THE UNIVERSITY OF THE WITWATERSRAND
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DEPARTMENT OF ORTHODONTICS AND PAEDIATRIC DENTISTRY
DIVISION OF ORTHODONTICS

LONGITUDINAL ASSESSMENT OF THE Z-ANGLE

A RESEARCH PROJECT SUBMITTED TO THE POSTGRADUATE COMMITTEE

in partial fulfilment of the requirements for the degree of

MASTER OF DENTISTRY

in the branch of
ORTHODONTICS

BY
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Declaration

I, Muhammed Kaka, declare that this research report is my own work. It is being submitted in partial fulfilment of the requirements for the degree of Master of Dentistry at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

DEDICATION

This Research Report is dedicated to my family: my parents, Goolam and Fazela who have supported me throughout my entire life and career and whose sacrifices have brought me to where I am today. My loving and supportive wife Tasneem, who has patiently stood by me and encouraged me to achieve this great milestone in my career. My children, Khalid and Nooh who are the coolness of my eyes and a source of great joy and happiness.

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ABSTRACT

Background: Several analytical soft-tissue reference lines have been derived to aid in orthodontic treatment planning. One of these is the Z-angle (Merrifield), which is a measure of the most protrusive lip to Frankfort horizontal. While there is multitude of information on the changes in the soft tissue of the lips, nose and chin, little is available on the longitudinal changes associated with the Z-angle.

Objective: To assess the longitudinal changes in the Z-angle from six to 18 years of age.

Methods: Records of 50 subjects were selected from the Denver and Michigan growth data based on Class I occlusion and good radiographs. Due to poor quality radiographs, the final sample was narrowed down to 34 subjects (17 male and 17 female). Five time points were evaluated: six, nine, 12, 15 and 18 years of age. Primary variables: Upper lip Z-angle (ULZ) and Lower lip Z-angle (LLZ). A 3rd variable was created from the first two, diffz as the difference between ULZ and LLZ. Other measurements included Total Chin thickness (TotChin) and upper (ULE) and lower (LLE) lip positions with respect to the E-line. General linear models (GLM) in SAS were used to assess interaction between time and gender and determine differences over time (α =0.05).

Results: GLM revealed no interaction between gender and time (p>0.05) for all variables except for TotChin. Diffz changed non-significantly from six to 18 years of age. However, both Z-angles increased over time and so did TotChin. ULE and LLE became more negative.

Conclusion: The Z-angle became more positive from childhood to adolescence. This was partly due to an increase in TotChin and a decrease in lip protrusion (ULE, LLE). diffz increased but non-significantly, which meant the upper lip became more retrusive compared to the lower lip.

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Facial harmony and balance among the anatomical structures of the face such as the lips, nose, chin and the supporting skeletal components, are recognised as important contributors to the goals of orthodontic treatment. In order for orthodontists to analyse these features and to accomplish the desired treatment goals, a comprehensive understanding of the normal growth process is crucial (Meng *et al.*, 1998). There are differences in the growth patterns of the hard and soft tissues of the face. Orthodontic treatment can alter both.

Considerable cephalometric research has been conducted to determine desired and appropriate soft tissue profiles as well as establish normative values for different groups of people (Ricketts, 1957, Steiner, 1960, Merrifield, 1966, Burstone, 1976,Holdaway, 1983). However, there does not appear to be particular agreement on the best method (Bishara, 1985). It is well accepted that the proportions of the soft tissues are constantly transforming in the growing child. These must be taken into account when determining the norms, especially for growing children.

Steiner defined what he called the ‘S-line’ as a plane that connected soft tissue pogonion to the centre of the lower border of the nose, a point half-way between subnasale and pronasale. He declared that in aesthetically pleasing and finely proportioned faces both the upper and lower lips would contact this plane (Steiner, 1960). However, we are unsure of the validity of this claim, since Steiner’s sample size was poorly documented. It may therefore not be a good reflection of the Caucasian population from which it was obtained.

Ricketts (Ricketts, 1957) identified the E-line as a plane that connected the soft tissue chin (soft tissue pogonion) with pronasale. According to Ricketts, the lips should lie behind the E-line with the upper placed 4mm and the lower 2mm behind the E-line.

However, this does not take into account the natural growth-related changes of the soft tissue profile.

Burstone (1976) illustrated the B-line as a plane that connected soft tissue pogonion to subnasale. He concluded that in ideal conditions the upper lip should lie ahead of this “B-Line” by 3.5mm and the lower by 2.2 mm. Burstone’s norm values were derived from a sample of 40 adult subjects who were selected by three artists at the Herron Institute of Art in Indianapolis, and were designed for surgical purposes. The mean age of the subjects used to derive the normative values was 23.8 years (Burstone, 1976). Therefore, this analysis cannot be applied to the growing child, but is perhaps more suitable for adults and especially when planning orthognathic surgery.

Holdaway (1983) proposed the Harmony line i.e. H-line, as a plane that ran tangent to soft tissue pogonion and the upper lip. He described an H-angle as the angle formed between the H-Line and the plane from soft tissue pogonion to soft tissue nasion. Holdaway (1983) stated that an H- angle of 10° was ideal.

Merrifield (1966) further defined the Profile Line as a plane connecting the soft tissue chin at Pog’ to the most protrusive lip. The inside inferior angle formed between this ‘Profile Line’ and the Frankfort horizontal plane is described as the Z-angle (Merrifield, 1966) and is a soft tissue angular measurement designed to evaluate facial aesthetics (Figure 1). The average Z-angle in adults is 82° (± 5°), and in children the normal Z-angle would be 78°. These values were derived from the examination of 40 untreated subjects, 40 completed cases treated by Dr. Charles Tweed and 40 patients treated to completion by Merrifield himself (Merrifield, 1966).

Of all the measurements previously described, the Z-angle probably provides the most accurate description of the soft tissue profile as it is not dependant upon the nose but that of the chin and the lip itself. The chin is a major determinant of the profile and has been utilized in growth prediction and placement of the teeth (Aki, 1994).

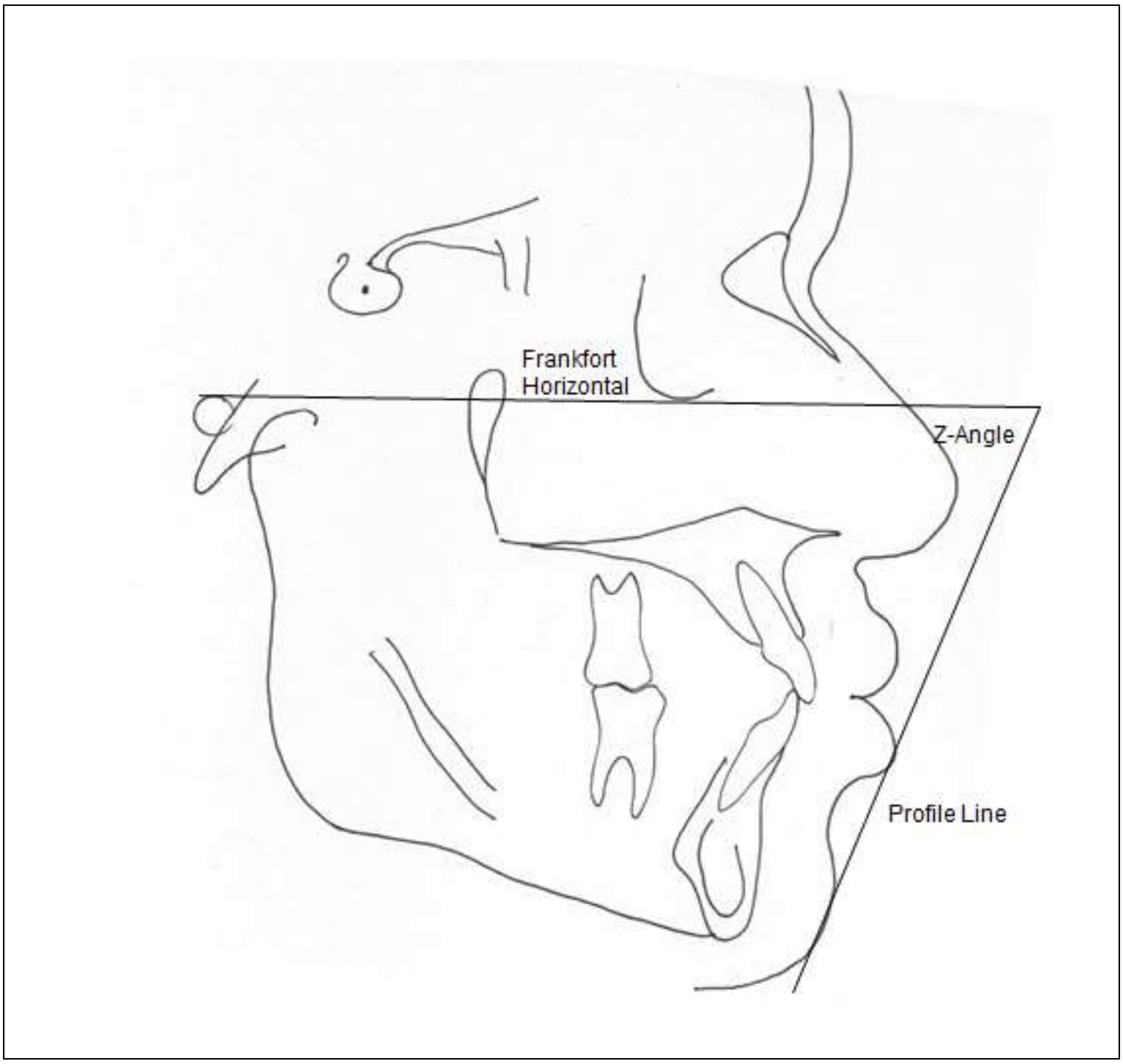

Figure 1. The Z-angle as described by Merrifield (1966)

