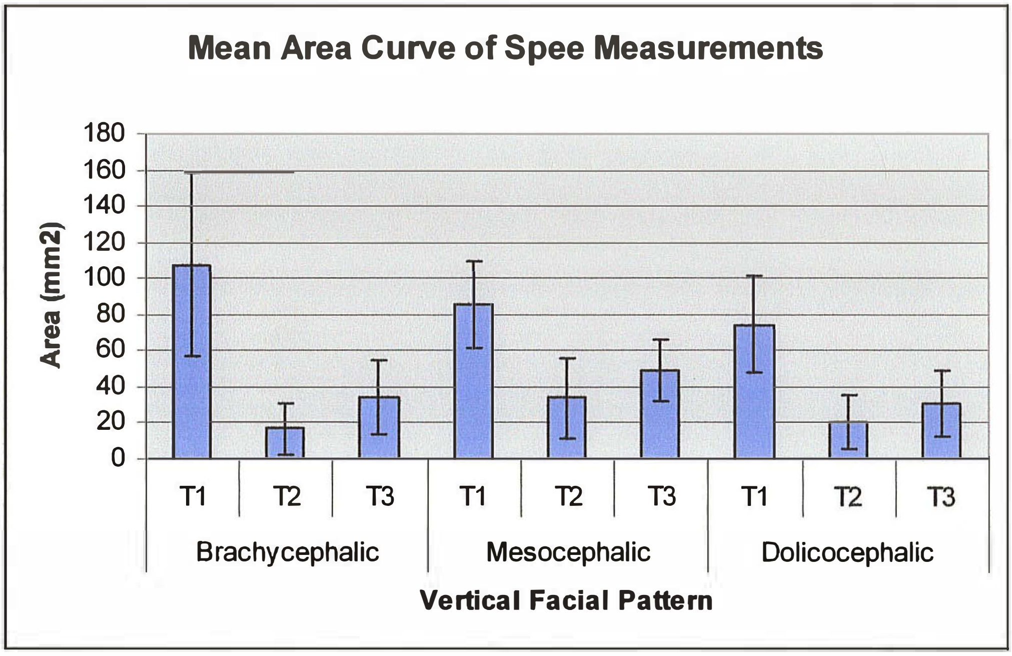
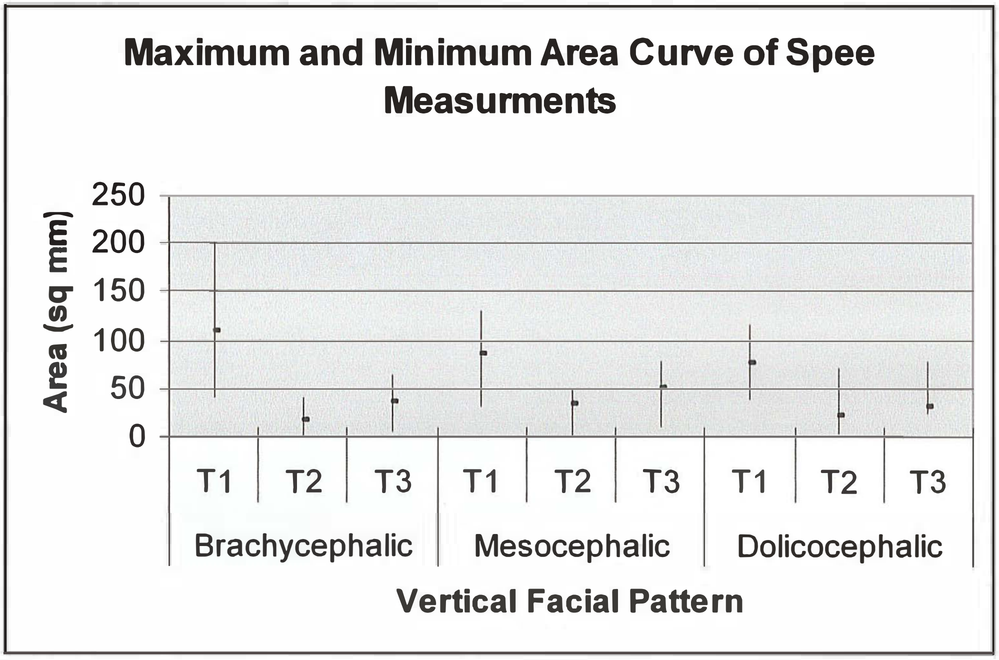


**Figure 5.4** Maximum and minimum area curve of Spee measurements according to facial type. T1, T2 and T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.



