EVALUATION, COMPARISON AND CORRELATION OF SOFT TISSUE AND HARD TISSUE CHANGES FOLLOWING ORTHODONTIC TREATMENT OF BIMAXILLARY DENTOALVEOLAR PROTRUSION MALOCCLUSION WITH ALL FOUR FIRST PREMOLAR EXTRACTIONS – A CEPHALOMETRIC STUDY.

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CONTENTS

Chapter no.	TITLES	PAGE NO.
1	INTRODUCTION	1
2	AIM AND OBJECTIVES	8
3	REVIEW OF LITERATURE	10
4	MATERIALS AND METHODS	29
6	RESULTS	37
7	DISCUSSION	48
8	LIMITATIONS	62
9	SUMMARY AND CONCLUSION	63
10	BIBLIOGRAPHY	66
ANNEXURE • Master chart		

LIST OF TABLES

Table No.	Title	Page No.
1	Comparison of hard tissue parameters before and after treatment	37
2	Comparison of soft tissue parameters before and after treatment	40
3	Comparison of incisor tip from TVL before and after treatment – hard tissue parameters	43
4	Comparison of distance of lip from TVL before and after treatment – soft tissue parameters	44

LIST OF GRAPHS

Graph No.	Title	Page No.
1	Horizontal bar chart showing mean distance for each hard tissue parameter before and after treatment.	39
2A	Horizontal bar chart showing mean distance for each soft tissue parameter before and after treatment.	42
2B	Horizontal bar chart showing mean angle for each soft tissue parameter before and after treatment.	42
3	Column chart showing mean distance of upper and lower incisor tip from TVL.	43
4	Column chart showing mean distance of upper and lower lip from TVL.	44
5	Scatter plot showing change in upper lip position versus change in upper incisor position.	45
6	Scatter plot showing change in lower lip position versus change in lower incisor position.	46

LIST OF COLOUR PLATES

SR. NO.	PLATE NO.	TITLES	
1	I	SOFT COPY OF LATERAL CEPHALOGRAM	PRE-TREATMENT
			POST-TREATMENT
2	II	CALIBERATION ON NEMOCEPH SOFTWARE	PRE-TREATMENT
			POST-TREATMENT
3	III	TRACED LANDMARKS ON NEMOCEPH SOFTWARE	PRE-TREATMENT
			POST-TREATMENT
4	IV	COMPLETED TRACING ON NEMOCEPH SOFTWARE	PRE-TREATMENT
			POST-TREATMENT
5	V	COMPLETED TRACING WITH TVL ON NEMOCEPH SOFTWARE	PRE-TREATMENT
			POST-TREATMENT
6	VI	UPPER AND LOWER INCISOR & UPPER AND LOWER LIP DISTANCE AS MEASURED FROM TVL	PRE-TREATMENT
			POST-TREATMENT

LIST OF ABBREVIATIONS

Sr. No.	Short Form	Full form
1	TMJ	Temporo Mandibular Joint
2	TM	Temporo Mandibular
3	LS	Labrale Superior
4	LI	Labrale Inferior
5	N	Nasion
6	2D	Two Dimensional
7	3D	Three Dimensional
8	U1	Upper Incisor
9	L1	Lower Incisor
10	TVL	True Vertical Line
11	Pog	Pogonion
12	PR	Prosthion
13	Id	Infradentale
14	HP	Horizontal Plane
15	E-Plane	Esthetic Plane
16	H-Line	Harmony Line
17	NHP	Natural Head Position
18	ICC	Intra Class Correlation Coefficient
19	MBT	McLaughlin Bennett Trevisi
20	mm	Millimeter
21	SD	Standard Deviation

INTRODUCTION

Much emphasis has been placed on the esthetics of mouth and its contribution to beauty of the face.[1,2] Orthodontics is a means to help in obtaining harmony of the facial profile. In the past there have been paradigm shifts of whether extraction or non-extraction treatment was the ideal way to treat orthodontic cases.[3]

The views have included those of Angle, in that a full complement of teeth in a proper occlusion would produce a harmonious face to Tweed's philosophy of placing the mandibular incisors upright over basal bone to provide the most stable occlusion and the best facial esthetics.[1,3]

Many studies exist in the orthodontic literature which looked at changes in the facial profile and incisor position as a result of orthodontic treatment with premolar extractions. These studies are important to help guide the clinician in making

treatment decisions and to know the effect they might have on the patient's soft tissue profile**.**