Subtelny (1959) reported from his longitudinal studies on facial features and profiles that the lips increase in both length and thickness until around the age of 15 years, after which time a constant vertical relationship is maintained. Forsberg and Odenrick (1979) evaluated the age- related changes of 120 Swedish children with normal occlusion at 8, 12 and 25 years of age. This study revealed significant changes with increasing age, as well as gender-related differences within the age groups. At the age of 12 the boys' lower lip was on the E-line whereas in girls the lower lip was approximately (-)2mm behind the E-line. At the final time-point (age 25) this value had decreased in males by (-)4mm and females by only (-)1,5mm. The study, however, was cross-sectional and may not generally be applicable as it does not account for individual variation.

Bishara, Hession and Peterson (1985) used cephalometric radiographs to evaluate longitudinal soft tissue profile changes by way of some commonly used soft tissue facial analyses, including the E-line, Holdaway's soft-tissue angle, and the Z-angle. They concluded that male and female growth-related changes were significantly different when assessed by the various analyses. They also reported that the Z-angle, angles of facial convexity and the Holdaway soft-tissue angles do not perform in a similar manner over time. Their recorded Z-angles were generally lower than those reported by Merrifield. These findings suggest that because most of these analyses reflect differing patterns over time, the established adult standards may not be applicable across all ages and could also be gender-specific.

Nanda *et al.* (1989) concluded that there was significant soft tissue facial change in males and females between the ages of seven and 18 years, expressed differentially between the two genders. Specifically, the upper lip, lower lip, nose and chin all increased over time. While the growth in females was only 2.65 mm for both lips combined, in men it was found to be as much as 6.9 mm (in a horizontal direction). Similarly Nanda *et al.* (1990) concluded that the vertical growth of the upper lip was completed by age 15 for both males and females, whereas the lower lip showed continued vertical growth and an increase in thickness past the ages of 15 for girls and 18 for boys. Formby, Nanda and Currier (1994) reported that the lip thickness at labrale superius and labrale inferius decreased, and these growth changes had the resultant effect of causing the lips to retrude with advancing age.

The longitudinal study by Blanchette *et al.* (1996) involving subjects with long and short faces from the Denver Growth Data, showed significant differences between men and women. Overall, boys exhibited continuous growth over the age of 17 as opposed to girls who achieved their adult soft tissue size at around the age of 14. Vahdettin and Altug (2012) arrived at similar conclusions, reporting in their study that the males showed more soft tissue changes than the females post-pubertal, whereas in the females most growth occurred between the pre-pubertal and pubertal growth periods.

Iwasawa, Moro and Nakamura (1997) used the Z-angle to assess facial aesthetics in Japanese subjects between the ages of 19 and 24 years. The researchers found that the normal Z-angle for men was 69.70° and 71.75° for the women, implying no significant sexual differences. However, this was a cross-sectional study in the Japanese and may not be applicable to all groups.

Erdinc, Nanda and Dandajena (2007) compared profile changes in patients treated with and without premolar extractions, and reported that the Z-angle was a good predictor of treatment outcome. None of the other parameters utilized in the study were as good as the Z-angle. While the study evaluated only patients out of treatment for a five year period, it forms a basis for recognising the importance of the Z-angle in longitudinal assessments of profile changes, with or without treatment.

The literature also points to a large degree of variation which exists in the growth patterns and growth velocity of the cranio-facial structures, be they hard or soft tissue. This implies that standards or normative values should be specific to the gender, the age and the racial profile of every patient. Whilst the current study only focussed on changes seen in Caucasian subjects of North-European ancestry, the results seen should assist the orthodontist to arrive at a suitable diagnosis for the individual patient.

CHAPTER II

STATEMENT OF PURPOSE

The Z-angle is one of many ways of assessing the soft tissue profile. Normative values have been derived for adults but not necessarily for children. A review of the literature revealed that there is no longitudinal data to substantiate the use of the Z-angle across a spectrum of different ages. The **primary objective** of this project, then, was to assess longitudinal changes in the Z-angle from six years of age to late adolescence or early adulthood of 18 years of age. We hypothesized that the Z–angle does not remain constant over time and that the values are age specific.

Secondary Objectives:

The secondary objectives of this project were:

1. To assess for gender differences, if any, in the Z-angle.
2. To evaluate whether the profile improved or deteriorated with age via use of the Z-angle.
3. To derive normative values of the Z-angle for different age groups from six to 18 years of age.

CHAPTER III

MATERIAL AND METHODS

This was a non-concurrent prospective study using lateral cephalometric radiographs from the records of the Child Research Council Study (Denver Growth Study, Waldo, 1935) and the University of Michigan Growth Study (UMGS). Both data sets comprised the serial records of subjects from age three to 42 years of age. While only serial radiographs were used in this study, other information available from the Denver Data includes study models, lateral oblique films and full body scans. The UMGS contains annual records of students who were enrolled at the University School from 1953 to 1970. The UMGS data are housed at the University of Michigan, School of Dentistry in Ann Arbor, Michigan, USA with some Denver data also available at the University of Michigan. Both data are available online through the American Association of Orthodontists Foundation Legacy Collection (http://www.aaoflegacycollection.org).

The subjects had to fulfil the following criteria in order to be included in the study:

1. No history of orthodontic treatment.
2. No craniofacial anomalies.
3. No orthognathic surgery.
4. Class I molar relationship with normal overbite and overjet at the terminal stage of the project (assessed on the study models).
5. Good cephalograms with good depiction of the soft and hard tissues.
6. Cephalograms available at six (T1), nine (T2), 12 (T3), 15 (T4) and 18 (T5) years of age or closest to these ages.

Investigative Technique

All the cephalometric radiographs were hand traced using a 0.5 mm mechanical 4H lead pencil on 0.003 inch matte acetate tracing paper on a viewing box for illumination. The traced cephalograms were digitized using Dentofacial Planner (Dentofacial Planner, Toronto, Ontario, Canada).

Landmarks, Planes and Variables

The following landmarks were used and are shown in Figure 2:

1. **Nasion** (**N):** The most anterior point on the frontonasal suture in the midsagittal plane.
2. **Pronasale** (**Prn)**: The most protruded point on the tip of the nose.
3. **Labrale superius** (L**s):** The most anterior point on the vermillion border of the upper lip.
4. **Labrale inferius** (L**i):** The most inferior point on the vermillion border of the lower lip.
5. **B-Point (B):** A midline point on the anterior curvature of the mandible, and is the deepest point located between infradentale and pogonion.
6. **Pogonion** (**Pog):** The most anterior point on the bony chin.
7. **Soft-tissue Pogonion** (**Pog')**: The most prominent point of the soft tissue chin in the mid-sagittal plane; located anterior to the equivalent bony landmark of pogonion.
8. **Gnathion** (**Gn):** The bony landmark on the curvature of the chin located by bisecting the angle formed between the mandibular plane and the facial plane (from nasion to pogonion).
9. **Menton** (**Me):** The inferior-most point on the lower border of the bony chin.
10. **Gonion** (**G)**: A point on the posterior curvature of the mandible located by bisecting the angle formed by lines tangent to the posterior border of the ramus and the inferior border of the mandible.
11. **Porion** (**Po):** The most superior point on the external auditory meatus.
12. **Orbitale** (**Or):** The lowest point on the inferior rim of the orbit.