## 5.5 LINEAR CURVE OF SPEE MEASUREMENTS

Mean curve of Spee linear and maximum and minimum values for pre-treatment, post-treatment and 5 years post treatment is given in Table 5.8 and are represented graphically in Figures 5.5 and 5.6. Pre-treatment mean linear curve of Spee values for the brachycephalic, mesocephalic and dolicocephalic sub-groups were found to be 5.59+/-2.73mm, 4.14+/-1.21mm and 4.20+/-1.34mm respectively. Post-treatment mean area values were determined as 0.74+/-0.63 mm, 2.15+/-1.16mm and 1.47+/-1.16mm for the brachycephalic, mesocephalic and dolicocephalic sub-groups respectively. In addition, minimum 5-year post-treatment mean area values were found to be 1.81+/-0.91mm, 2.80+/-0.69mm and 2.05+/-0.89mm for the brachycephalic, mesocephalic and dolicocephalic sub-groups respectively. (Figure 5.5)

Maximum and minimum mean curve of Spee values for the brachycephalic sub-group were 11.51-2.30, 2.11-0.11 and 2.92-0.21mm for the pre-treatment, post-treatment and minimum 5-year post-treatment time intervals respectively. For the mesocephalic group the values were 6.31-1.95, 4.05-0.00 and 3.93-0.39mm for the three time periods specified. As well, the dolicocephalic maximum and minimum values were 6.03-1.91, 4.13-0.26 and 3.47-1.29mm for the three respective time intervals. (Figure 5.6)

Table 5.8 Linear curve of Spee measurements according to facial type. T1, T2, T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.

| Group | Treatment Period | Mean Linear (mm) | SD | Maximum (mm) | Minimum (mm) |
|---|---|---|---|---|---|
| Brachycephalic (n=9) | T1 | 5.59 | 2.73 | 11.51 | 2.30 |
| | T2 | 0.74 | 0.63 | 2.11 | 0.11 |
| | T3 | 1.81 | 0.91 | 2.92 | 0.21 |
| Mesocephalic (n=25) | T1 | 4.14 | 1.21 | 6.31 | 1.95 |
| | T2 | 2.15 | 1.16 | 4.05 | 0.00 |
| | T3 | 2.80 | 0.69 | 3.93 | 0.39 |
| Dolicocephalic (n=10) | T1 | 4.20 | 1.34 | 6.03 | 1.91 |
| | T2 | 1.47 | 1.16 | 4.13 | 0.26 |
| | T3 | 2.05 | 0.89 | 3.47 | 1.29 |

Figure 5.5 Mean linear curve of Spee measurements according to facial type. T1, T2, T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.

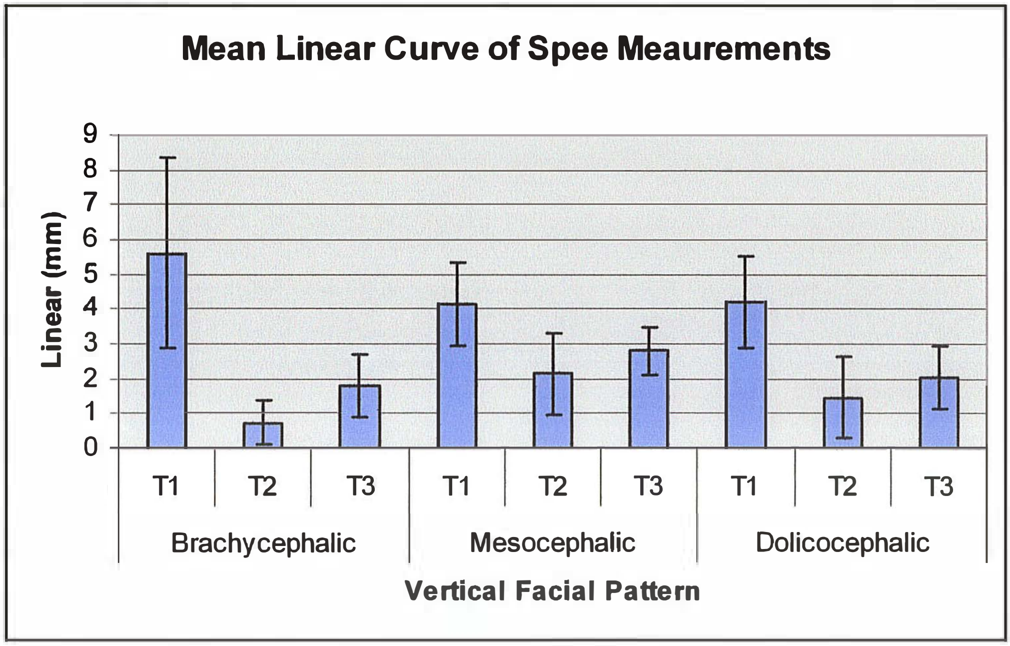
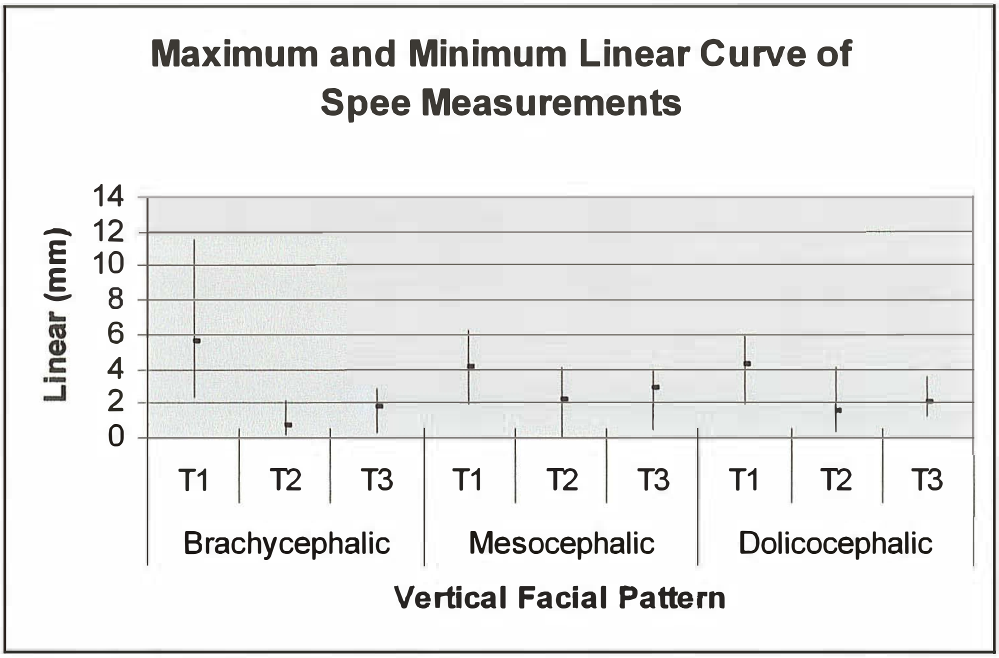