In orthodontics, at present we are on the threshold of a paradigm shift that changes the fundamental conceptual underpinnings of orthodontics, and with it, the traditional emphasis in diagnosis and treatment planning. Formerly, the emphasis was on the dental and skeletal components; now, greater attention to the soft tissue aspects of orthodontics is required.[4]

For 100 years, orthodontic theory and practice has been largely based on the "Edward H. Angle Paradigm" wherein the objectives of treatment were to obtain ideal proximal and occlusal contact of teeth (occlusion), classical balanced facial esthetics, perfect function and immutable denture stability for each individual.[4]

Orthodontic treatment outcomes are a compromise between the orthodontist's wishes and nature's demands, particularly in the long run. It has taken long to realize that soft tissues largely determine the limitations of orthodontic treatment.[4]

As patients become more concerned with the esthetics of their smile, it has become more relevant for orthodontists to pay attention to the soft tissue framework and hence the paradigm shift in modern orthodontic diagnosis and treatment planning.

Hard tissue structural discrepancies have been traditionally viewed as major limitation of orthodontic treatment. In reality, it is the soft tissues that more closely determine therapeutic modifiability.[5]

The boundaries of dental compensation for an underlying jaw discrepancy are established by several aspects of soft tissue relationships and function.[6]

These include:

1) pressures exerted on the teeth by the lips, cheeks and tongue.[7]
2) limitations of the periodontal attachment.
3) neuromuscular influences on mandibular position.
4) contours of the soft tissue facial mask.
5) lip-tooth relationships and anterior tooth display during facial animation.[5,8]

The physiologic limits of orthodontic treatment i.e the ability of the soft tissues to adapt to changes in tooth and jaw positions are often narrower than the anatomic limits of treatment. In the correction of a severe malocclusion in a growing patient, it is not unusual to produce a change of 7-10 mm in a molar relationship overjet or overbite. Yet the tolerances for soft tissue adaptation from an equilibrium, periodontal, TMJ, facial balance, and anterior tooth display standpoint are often less than half this amount.[4]

Designing of an orthodontic treatment plan not only includes envisioning the consequent facial change but also future of the post treatment occlusion. Orthodontic results should be evaluated on the basis of overall benefit to the patient. Treatment 'failures' are generally the result of poor treatment response rather than inadequate treatment, and treatment response is also, to a great extent, determined by the soft tissues. Thus, it is the orthodontist's task in diagnosis and treatment planning to

ascertain an individual's available limits of soft tissue adaptation, given the dental and skeletal changes that the orthodontist and patient would like to create.[4]

The soft tissue paradigm states that both the goals and limitations of modern orthodontic and orthognathic treatment are determined by the soft tissues of the face, not by the teeth and bones. This reorientation of orthodontics away from the Angle paradigm that dominated the twentieth century is most easily understood by comparing treatment goals, diagnostic emphasis and treatment approach in the two paradigms.

Angle versus Soft tissue Paradigms: A new way of looking at treatment goals

Parameter	**Angle Paradigm**	**Soft tissue Paradigm**
Primary treatment goal	Ideal dental occlusion	Normal soft tissue proportions and adaptations
Secondary goal	Ideal jaw relationships	Functional occlusion
Hard/soft tissue relationships	Ideal hard tissue proportions produce ideal soft tissues	Ideal soft tissue proportions define ideal hard tissues
Diagnostic emphasis	Dental casts, cephalometric radiographs	Clinical examination of intra-oral and facial soft tissues
Treatment approach	Obtain ideal dental and skeletal relationships, assume the soft tissues	Plan ideal soft tissue relationships and then place teeth and jaws as needed to

Parameter	**Angle Paradigm**	**Soft tissue Paradigm**
	will be OK	achieve this
Function emphasis	TM Joint in relation to dental occlusion	Soft tissue movement in relation to display of teeth
Stability of result	Related primarily to dental occlusion	Related primarily to soft tissue pressure/equilibrium effects

With soft tissue paradigm, there must be increased focus on clinical examination rather than examination of dental casts and radiographs, leading to a different approach in obtaining important diagnostic information and that information is used to develop treatment plans which were impossible to design without such information. The change in paradigm helps to provide a more esthetic benefit to the patients rather than just functional correction.