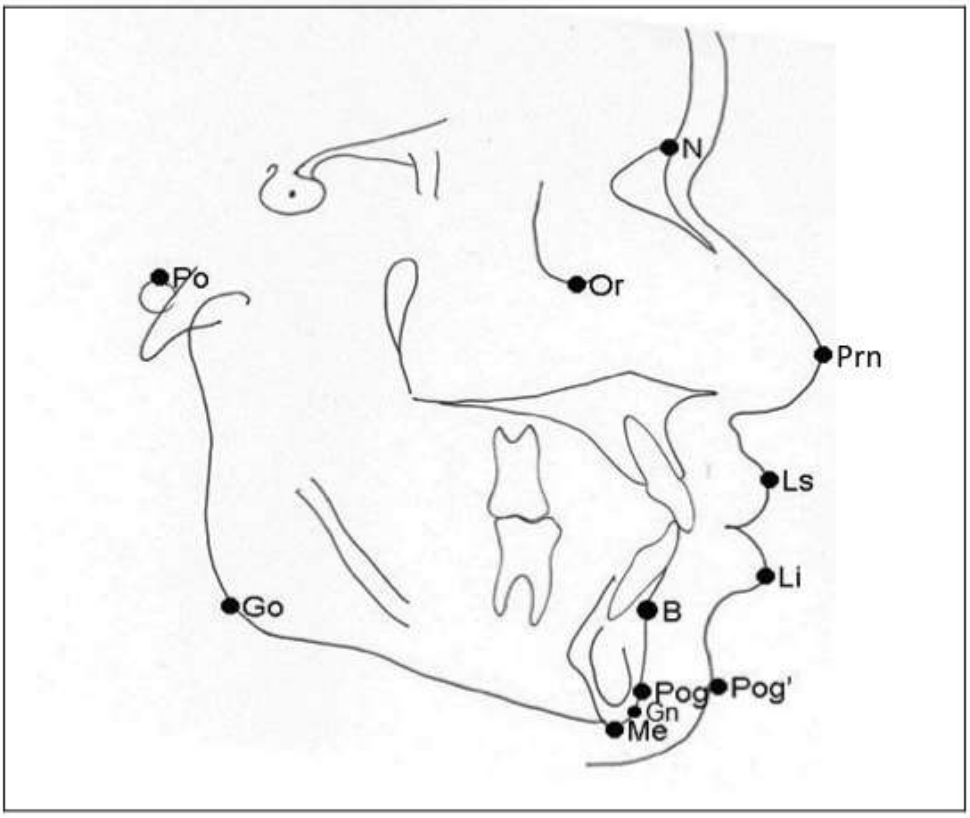

Figure 2. Cephalometric Landmarks

Reference Planes

The hard and soft tissue planes used for reference are defined below and shown in Figure 3.

1. **Frankfort Horizontal Plane (FH):** A horizontal plane passing through Orbitale (Or) and Porion (Po). This plane served two key purposes:
    a. Construction of the Frankfort Mandibular Plane Angle (FMA).
    b. Unless otherwise stated, all linear measurements were made either parallel to or perpendicular to this plane.
2. **Mandibular Plane (MP):** A line representing the inferior border of the mandible that connects Go and Gn. It is one of two planes required for the construction of FMA, the other being FH.
3. **Esthetic Plane (E-**Line): The tangential plane connecting Prn and Pog'. The purpose of the plane is to relate the positions of the upper and lower lips.
4. **Nasion-Perpendicular (N-Perp):** A vertical plane extending inferiorly from N perpendicular to FH.
5. **NB Line:** A vertical line which extends from Nasion (N) through B-point (B).

Measurements

Angular and linear measurements were utilized in this study. The angular measurements are shown in Figure 1 while the linear measurements are displayed in Figure 4.

<u>Angular Measurements:</u>

1. Z-angle: The traditional **Z-angle** is the angle formed between the profile line from Pog' to the most protrusive lip and the FH plane (Merrifield, 1966). See Figure 3. However, in this study, two Z-angles were utilized as described by Erdinc, Nanda and Dandajena (2007) and are as follows:
    a. **Upper lip-Z (ULZ)**: The angle formed between FH and the profile line constructed between Pog' and Ls (Figure 4).
    b. **Lower lip-Z (LLZ)**: The angle formed between FH and the profile line constructed between Pog' and Li (Figure 4).

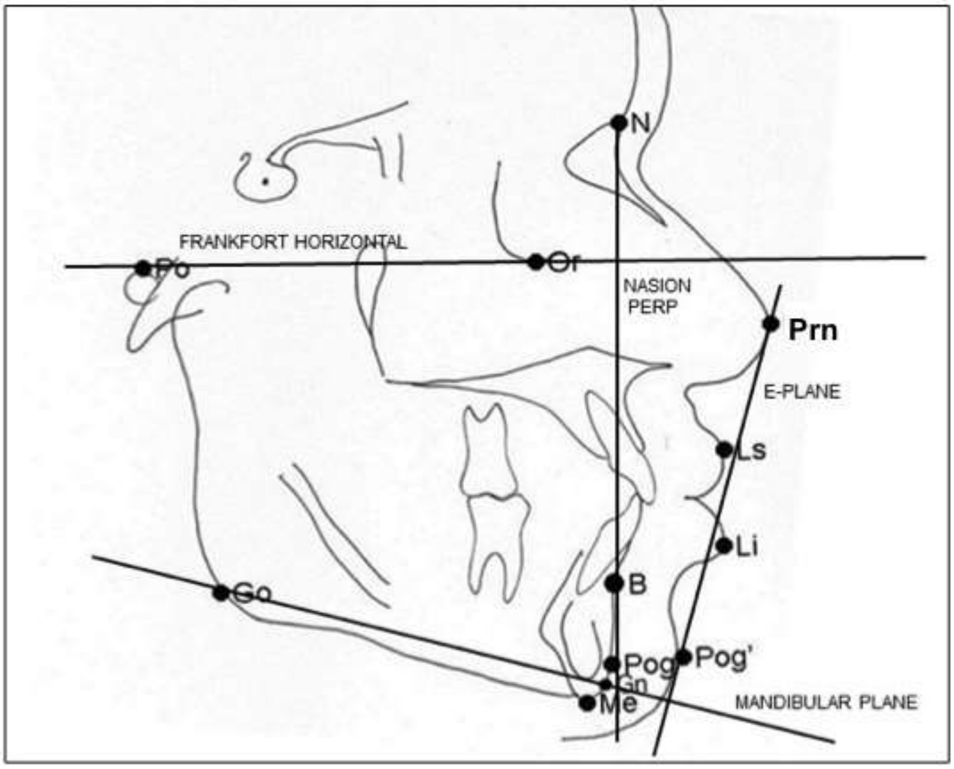

Figure 3. Cephalometric planes.

c. **diffZ**: Is practically the angle formed between Ls and Li with its vertex at Pog'. It is calculated as the difference between ULZ and LLZ. The lip with the smaller Z-angle is the most protrusive lip and a positive diff-Z-angle value is indicative of a more protrusive lower lip (Figure 4).

2. Frankfort Mandibular Plane Angle (FMA): The angle formed between the FH and the mandibular plane. FMA was used to assess for homogeneity with the sample as relates to the direction of growth.

Linear Measurements:

All measurements from a landmark to a line were made perpendicular to that line from the respective landmark.

1. Total Chin (TotChin): The horizontal distance between soft tissue Pogonion (Pog') to the NB line.
2. Soft-Tissue Chin (STChin): The horizontal distance from soft tissue Pogonion (Pog') to hard tissue Pogonion (Pog), calculated as the difference between TotChin and Pog-NB.
3. Upper Lip to E-Plane (ULE): The distance from the upper lip to the E-plane.
4. Lower to E-Plane (LLE): The distance from the lower lip to the E-plane.
5. Nose Depth (NoseDpt): The distance from N to Prn, measured parallel to FH.

Error of Method

There were two possible sources of error: tracing error and error of digitisation. To determine the error of tracing, 10 cephalograms were randomly selected, retraced and digitized. The values obtained from the digitisations of the second tracing were compared against those of the first by way of the *t*-test. For the error of digitisation, 10 cephalometric radiographs were digitised twice within a week of each other for a total of three digitisations i.e., initial plus the last two. The three sets of measurements were compared using one-way ANOVA.