**Figure 5.6 Maximum and minimum linear curve of Spee measurements according to facial type. T1, T2, T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.**



## 5.6 CURVE OF SPEE CHANGES

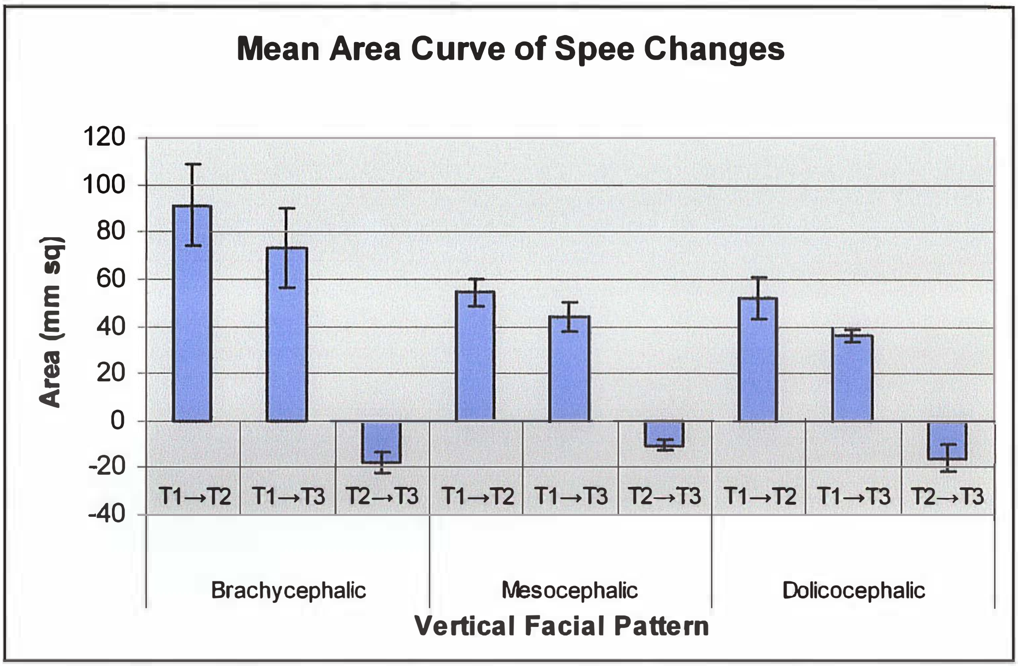
Mean area curve of Spee difference between pre-treatment (T1), post-treatment (T2) and 5-years post-treatment (T3) is given in Table 5.9 and represented graphically in Figure 5.7. In the brachycephalic facial type a mean change of 91.05mm$^2$ was observed between pre-treatment and post-treatment curve of Spee. ($p<0.0001$) A significant mean relapse of 17.81 mm$^2$ was noted between post-treatment (T2) and 5 years post-treatment (T3). ($p<0.05$)