The term "Bimaxillary Protrusion" was first used as early as 1897 by **Dr. Calvin C. Case** in his textbook published in **1921**, "Dental Orthopedia and Correction of Cleft Palate."[9]

It is a condition characterized by protrusive and proclined upper and lower incisors and an increased procumbency of the lips. Underlying skeletal prognathism and dentoalveolar protrusion produce a convex lower facial profile, procumbent lips and a protrusive anterior dentition, often resulting in lip incompetence, mentalis strain and excessive gingival display.[10] This situation is esthetically unacceptable to some patients, and they seek orthodontic treatment.

Because the teeth have a normal molar relationship and a relatively normal overbite and overjet, some clinicians in the past considered these cases to be in perfect harmony and balance with their physiognomy.

The negative perception of protruding lips and an overly protrusive dentition leads many patients with bimaxillary protrusion to seek orthodontic care to decrease this procumbency.[11] To fulfil this objective, four premolar extraction is planned to create room for retraction of anterior teeth. Orthodontic treatment can correct dentoalveolar protrusion by uprighting and retracting the anterior teeth, after the extraction of four premolars has been done. The etiology of bimaxillary protrusion is multifactorial and consists of a genetic component as well as environmental factors, such as habits, musculature,etc.

The goals of orthodontic treatment of bimaxillary protrusion include the retraction and retroclination of maxillary and mandibular incisors with a resultant decrease in soft tissue procumbency and convexity. This is most commonly achieved by the extraction of four first premolars followed by the retraction of anterior teeth using maximum anchorage mechanics.[12]

The effect of first premolar extractions has a remarkable impact on improving the attractiveness of the face with a large range of soft tissue response involving anterior retraction.

Although facial attractiveness is a matter of personal preference and is relative concept, a positive response was observed in individuals with Bimaxillary Protrusion following treatment.

In this digital era, Nemoceph, a 2-dimensional software has made analysis, diagnosis and treatment planning of the malocclusions and the dentofacial skeleton remarkably easier. Thus, the purpose of this study is to evaluate, compare and correlate the concurrent soft tissue and hard tissue changes following orthodontic treatment of Bimaxillary Protrusion malocclusion patients with all four first premolars extractions using the Nemoceph Software.

AIMS AND OBJECTIVES

Aim of the study

To test the hypothesis that there is a definitive correlation between the soft tissue and hard tissue changes following orthodontic treatment of Bimaxillary Dentoalveolar Protrusion malocclusion with all four first premolar extractions.

Objectives of the study

1. To evaluate hard tissue changes following orthodontic treatment of Bimaxillary Dentoalveolar Protrusion malocclusion with all four first premolar extractions.

2. To evaluate soft tissue changes following orthodontic treatment of Bimaxillary Dentoalveolar Protrusion malocclusion with all four first premolar extractions

3. To compare the changes between soft tissues and hard tissues in pre-treatment and post-treatment lateral cephalograms.

4. To correlate the soft tissue parameters with the hard tissue parameters in pre-treatment and post-treatment lateral cephalograms.

REVIEW OF LITERATURE

As early as **1907, Angle** [13] said that On a daily basis, orthodontists are faced with the decision whether to extract or not extract teeth when diagnosing and planning treatment. This decision has been a topic of debate for a long time. In 1907, Angle suggested that if the dentition was intact and arranged in an optimum occlusion, the soft tissue would then assume a harmonious position.

Milo Hellman (1939)[14] conducted study on adult males. The various measurements were taken directly from the individuals face. He showed the distribution of normal, sub-normal and super-normal dimension of facial features among individuals with different type of occlusion. He described some 'standard' which provide a quantification that greatly reduces the confusing intricacies of facial variation and simplifies the practical problem of appraising faces of orthodontic needs.

Tweed (1944)[15] thought the removal of teeth was often necessary to obtain normal occlusion. He proposed the use of a skeletal diagnostic triangle as an aid to treatment planning, with the assumption that an upright mandibular incisor over basal bone is both stable and esthetics.

Nance (1949)[16] was one of the first orthodontists to advocate the extraction of four second premolars instead of the common practice of four first premolars. He recommended this extraction pattern in cases with mild bimaxillary protrusion and crowding. In such cases, he proposed the molar would move further forward into the extraction space than in four first premolar extraction cases. He felt that this does not allow as much incisor retraction, thus the facial soft tissue will have less of a tendency to distort.