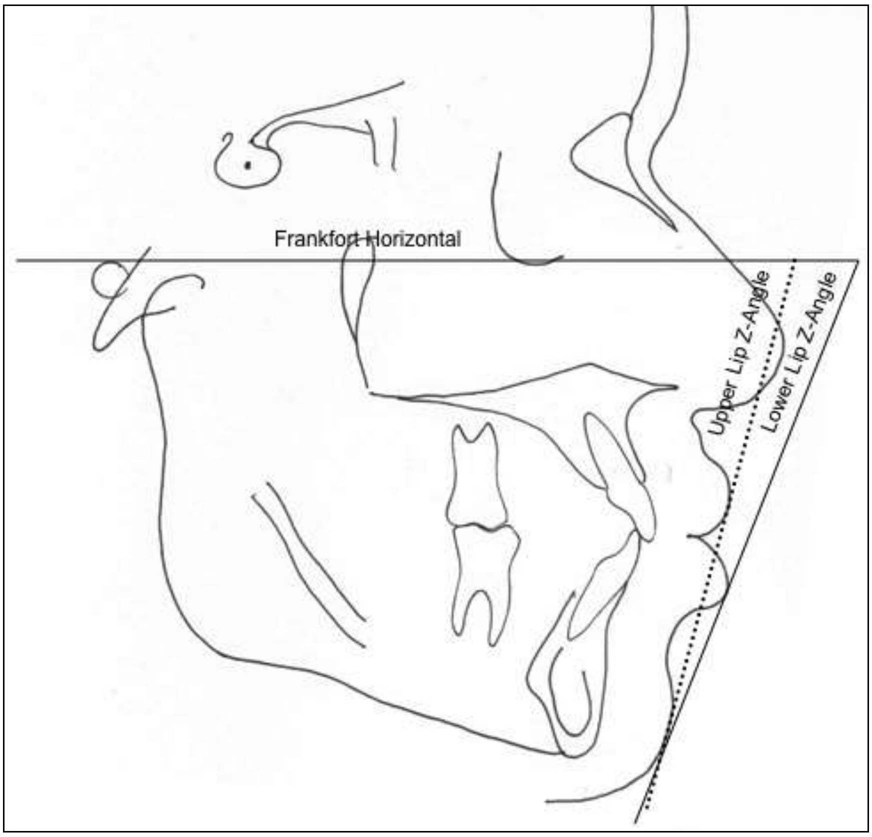

Figure 4: Upper and Lower Z-Angles

Data analysis

The data were analysed using SAS© (SAS Institute, Carry, NC). The results of the digitisations were first exported into Microsoft Excel © where primary manipulations were conducted, then into SAS© where the comprehensive analysis was done. The data were compared using the generalized linear mode (GLM) in SAS©. We assessed for interaction among three factors: time, gender and data source. There were five time points: T1 = six years; T2 = nine years; T3 = 12 years; T4 = 15 years; T5 = 18 years. There were two data sources: Denver and Michigan. Due to the small sample size of subjects from the Michigan group, “exact” methods of comparison were employed in SAS.

CHAPTER IV

RESULTS

The final data comprised 34 subjects, 27 of whom were from Denver and the remaining seven were from the Michigan data. No data were available for the Michigan group at T5. One radiograph (female) from the Michigan group was excluded at T1 because the subject was in open posture. A descriptive summary of the study sample is provided in Table I.

The GLM procedure revealed no interaction among Gender, Time and Data Source in the variable age and neither were there significant findings for the main effects of Gender and Data Source (Table II). However, the main effect Time was significant ($p<0.0001$). The least squares means (LSMean) of the age at the various time points are shown in Table III. The Bonferroni multiple comparisons showed significant differences among all five time points as related to age (Table IV).

FMA showed significant interaction between gender and time (Table V) necessitating stratification by gender for the variable FMA. Upon stratification, however, there was no significant change in FMA over time within each gender (Table VI). The male subjects generally had larger FMA compared with the females (Figure 5 and Table VII). Also, FMA gradually decreased, although non-significantly, from T1 to T5 (Figure 5).

Table I. Summary information on the number of subjects from each data source at the various time points.

		Time				
Gender	**Data Source**	**T1**	**T2**	**T3**	**T4**	**T5**
Female	Denver	15	15	15	15	15
	Michigan	1	2	2	2	0
Male	Denver	12	12	12	12	12
	Michigan	5	5	5	5	0
	Total	33	34	34	34	27

Table II ANOVA results for age.

Source	DF	F Value	Pr > F
SOURCE*Time*Gender	4	0.41	0.7983
SOURCE*Time	4	0.79	0.5318
Time*Gender	5	0.26	0.9316
Time	4	3108.26	<.0001

Table III Least squares means for age at the various time points.

Time	Gender	LSMean (years)	LSMean Number
T1	F	5.93	1
	M	5.92	2
T2	F	9.05	3
	M	9.20	4
T3	F	11.99	5
	M	12.10	6
T4	F	14.96	7
	M	14.92	8
T5	F	18.19	9
	M	18.12	10

Table IV Results of the Bonferroni multiple comparisons test for age.

i/j	1	2	3	4	5	6	7	8	9	10
1		1	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		1	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		1	<.0001	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	1		<.0001	<.0001	<.0001	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		1	<.0001	<.0001
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1		<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		1
10	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1	

Table V. Results of the GLM procedure for the variable FMA.

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Time	4	263.71	65.93	19.38	<.0001
Gender	1	253.62	253.62	74.54	<.0001
*Time*Gender*	*4*	*46.20*	*11.55*	*3.39*	***0.0114***

TABLE VI. Stratified results for FMA of the two genders. Table (a) = male and Table (b) = female.

(a) Male.

Source	**DF**	**Type III SS**	**Mean square**	**F Value**	**Pr > F**
Time	4	131.20	32.7994786	1.42	0.2361

(b) Female.

Source	**DF**	**Type III SS**	**Mean square**	**F Value**	**Pr > F**
Time	4	187.54	46.8853002	2.11	0.0879

Table VII. Summary statistics for FMA by gender. LCL = 95% lower confidence level of the mean, UCL = 95% upper confidence level of the mean.

GENDER	TIME	N	LSMEAN	LCL	UCL
F	T1	16	23.2	20.85	25.55
	T2	17	21.14	18.86	23.41
	T3	17	20.61	18.33	22.88
	T4	17	19.92	17.66	22.2
	T5	15	18.48	16.06	20.9
M	T1	17	24.4	22.07	26.72
	T2	17	24.43	22.11	26.75
	T3	17	23.88	21.56	26.21
	T4	17	23.33	21.01	25.65
	T5	12	20.62	17.85	23.38

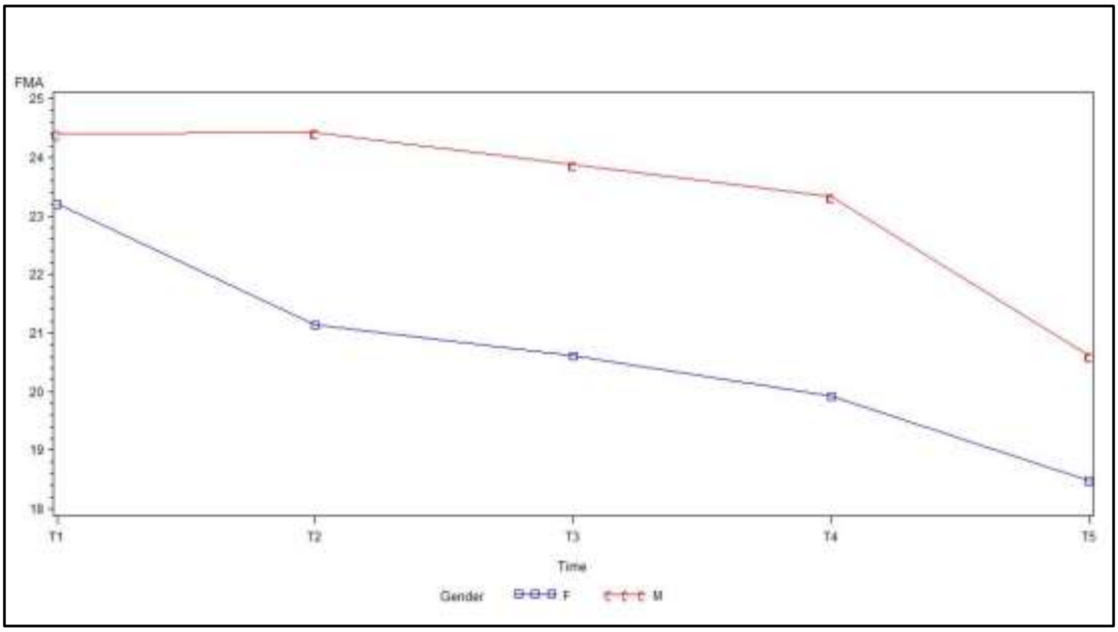

Figure 5. Changes in FMA over time for males and females. Generally, the male subjects had larger FMA values than the females.

The distance from the upper lip to the E-plane (ULE) decreased and became more negative during the time periods T1-T5, with significant interaction between time and gender. See Table VIII and Figure 6. The mean changes for each gender are displayed in Table IX.