**Table 5.9 Mean area curve of Spee changes between pre-treatment (T1), post-treatment (T2), and 5 years post-treatment (T3)**

**(*-Denotes statistical significance p<0.05 **-denotes statistical significance p<0.01 ***-denotes statistical significance p<0.001)**

| Group | Time Interval | Mean Difference Area ($mm^2$) | Standard Error | P Value |
|---|---|---|---|---|
| Brachycephalic (n=9) | Time T1→T2 | 91.05 | 17.45 | <0.0001*** |
| | Time T1→T3 | 73.24 | 16.88 | <0.0001*** |
| | Time T2→T3 | -17.81 | 4.35 | 0.0485* |
| Mesocephalic (n=25) | Time T1→T2 | 54.29 | 5.65 | <0.001*** |
| | Time T1→T3 | 43.61 | 6.22 | 0.0002*** |
| | Time T2→T3 | -10.68 | 2.27 | 0.0976 |
| Dolicocephalic (n=10) | Time T1→T2 | 51.77 | 8.91 | <0.0001*** |
| | Time T1→T3 | 36.03 | 2.28 | <0.0001*** |
| | Time T2→T3 | -15.74 | 5.99 | 0.0819 |

**Figure 5.7 Mean area curve of Spee changes according to facial type. T1, T2, T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.**



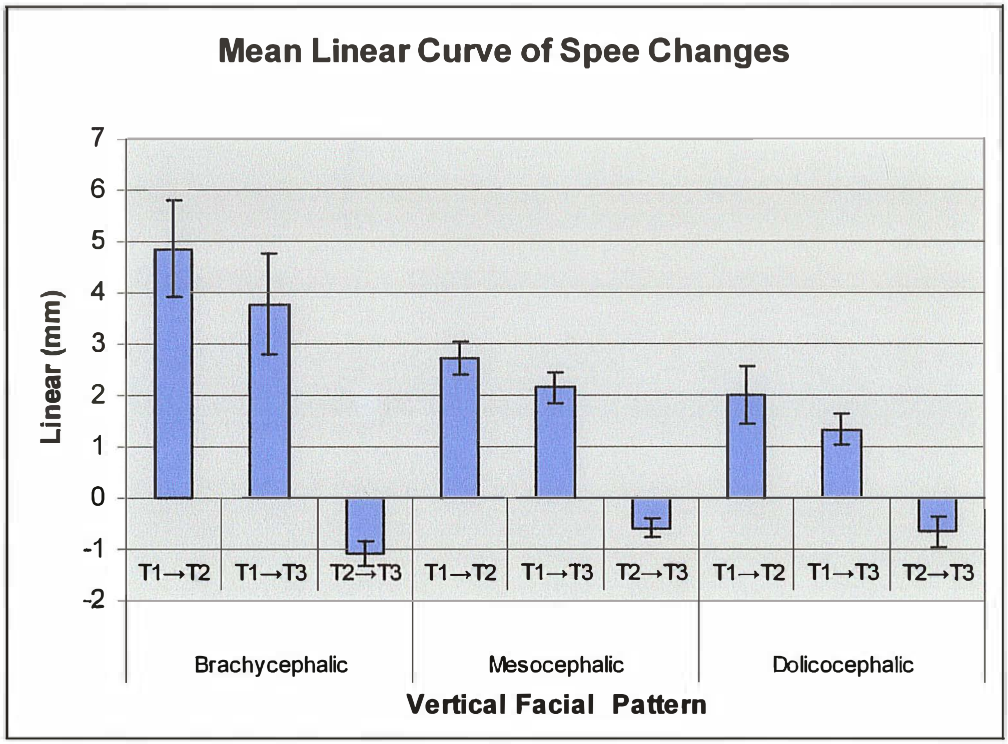
In the mesocephalic group a mean change of 54.29 mm$^2$ was observed between T1 and T2. ($p<0.0001$) A mean relapse of 10,68 mm$^2$ was observed between T2 and T3 however, the amount was found to non-significant. The dolicocephalic group showed a mean change of 51.77 mm$^2$ between T1 and T2. ($p<0.0001$) and a mean relapse of 15.74 mm$^2$ was observed between T2 and T3 that was not of significance.

**Table 5.10 Mean linear curve of Spee changes between pre-treatment (T1), post-treatment (T2) and 5 years post-treatment (T3)**

**(*-Denotes statistical significance p<0.05 **-denotes statistical significance p<0.01 ***-denotes statistical significance p<0.001)**

| Group | Time Interval | Mean Difference Linear (mm) | Standard Error | P Value |
|---|---|---|---|---|
| Brachycephalic (n=9) | Time T1→T2 | 4.85 | 0.934 | <0.0001*** |
| | Time T1→T3 | 3.78 | 0.986 | <0.0001*** |
| | Time T2→T3 | -1.07 | 0.236 | 0.0436* |
| Mesocephalic (n=25) | Time T1→T2 | 2.73 | 0.319 | 0.0003*** |
| | Time T1→T3 | 2.15 | 0.295 | 0.001*** |
| | Time T2→T3 | -0.58 | 0.166 | 0.2194 |
| Dolicocephalic (n=10) | Time T1→T2 | 1.99 | 0.560 | <0.0001*** |
| | Time T1→T3 | 1.34 | 0.298 | <0.0001*** |
| | Time T2→T3 | -0.65 | 0.309 | 0.0870 |

**Figure 5.8 Mean linear curve of Spee changes according to facial type. T1, T2, T3 represent pre-treatment, post-treatment and 5-years post-treatment respectively.**



Mean linear curve of Spee difference between pre-treatment (T1), post-treatment (T2) and minimum 5-years post-treatment (T3) is given in Table 5.10 and represented graphically in Figure 5.8. In the brachycephalic facial type a mean change of 4.85mm was observed between pre-treatment and post-treatment curve of Spee. ($p<0.0001$) A significant mean relapse of –1.07 mm was noted between post-treatment (T2) and minimum 5-years post-treatment (T3). ($p<0.05$) In the mesocephalic group a mean change of 2.73 mm was observed between T1 and T2. ($p<0.001$) A mean relapse of 0.58 mm was observed between T2 and T3 however, the amount was not found to be statistically significant. The dolicocephalic group showed a mean change of 1.99 mm between T1 and T2. ($p<0.0001$) A mean relapse of 0.65 mm was observed between T2 and T3 that was not statistically significant.

# CHAPTER 6

# DISCUSSION

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# CHAPTER 6

# DISCUSSION

## 6.1 OVERVIEW

The exact significance of the curve of Spee in humans is largely unknown; although several hypotheses have been suggested. (Wheeler, 1970; DuBrul, 1980; DuBrul, Osborn, 1982; Barager and Osborn, 1987; Enlow, 1990; Osborn, 1993; Ash and Ramfjord, 1995) These studies suggest the formation and significance of the curve of Spee may be attributed to morphological, biomechanical or adaptional processes. It is interesting however, that no study has been completed previously to quantify the possible relationships between vertical skeletal morphology and the curve of Spee. The present study set out to investigate the association between vertical facial morphology and the initial depth of curve of Spee and further, the amount of relapse following orthodontic leveling.

## 6.2 CURVE OF SPEE MEASUREMENT

No standardized method has been developed in the literature to measure the curve of Spee. This is intimately involved with the fact that no definitive description of the curve of Spee has been established as related to orthodontics. Previous studies have used lateral cephalograms (Braun and Schmidt, 1956; Givins, 1970) or plaster study models

(Sondhi et al., 1980; Bishara, 1989; Braun et al., 1996; De Praeter et al., 2002) to measure the curve of Spee. Complicating this even further, several different measurement techniques have been employed (Sondhi et al., 1980; Bishara, 1989; Braun et al., 1996; De Praeter et al., 2002).

Measurement of the curve of Spee using lateral cephalograms similar to that of Braun and Schmidt (1956) and Givins (1970) was not performed in this study due to the inherent difficulty in reliably establishing landmarks such as cusp tips on the cephalogram. As well, it was felt that limitations of radiographic films such as projection errors would decrease the reliability of the curve of Spee measurements.

In this study, the curve was reliably measured on study models using a method established by Braun et al. (1996). This method was selected because it most closely approximates the method most orthodontists employ clinically when establishing the magnitude of the curve of Spee. In clinical practice the curve of Spee is assessed by placing a flat plane on the mandibular model that customarily contacts the incisor teeth and the most distally placed molar. The depth is then either assessed visually from the lateral aspect or measured bilaterally using a ruler or Boley gauge.

A novel way of measuring the curve of Spee was also introduced in the study, whereby an area calculation of the curve of Spee was obtained. Previous investigations involved measuring the curve through linear or best-fit curve measurements. It was hypothesized that the area measurement as described in Figure 4, would eliminate possible errors due to tooth malposition and would therefore more accurately reflect the character of the curve.

## 6.3 SAMPLE SELECTION

This study evaluated the initial curve of Spee measurements and relapse tendencies of patients partitioned according to vertical facial pattern. The records of approximately 350 subjects were subjected to the inclusion criteria listed in Table 2. These stringent criteria were used to establish a population of 44 subjects that was as homogenous as possible. Only non-extraction patients were selected to eliminate the possible effects of extractions on the curve.