The distance between the lower lip and the E-plane also decreased from T1 to T5 and became more negative. There was significant interaction between time and gender as relates to the position of the lower lip to the E-plane (Table X and Figure 7).

Nose depth showed a constant increase over the entire time period in both males and females with significant interaction between time and gender. Stratification by gender showed larger increase in men compared to the females, of which change occurred at between T3 and T4. See Table XII and XIII and Figure 8.

The total chin (TotChin) increased over the time period with significant interaction between gender and time (Table XIV). Stratification by gender showed a steeper and larger change in the male subjects compared with the females (Figure 9). The males showed a significantly larger value at T5 compared with the female subjects (Table XV and Figure 9). The soft tissue chin (STChin) showed significant interaction between gender and time (Table XVI). While the female subjects plateaued at T3, the male subjects increased significantly at the time only to plateau at T4. See Table XVII and Figure 10.

TABLE VIII Statistics for upper lip changes with respect to E-line over time.

(a) GLM procedure to assess for interaction between time and gender. Significant interaction between the two main effects required stratification by gender = male (b) and gender = female (c).

(a) Male

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	272.0154688	68.0038672	22.92	<.0001
Gender	1	11.1815208	11.1815208	3.77	0.0546
Time*gender	4	53.6516109	13.4129027	4.52	0.0020

(b) Female

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	129.0379668	32.2594917	5.35	0.0008

(c)

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	266.6991982	66.6747996	6.41	0.0002

Table IX. Least squares means (LSMean) of changes in Upper Lip to E-line stratified by gender. M = male, F = female. See Figure 6 for the plot of Upper Lip to E-line.

TIME	LSMEAN	
	M	F
T1	0.25	0.86
T2	0.44	0.71
T3	-0.74	-1.39
T4	0.25	-2.22
T5	-3.30	-4.01

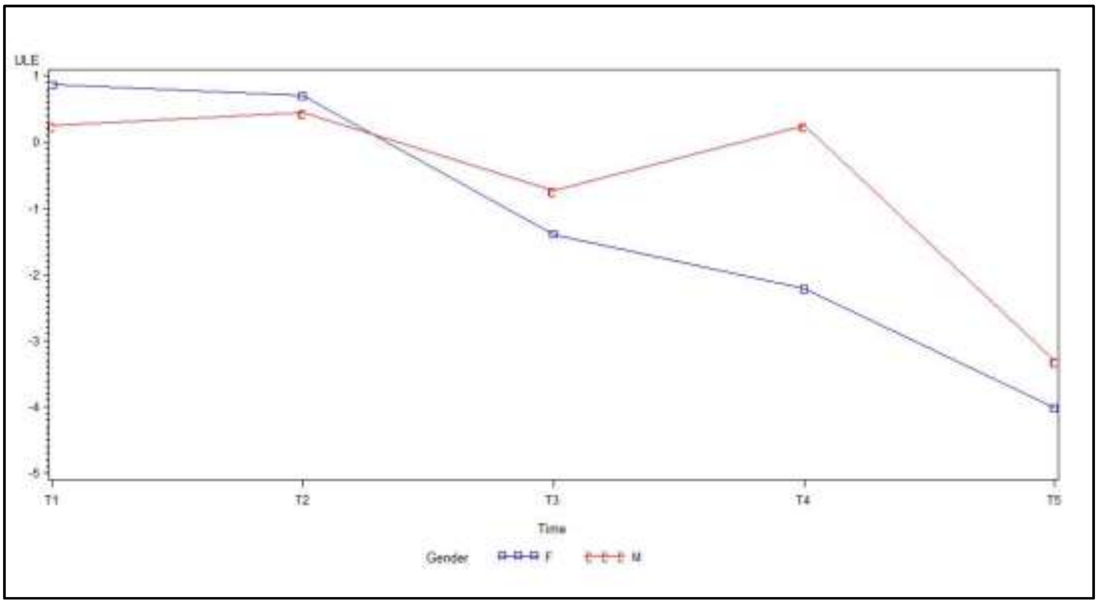

Figure 6. Changes in upper lip to E-line from T1 to T5 for males and females

Table X. Statistical results for lower lip changes with respect to E-line stratified by gender. (a)Table of main effects. (b) Male (c) Female.

(a)

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	103.18674	25.7966869	9.16	<.0001
Gender	1	1.7492420	1.7492420	0.62	0.4322
Time*gender	*4*	*32.758559*	*8.1896397*	*2.91*	*0.0245*

(b)

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	44.254267	11.0635667	1.75	0.1486

(c)

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	79.763441	19.9408603	1.52	0.2036

TABLE XI. Summary statistics of lower lip to E-line (LLE) stratified by gender. See Figure 7 for the plot of lower lip to E-line.

TIME	LSMEAN	
	M	F
T1	0.88	0.90
T2	0.68	1.15
T3	0.07	-0.14
T4	1.05	-0.81
T5	-1.18	-1.49

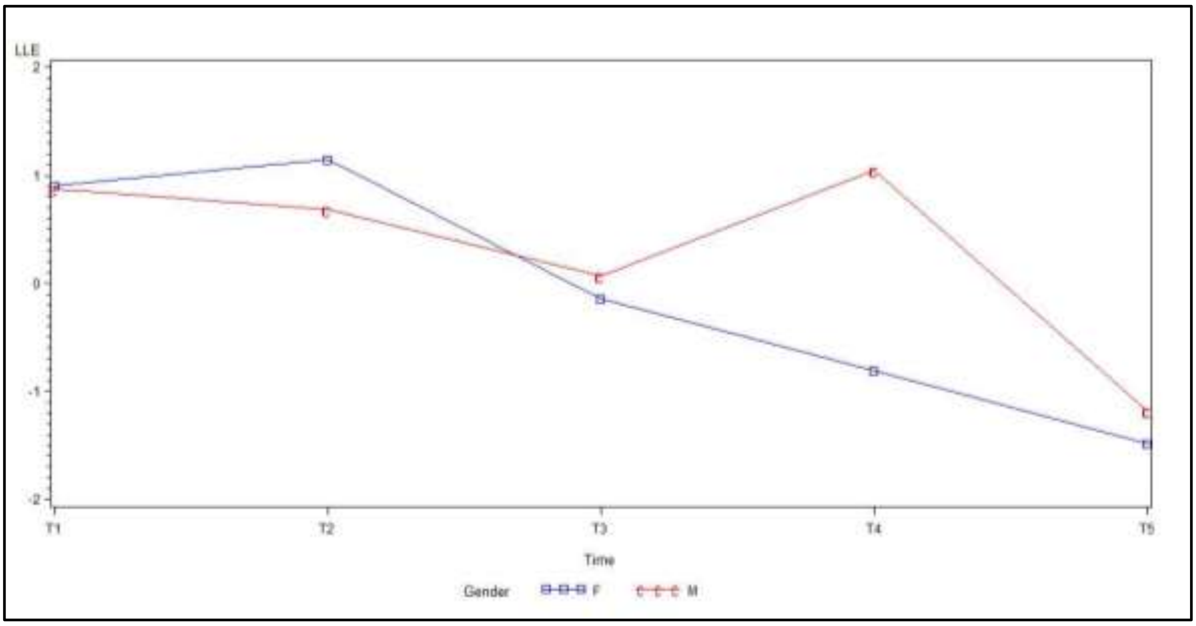

Figure 7. Changes in lower lip to E-line (LLE) over time for males and females.

Table XII. Statistical results for nose depth (NoseDPT) showing significant interaction between time and gender.

Variable	Source	F-value	P>F
NOSEDPT	Time	201.78	<0.0001
	Gender	0.89	0.3479
	Time*gender	8.69	<0.0001

Table XIII. LSMeans for nose depth stratified by gender.