It was important for all teeth excluding the third molars to be present and fully erupted at the start of treatment to minimize the effects of tooth eruption on curve of Spee changes. Obviously, as a patient enters the early permanent dentition stage from the late mixed dentition stage, the character of the curve of Spee would change due solely to the tooth eruption process. It was necessary to minimize these effects through selection of patients whereby the majority of the active tooth eruptive phase was completed. (Age 12-17Yrs)

Influences on the curve of Spee from antero-posterior displacements were minimized through selection of only Angle Class I and Class II subjects. Orthlieb (1997) found that the radius of the curve of Spee was smaller in Angle Class III malocclusions compared to Class II malocclusions. Class III malocclusions were eliminated from the study partly on this basis and because of the fact that these patients represent only a small segment of the population. Braun and Schmidt (1956) evaluated possible differences in the curve of Spee with different Angle classifications and found that no significant differences could be established between Angle Class I and Class II malocclusions. Contrary to this, Farella et al. 2002 found that the position of the mandibular condyle in relation to the occlusal plane influences the COS and as the mandibular dentition moves forward the curve is less pronounced

Records of patients a minimum of 5 years post-treatment were also required. It was felt that a minimum period of 5 years was necessary to establish relapse potential of the orthodontic treatment. Several authors who contend that a minimum of 5 years must elapse before post-treatment changes can be considered to be complete share this view. (Gianelly and Goldman, 1971; Sondi et al., 1980)

Five cephalometric indicators of vertical facial pattern (PP-MP, Y-Axis, SN-MP, P-A Face Ht, UAFH/LAFH) were applied to the sample to create three separate vertical facial pattern sub-groups. A hypo-divergent sub-group (n=9), a normal sub-group (n=24) and a hyper-divergent sub-group (n=10) formed the basis of the study. To be included in a particular sub-group, a minimum of three of the five variables was to be one standard deviation from the established norm. Mean cephalometric values for the three facial types are given in Table 7. Mean P-A Face Ht and UAFH/LAFH were found to decrease from hypo-divergent to hyper-divergent facial types and mean PP-MP, Y-axis and MP-SN angles showed a general increase from hypo-divergent to hyper-divergent facial types. This is in agreement with Buschang et al. (2002) who suggests that subjects who demonstrate increased MP-SN angles, increased LAFH measurements, increased LAFH/ UAFH ratios and decreased P-A Face Ht are likely to exhibit a hyper-divergent facial type and would show a corresponding increase in these measurements.

## 6.4 SEX DISTRIBUTION

The sex distribution, mean treatment time and mean age at the initiation of treatment for the three vertical facial sub-groups is outlined in Table 8. The data demonstrates an overall bias toward female subjects (n=30) compared to male (n=14). The brachycephalic sub-group was found to have a 2:1 ratio of female (n=6) to male (n=3) compared to the mesocephalic sub-group that was found to have a greater than 3:1 female (n=19) to male (n=6) distribution. The dolicocephalic sub-group was found to be equally distributed between females (n=5) and males (n=5). The significance of the skewed sex distribution is probably of little consequence. In the subjects investigated, the initial curve of Spee measurement, post-treatment measurement and post-treatment relapse were not found through two-way ANOVA to exhibit a gender effect. This lack of sexual dimorphism in curve of Spee measurements is consistent with previous investigations and is confirmed in this study. (Ferrario et al., 1992; Ferrario et al., 1997; Orthlieb, 1997; Farella, 2002)

## 6.5 COMPARISON OF LEFT AND RIGHT SIDE CURVE OF SPEE MEASUREMENTS

Linear and area curve of Spee measurements were performed on both the left and right sides of the 44 subjects included in this study. The measurements for each linear and area curve of Spee measurements were compared statistically using a paired t-test and found to have no statistical differences between sides. ($p>0.01$) This is in agreement with a previous investigation by Caracara et al. (2001) that found no differences in the magnitude of the curve of Spee between right and left sides. However, Ferrario et al (1991) found when describing the curve of Spee that the right hand side of the curve of Spee was significantly flatter compared to the left side in male subjects.

## 6.6 FACIAL TYPE AND INITIAL CURVE OF SPEE DEPTH

One of the main objectives of the study was to discern whether vertical facial type had an association with initial curve of Spee value. Curve of Spee values for each of the time periods pre-treatment (T1), post-treatment (T2) and minimum 5-years post-treatment (T3) are presented in Tables 10 and 11. The pre-treatment curve of Spee area measurements presented in Table 10 were found to be larger for the brachycephalic sub-group compared to the mesocephalic and dolicocephalic subgroups. The pre-treatment linear values demonstrated in Table 11 showed a similar trend with the brachycephalic sub-group showing the largest curve of Spee magnitude. The linear and area values were not however found to be statistically significantly different from the two other facial types. Farella (2002) found through regression analysis that the curve of Spee was of greater magnitude in short faced individuals. The results of this study tend to support this contention although they cannot be confirmed due to lack of statistical significance.

A wide degree of individual variability was observed for the three vertical facial types at all three time periods. (Tables 10 and 11) For example the pre-treatment area curve of Spee measurements for the hypo-divergent facial type were found to have a mean value of 107.62mm$^2$ with a standard deviation of 51.12. The maximum and minimum values were recorded as 198.90 and 39.99 mm$^2$ respectively with a range of 158.91 mm$^2$. This wide range of individual variability in curve of Spee measurements is consistent with previous investigations. (Carcara, 2001; Farella et al., 2002; Kuitert et al., 2002)

The curve of Spee was found to significantly decrease from pre-treatment (T1) to post-treatment (T2) time periods in all vertical facial pattern sub-groups. (Tables 12 and 13) The time period from T1 to T2 represents the change due to active orthodontic intervention and resulted in a general flattening of the curve of Spee. This is not surprising given that a relatively common objective in orthodontic treatment involves curve of Spee reduction. (Andrews, 1972) The curve of Spee was found to be leveled to a greater extent in the brachycephalic sub-group represented by the closer approximation to 0 for both the linear (Table 10) and area (Table 11) measurements. The area and linear values at post-treatment (T2) were not statistically significantly different for the three vertical facial pattern sub-groups and were considered similar.

## 6.7 CURVE OF SPEE RELAPSE

A second major objective of the study was establishing the relapse tendency of the curves of Spee as a function of vertical facial pattern. The changes of curve of Spee from post-treatment (T2) to minimum 5-years post-treatment (T3) were defined as the relapse of the curve of Spee toward pre-treatment values. The data from Tables 12 and 13 indicate a statistically significant change toward pre-treatment values for the brachycephalic sub-group for both area (Table 12) and linear (Table 13) measurements. ($p<0.05$) This is a similar finding to that of Givins (1970) who found that low mandibular plane angle cases showed the greatest amount of curve of Spee relapse compared to any other sub-group in his 33 subject sample. A general relapse toward pre-treatment values is seen for all facial types however the mesocephalic and dolicocephalic facial type changes were not statistically significant. The results are characterized graphically in Figures 7 and 8.

The significance of the curve of Spee is widely known. Osborn (1993) argues against the widespread doctrine in dentistry that the three variables of articular eminence inclination, molar cusp height and incisor overbite are not related to curve of Spee depth. It has also been identified that most other mammals have curves of Spee, yet they do not have incisor overbite or steep articular eminences. (Osborn 1987, Barager et al 1987) As well, many cusp tips are worn flat throughout the life of an individual through a natural process of attrition. The curve of Spee is therefore likely to serve a similar function in humans as that of animals and is a function of skeletal morphology rather than serving an adaptive role as part of the dentition. This study suggests an association between an increased pre-treatment curve of Spee depth in hypo-divergent facial types similar to that of Farella (2002); however, the values were not found to be different to a statistically significant degree. Farella et al. (2002) found that the curve of Spee is highly variable between individuals and influenced only a minor extent by craniofacial morphology. The group suggested however that the depth of the curve of Spee was influenced by the ratio between posterior and anterior face height indicating vertical facial patterning.

Relapse of the curve of Spee has been described by several investigators as being a normal physiologic process. (Andrews, 1972; Koyama, 1979; Ash, 1984) Some investigators have determined that an orthodontically leveled curve of Spee is a relatively stable procedure (Hechter, 1975; De Praeter, 2002) whereas others have noted relapse tendencies. (Givins, 1970; Kuitert, 2000; Carcara; 2001) The extent of relapse as well as identification of possible contributing factors has not however been extensively studied. Carcara et al. (2001) found a statistically significant change ($P<.001$) in the curve of Spee following removal of retention appliances in Angle Class I and Class II cases. He found that the curves increased from a mean of 0.11mm post-treatment to a mean of 0.48mm after a significant post-retention period. The curves of Spee in these cases were found to relapse on average 0.37mm over a 7 year 5 month period. The results of this study are similar to the present study although they are of differing magnitudes. For the brachycephalic group the mean relapse was calculated as 1.07mm and 17.88mm$^2$ for the linear and area curve of Spee measurements respectively. For the mesocephalic and dolicocephalic groups the measurements were found to be less at 0.58mm, 10.68 $mm^2$ and 0.65mm, 15.74 $mm^2$ respectively.

A possible explanation of the identified increase in curve of Spee relapse in the hypo-divergent facial type comes from biomechanical differences associated with different vertical facial types. It has been suggested by a variety of authors that the curve of Spee may offer a functional biomechanical advantage in that the curve allows masticatory forces to be directed along the long axis of the premolar and molar teeth. (DuBrul, 1980; Osborn, 1982; Barager and Osborn 1987) Importantly, investigators have also found that short faced individuals generate higher occlusal masticatory forces compared to long-faced individuals. (Ringqvist, 1973; Proffit et al., 1981) It is therefore likely that hypo-divergent individuals would experience the greatest relapse of the curve of Spee toward pre-treatment values due to the increased strength of the masticatory system demonstrated by these individuals. To add further support to this hypothesis, Osborn (1993) found a positive correlation between the curve of Spee and the inclination of the masseter muscle. He found that the angulation of the mandibular molars closely approximated the orientation of the superficial fibers of the masseter muscle. It is likely in brachycephalic individuals who exhibit increased masticatory forces, there will be a greater tendency for the molar teeth to realign with the musculature in an effort to regain the biomechanical advantage.