NOSEDEPTH		
TIME	M	F
T1	22.56	22.09
T2	24.80	25.45
T3	26.72	28.85
T4	31.73	30.29
T5	33.79	31.23

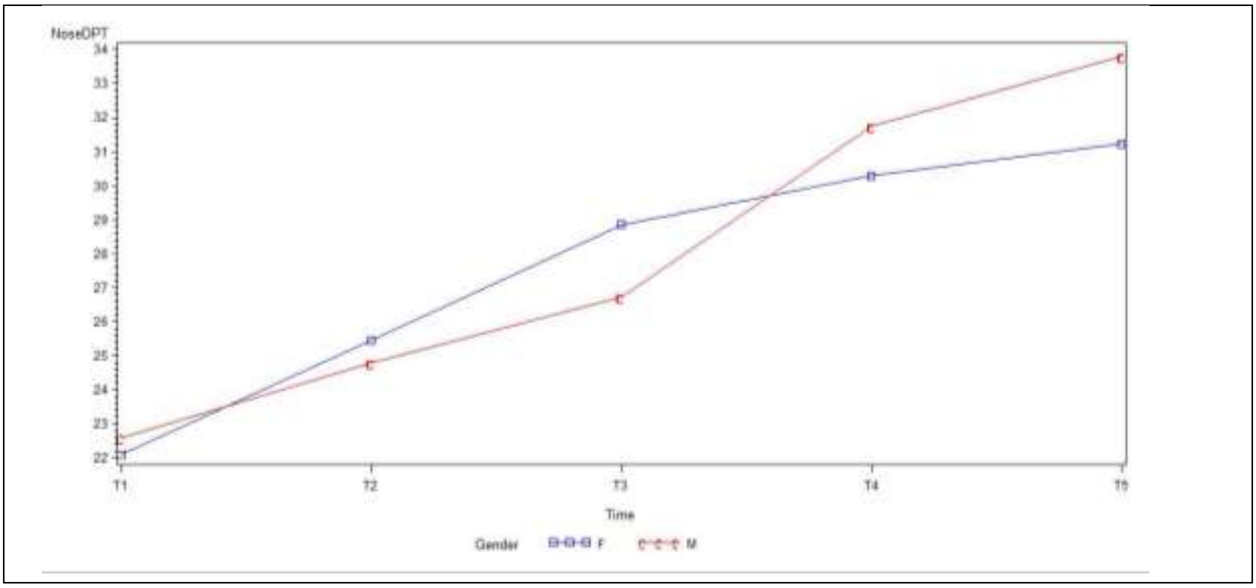

Figure 8. Changes in nose depth for males and females from T1 to T5.

Table XIV. ANOVA results for comparison of time and gender effects on the total chin (TotChin).

Variable	Source	F-value	P>F
TotChin	Time*Gender	10.23	<0.0001

Table XV. LSMeans for total chin (TotChin) stratified by gender.

TOTAL CHIN		
TIME	M	F
T1	10.04	10.19
T2	11.92	12.12
T3	13.26	13.34
T4	16.23	13.68
T5	16.16	13.61

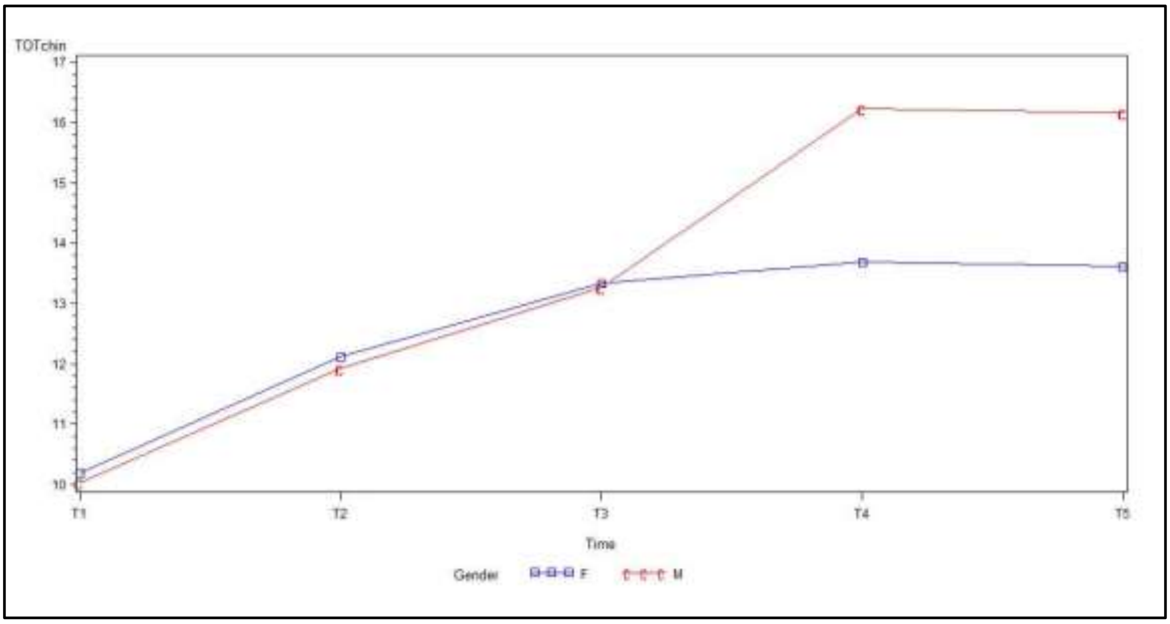

Figure 9. Plot of changes in total chin over time for males and females.

Table XVI. ANOVA results for changes in soft tissue chin. (STChin = soft tissue chin.)

Variable	Source	F-value	P>F
STChin	Time	24.56	<0.0001
	Gender	13.57	0.0003
	Time*Gender	8.32	<0.0001

Table XVII. LSMeans for soft tissue chin stratified by gender. STChin = soft tissue chin.

STChin	Gender	
TIME	M	F
T1	9.87	9.88
T2	10.24	10.48
T3	10.93	11.18
T4	13.15	11.06
T5	12.96	10.93

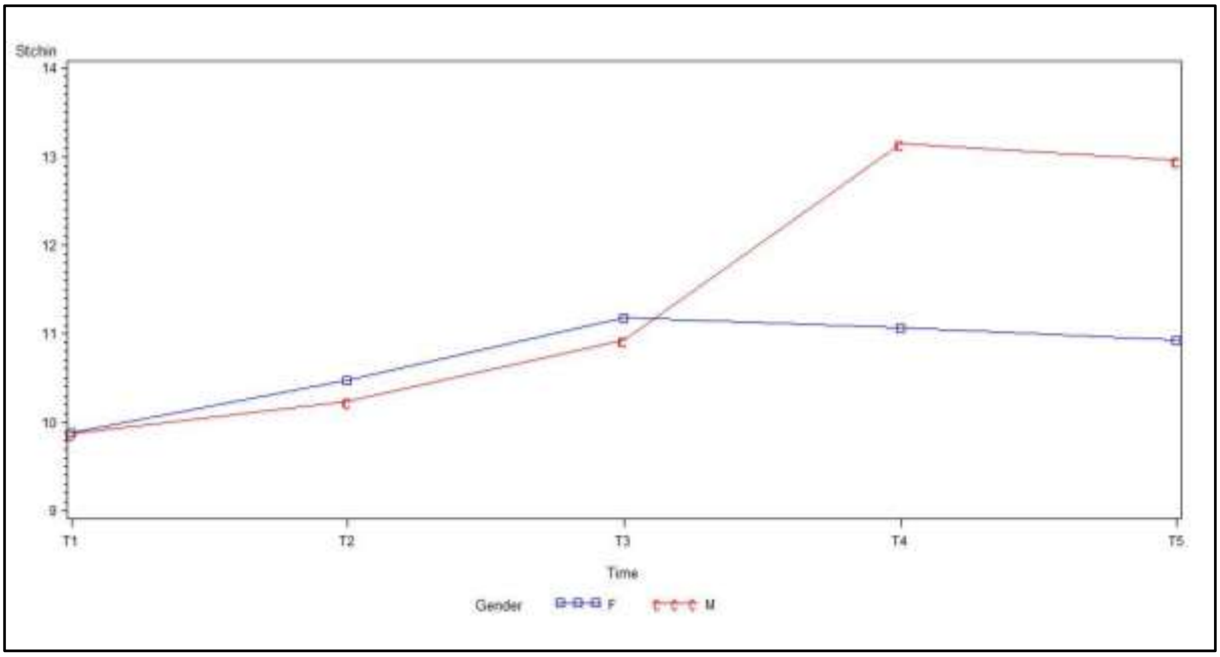

Figure 10. Changes in soft tissue chin for males and females from T1 to T5

The LLZ-angle showed significant increase from T1 to T5, however with no interaction between gender and time. See Table XVIII. For descriptive purposes, the LLZ was stratified by gender. The females showed a gradual increase until T4, whereas the males show a marked increase from T4-T5 and finished with a higher lower lip Z-angle than the females. Figure 11 illustrates the changes seen in the lower lip Z-angle from T1 to T5 for both males and females.

The Upper Lip Z-angle (ULZ) also increased from T1 to T5 with non-significant interaction between gender and time (Table XX and Figure 12). Stratification by gender for descriptive purposes showed that the ULZ for the male subjects was generally larger than that of the male subjects but only up to T4.

The diffZ increased from T1 to T5 with no significant interaction between time and gender (Table XXII). The male subjects, however, had larger diffz compared to the females and for descriptive purposes, the behaviour of diffZ was stratified by gender (Figure 13).

Table XVIII: Statistics for Lower Lip Z-angle. LLZ = lower lip Z-angle.

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	125.194546	281.298636	17.99	<.0001
Gender	1	523.877181	523.877181	33.51	<.0001
Time* Gender	4	110.119298	27.529824	1.76	0.1412

Table XIX. LSMeans of the LLZ from T1 to T5.

TIME	LLZ(º)
T1	72.08
T2	72.33
T3	74.61
T4	77.61
T5	79.44

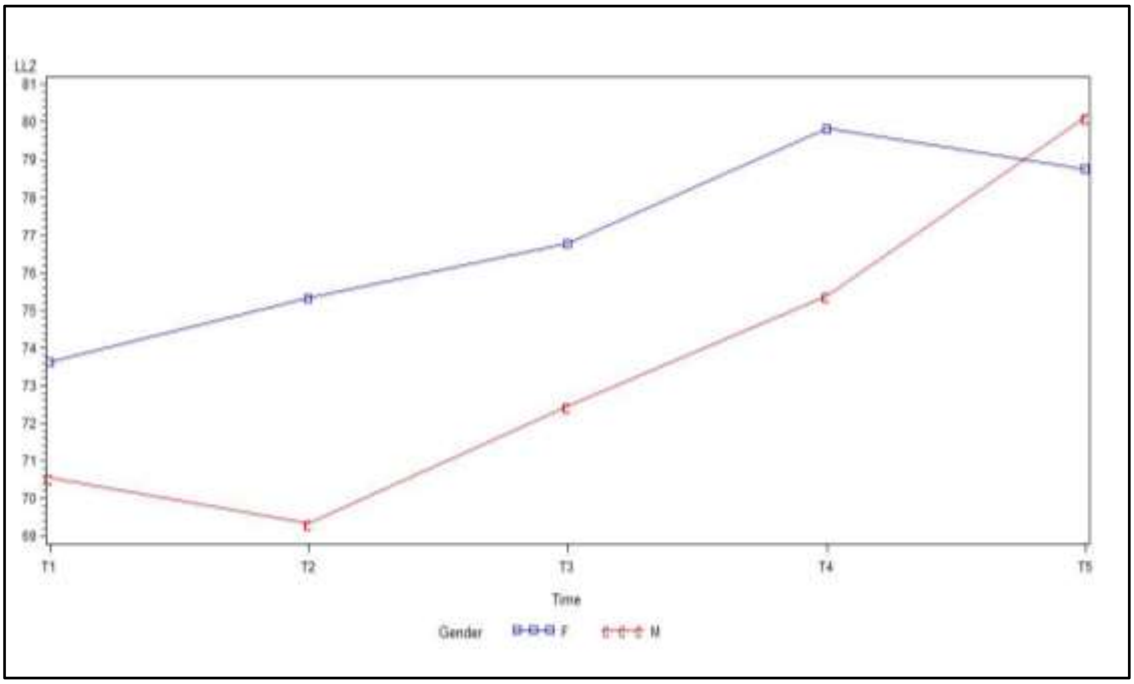

Figure 11. Changes in the lower lip Z-angle for males and females

Table XX: ANOVA results for upper lip z-angle (ULZ)

Source	DF	Type III SS	Mean square	F Value	Pr > F
Time	4	1329.53247	332.383118	43.84	<.0001
Gender	1	88.289841	88.289841	11.64	0.0009
Time* Gender	1	26.463863	6.615966	0.87	0.4826

Table XXI. Summary statistics of the upper lip Z-angle (ULZ) from T1 to T5.

TIME	ULZ
T1	71.78
T2	73.53
T3	75.70
T4	78.27
T5	80.07

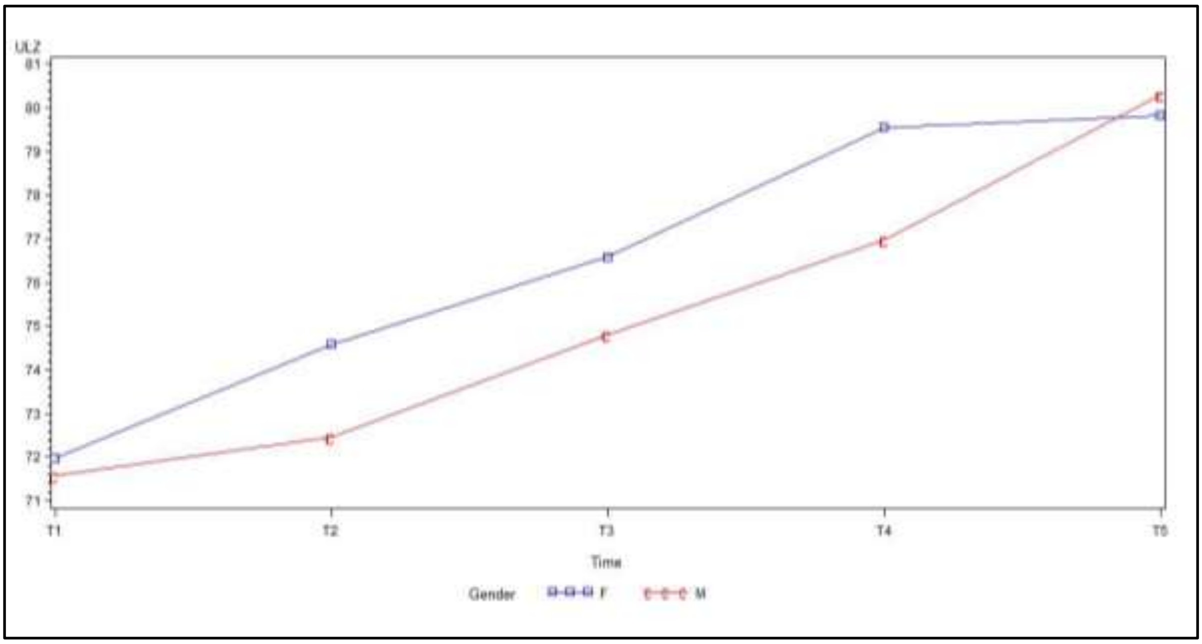

Figure 12. Changes in the upper lip Z-angle (ULZ) over time for males and females

Table XXII. Summary statistics for diffZ.

Source	**DF**	**Type III SS**	**Mean square**	**F Value**	**Pr > F**
Time	4	46.8790999	11.7197750	1.92	0.1123
Gender	1	*182.0366560*	*182.0366560*	*29.75*	*<.0001*
Time* Gender	4	58.1759740	14.5439935	2.38	0.0557

Table XIII. LSMeans for diffz from T1 to T5 for both genders combined.

TIME	diffZ
T1	-0.30
T2	1.20
T3	1.09
T4	0.66
T5	0.63

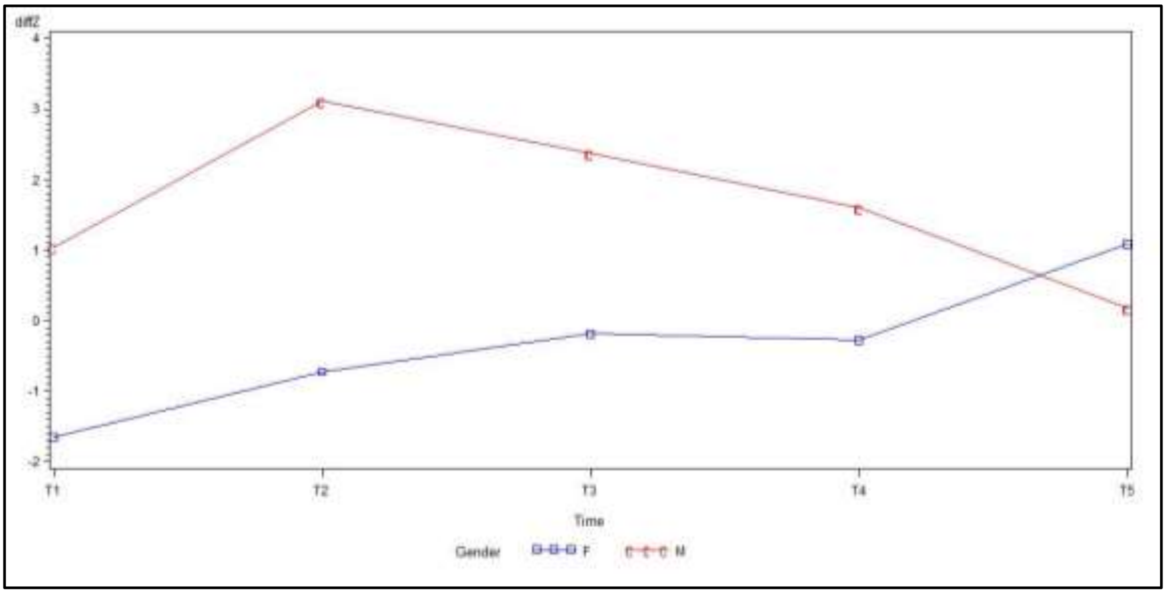

Figure 13. Changes in the diffz for males and females.