## 6.8 CURVE OF SPEE RELAPSE AND ARCH PERIMETER

The effect of leveling the curve of Spee on arch perimeter has been well investigated. It is generally assumed that leveling a deep curve of Spee results in an increase in arch perimeter; although, the exact amount of the increase is currently debated. (Baldridge,1969; Proffit and Akerman,1986; Garcia,1985; Germane,1992; Braun et al., 1996) Leveling the curve of Spee during the active phase of orthodontic treatment could be recognized as a measure to minimize the amount of post-treatment lower incisor relapse. Data from this study would indicate that hypo-divergent facial types demonstrate the greatest capacity for adaptation as the curve of Spee re-establishes following orthodontic treatment.

## 6.9 NULL HYPOTHESIS DEDUCTIONS

**Null Hypothesis #1** There is no relationship between initial curve of Spee depth and vertical facial pattern

This statement was **accepted** as the pre-treatment curve of Spee measurements were not found to be statistically significantly different among the three vertical facial pattern sub-groups

**Null Hypothesis #2** The curve of Spee will not change through the administration of orthodontic treatment

This statement was **rejected** as the curve of Spee was found to decrease from pre-treatment to post-treatment stages to a statistically significant degree.

**Null Hypothesis #3** Three is no association between vertical facial pattern and re-establishment of the curve of Spee following orthodontic leveling

This statement is **rejected** for the brachycephalic sub-group that demonstrated a statistically significant relapse toward pre-treatment values. The statement is **accepted** for the mesocephalic and dolicocephalic sub-groups which failed to demonstrate a statistically significant relapse from post-treatment values.

**Null Hypothesis #4** There is no difference between the measurement characteristics of conventional curve of Spee measurements with a novel measurement

This statement is **rejected**. Although similar trends are seen using linear and area curve of Spee measurements the two methods are not inter-changeable and one may not be substituted for the other.

# CHAPTER 7

# STUDY LIMITATIONS AND CONCLUSIONS

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# CHAPTER 7

# STUDY LIMITATIONS AND CONCLUSIONS

## 7.1 STUDY LIMITATIONS

It is necessary to establish possible limitations of this study to characterize the strength of the study and provide direction for future research.

One limitation of the current study was the size of the sample. Through confirmation with Dr. T. Hassard, a statistician at the University of Manitoba, it was decided to increase the strength of the study by using very stringent inclusion criteria. In addition, the sample was further reduced due to only including subjects that had completed orthodontics for a minimum of 5 years. As stated previously, many retention/relapse studies have inadequate time periods to realize any significant change. Due to the homogenous sample the current study was able to include only 44 subjects.

Because only study models were used, the study lacks understanding in respect to stability of the curve of Spee using different arch leveling techniques. This study did not attempt to differentiate the relapse potential when various orthodontic biomechanical systems are employed. It is possible that the relapse potential is higher for incisor intrusion versus premolar extrusion or vice versa. With a larger sample size a future combined study model/radiographic analysis may provide insight into the relapse potential of various techniques.

A third, and important limitation to the study was the consideration of normal growth. It is possible and in fact likely that the curve of Spee changes as a normal physiologic process. These changes however have not been documented and it is impossible to differentiate the effects of relapse from orthodontic treatment from those of growth. A possible future research project could measure the changes in the curve of Spee of various vertical facial patterns in untreated subjects to ascertain curve of Spee changes irrespective of orthodontic treatment. As well, a control group of untreated individuals could be used, but this has ethical concerns whereby denying treatment to use a patient as a control subject would be unacceptable.

A fourth and final limitation of this study deals with the difference between statistical and clinical significance. Although a distinct difference was noted between the facial types in respect to relapse following orthodontic leveling, the exact clinical significance of this is not known. The magnitude of the difference between the sub-groups is small and may not be of any importance clinically.

## 7.2 CONCLUSIONS

From the present study, the following conclusions can be drawn:

1. Orthodontic treatment biomechanics can successfully level the curve of Spee in all three vertical facial types
2. The magnitude of the pre-treatment curve of Spee depth does not seem to be associated with specific vertical facial patterns
3. Great variability exists for pre-treatment curve of Spee depth in all facial types
4. The hypodivergent facial type seems to demonstrate a statistically significant increase in post-treatment relapse ($p<0.05$) compared to other vertical facial types; however, the clinical significance of this association is uncertain.

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