Table XIV. Summary of changes in the Z-angle between adjacent time points.

Time	N	Variable	Mean	Std	Min	Max	LCL	UCL	P-value
T1T2	33	diffLLZ	-0.18	6.87	-12.9	10.8	-2.62	2.25	
		diffULZ	-1.62	4.13	-9.9	10.7	-3.084	-0.15	
		diffZ2	-1.43	4.61	-9.1	9	-3.07	0.20	0.0836
T2T3	34	diffLLZ	-2.28	4.54	-9.4	12	-3.87	-0.69	
		diffULZ	-2.17	3.69	-9.3	8	-3.46	-0.88	
		diffZ2	0.11	2.9	-6.1	6	-0.90	1.12	0.8325
T3T4	34	diffLLZ	-2.99	5.09	-12.5	10.7	-4.77	-1.22	
		diffULZ	-2.56	3.87	-10.5	6.5	-3.91	-1.22	
		diffZ2	0.43	2.98	-6	6.3	-0.61	1.47	0.4076
T4T5	27	diffLLZ	-1.16	4.08	-9.1	7.2	-2.77	0.46	
		diffULZ	-1.43	2.64	-6.4	4.1	-2.48	-0.38	
		diffZ2	-0.27	2.39	-5.6	4.7	-1.22	0.67	0.5556

CHAPTER V

DISCUSSION

In order for orthodontists to adequately achieve their predetermined treatment objectives and a predictable change in facial aesthetics, the nature and quantity of the expected growth must be well anticipated. Since growth is so closely linked to orthodontic treatment and to a large extent contributes to determining the final result in growing patients, it is imperative that the treating orthodontist has a thorough knowledge and understanding of the growth patterns of the facial structures. The emphasis in orthodontic treatment today is the face with particular reference to the soft tissue and this too goes through some significant changes. The purpose of this research was to assess longitudinal soft tissue changes of the facial profile using the Z-angle. A number of other parameters that assess the soft tissue were also included to appreciate the changes associated with the Z-angle.

The Z-angle has traditionally been described as the angle which is formed between Frankfort horizontal and the line from the chin to the most protrusive lip. Erdinc, Nanda and Dandajena (2007) further described two Z-angles in a similar manner but with reference to the upper and lower lips as upper Z-angle and lower Z-angle. This is the format that was followed in this study and will be discussed accordingly.

The LLZ increased from T1 (72.08°) to T5 (79.44°), with a more gradual change in the females compared to the males. The females showed a steady and uniform increase in the LLZ from T1 up until T4, after which there was a sharp decrease from T4 – T5. The males on the other hand showed an initial decrease from T1-T2, followed by a steady and uniform increase from T2 – T4 which ran almost parallel to that of the females. Thereafter the males showed a sharper increase from T4 –T5 and finished with a higher LLZ than the females.

The Z-angle is not influenced by changes in the nose depth. While the nose depth increased with resultant decrease in the E-lines, the Z-angle gradually increased for both the upper and lower lips. There are two possible reasons for this change: increase in chin thickness and retrusion of the lips.

TotChin increased for both males and females with the females plateauing at T3 and the male subjects continuing to increase. Similar behaviour was noted for the STChin. Thus a major contributor to the change in the Z-angle could be the position of the chin with much of the change emanating from increases in STChin. Other investigators have reported increases in the bony chin up till early adulthood (Formby *et. al.*1994). Similar observations are noted in this study but only up till T3 in the females and T4 in the males.

The total chin is a composite of the STChin and hard tissue as measured from Pog-NB. The hard tissue chin can be used for prediction of mandibular growth, together with FMA. According to Aki *et. al.* (1994), individuals with prominent chins and low FMA tend to be horizontal growers. The subjects in this study had average FMA at T1 (23.2º and 24.4º for the females and males, respectively) which decreased non-significantly to 18.4º for the females and 20.6º for the males at T2 thus indicating a horizontal growth pattern for the subjects. Just as much, there was significant increase in the total chin which was coupled with improvement in the Z-angles, particularly the LLZ. Interesting enough, however, the diffZ did not change.

While not directly assessed in this study, lip thickness at both labrale inferius and labrale superius decreases with advancing age (Formby *et al,* 1994). Unlike the Z-angles which experienced uniform change as measured by the diffZ, the lip positions with respect to the E-line continued to decrease to negative values due to changes in the nose as measured by the nose depth as well as the chin position (Nanda *et. al,* 1995*)*. This makes the Z-angle more reliable than the E-lines in predicting the integumentary profile.

The Z-angles changed at a uniform pace in this study. The findings of this study indicate that one cannot use the same Z-angle across different age groups as reported by Merrifield (1966), who recorded a mean Z-angle of 78 degrees. While the eventual value of 77.4º reported in this study is similar to that advocated by Merrifield, care should be taken to not treat to adult values at all times as the Z-angle normalizes with advancing age. While Zylinski *et al.* reported similar findings of improvement in the Z-angle with advancing age, the sample they utilized was cross-sectional. However, as is the case in this study, it showed differences among age groups in the Z-angle.

As was the case with Zylinski *et. al.,* differences in the samples need to be noted between this study and that of Merrifield. Whereas we studied untreated normal growing subjects with Class I occlusion with a horizontal growth pattern, Merrifield sampled patients post treatment with the most ideal measurements for their FMA, FMIA, IMPA and ANB angles (Merrifield, 1966).

While Merrifield assessed only the most protrusive lip, our reference was to both lips as described by Erdinc, Nanda and Dandajena (2007). In our study, the upper lip was consistently protrusive and this was maintained from T1 to T5. The value of the most protrusive lip was different from that reported by Merrifield. However, the relationship between the upper and lower lips were maintained throughout the period under investigation as evidenced by the diffZ, which remained constant from T1 to T5. Important however is the fact that the Z-angles increased without intervention thereby showing that the Z-angle is not a constant measure, and it varies by age. This needs to be taken into consideration during treatment planning and growth forecasting. The subjects in this study had a mean FMA of 23^{o}, indicating horizontal growth of the subjects. High angle patients may not behave in the same manner as their mandibles tend to show an opening growth rotation. Such growth patterns can be determined as early as age six (Nanda, 1988).

The results of this study show that the Z-angle does not remain constant over time. When the patient has a normal growth pattern as evidenced by the FMA, the Z-angle is expected to improve. Care should be taken in treatment planning to consider the future changes.

CHAPTER VI

SUMMARY AND CONCLUSION

Lateral cephalometric radiographs of 17 boys and 17 girls with Class I occlusion and no history of orthodontic treatment were evaluated over the ages of six to 18 years to assess the age related changes to the Z-Angle. All the subjects were Caucasians of North European ancestry. The Z-angle increased from childhood to adolescence for both upper and lower lips. This illustrated that the profile becomes flatter with time in both genders. As such, we failed to reject the hypothesis that the Z-angle changes with advancing age.

Changes in the Z-angle were associated with increases in the total chin and the soft tissue chin. Concomitantly, both upper and lower lips receded with an advancing chin and nose as evidenced by increases in total chin and deepening of the nose depth. These findings can be relied upon since the growth pattern of the subjects was consistent as confirmed by the FMA. While there was some sexual dimorphism, the male subjects were generally larger than the females. However, the growth pattern was identical for both.

The findings of this study can be summarized as follows:

1. Lateral cephalometric radiographs of 17 boys and 17 girls with Class I occlusion and no history of orthodontic treatment were evaluated over the ages of 6 years to 18 years to assess the age related changes to the Z-Angle. All the subjects were Caucasians of North European ancestry.

2. The findings of this study showed that the Z-Angle did change with age as it increased from T1 to T5 time periods. One cannot rely on the adult values when treatment planning the growing child, but should instead consider the possible changes which occur to the Z-angle naturally. This study has shown that the currently established normative values of the Z-Angle are not applicable at all ages, due to the constant change in the Z-Angle.

3. The changes in the Z-angle could be linked to forward growth of the chin and retrusion of the lips.

4. There was some sexual dimorphism in the behaviour of the Z-angle, with the females plateauing earlier than the male subjects. Effectively however, the values were similar.

Limitations

The study analysed only those subjects with an average FMA. We do not know how high angle patients would behave. Furthermore, the study was only based on cephalometric evaluation without regard to the clinical patient profile.

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