Riedel (1950)[17] concluded that various points which make up the hard tissue profile outline, i.e points A, the upper incisor, the lower incisor and points B and Pog, bear harmonious relationship to each other in patients presenting "good" profiles. In the correction of a particular malocclusion it should be the aim of the orthodontist to produce such facial balance or harmony which is possible within the limitations of the case. If it is not possible in a particular instance to reduce the angle of convexity or change the apical base relationship, then atleast the orthodontist may reduce the protrusion of the teeth.

Dewel (1955)[18] proposed similar indications for four second premolar extractions. He proposed that border-line cases with acceptable facial balance and mild to moderate tooth size arch length disprepancy were the best candidates for this extraction pattern.

Burstone (1958)[19] in evaluating the integumented profile on the Herron sample felt that much variation exists between individuals in regard to soft tissue thickness, length and posture overlying the hard tissue foundation of the human face. He found that there is no fact in the hypothesis that lip posture followed the posture of the underlying teeth. On the contrary, Burstone suggested that the lip posture may be the etiological factor causing a malrelationship of the teeth and advocated that the lip posture should be a primary factor in treatment planning. Lip length and posture are different for each individual and therefore affect and are effected differently. Burstone stated that, in diagnosing an orthodontic case, the soft tissue should be a criterion as well as the dental and skeletal structures because the soft tissue is the final determiner of facial esthetics and harmony.

Subtelny (1959)[20] conducted a longitudinal study in order to assess the soft tissue profile changes and their relation to the underlying skeletal profile. He studied serial cephalometric radiographs of 30 subjects from 3 months to 18 years of age. The composite result of this study indicated that all parts of the soft tissue profile did not exactly match the underlying skeletal profile – some areas were found to diverge in soft tissue contour from the underlying skeletal structures, while other areas showed a strong tendency to follow the skeletal changes directly.

Milton Neger (1959)[21] had done a study on 48 young male and female subjects with different occlusion to evaluate the soft tissue profile in a quantitative manner on a profile photograph with six profile angles established between upper lip, lower lip and chin. The information gained from the study that, the straight profile does not necessarily accompany normal occlusion. This study also concluded that a

proportionate change or improvement of the soft tissue profile does not necessarily accompany extensive dentition changes and that, therefore, one can no longer rely entirely on a dentoskeletal analysis for accurate information on the soft tissue facial profile changes which have occurred during orthodontic treatment.

Steiner's S-line(1960)[22] was drawn from soft-tissue pogonion to the columella of the nose. In an esthetically pleasing face, both the upper and lower lips should fall on this line.

Bloom (1961)[23] found that as the maxillary incisors changed so did the superior sulcus, upper lip and lower lip and as the mandibular incisors changes, the inferior sulcus and lower lip changed.

Richard Hambleton (1964)[24] reported on the soft tissue covering of the skeletal face. He stated that the facial curtain is more than just the underlying bone. It is also made up of muscles, fatty tissue, nerves and blood vessels. He said " the assumption that the integumented profile will take care of itself unaided should not be relied upon." The orthodontist should keep in mind the age and growth factors inherent in the face of the individual.

Rudee (1964)[25] also found a slightly higher ratio for upper incisor to upper lip retraction and a slightly lower ratio for lower incisor to lower lip retraction than previous studies mentioned. The ratios he found were 2.9:1 and 0.6:1 respectively. The author did find a high correlation for both the upper lip response (r=0.73) and lower lip response (r=0.70) to incisor retraction.

Merrifield's line (1966)[26] of reference was called the profile line. The line is drawn from the tangent of the soft-tissue chin and to the most anterior point of the most protruding lip and extended upward to the Frankfort plane. He believed this was a useful reference line because it was positioned in the area of the face in which the orthodontist has the most influence through tooth movements.

Burstone (1967)[27] had an esthetic line of his own, the B-line, that helped to evaluate the relative protrusion or retrusion of the lips. The B-line connects subnasale and soft-tissue pogonion. On average, the upper lip lies 3.5 mm anterior to the line and the lower lip lies 2.2 mm anterior to the line.

Ricketts (1968)[28] did more extensive work in the study of the lips and the profile. He went as far as to classify mouth disharmonies. There were four types that described the position of the lips in relation to the E-plane. Type I and II were classified as disharmonies, where types III and IV were imbalances. Type I involved both the upper and lower lip being beyond the esthetic plane and was termed bimaxillary protrusion. Type II was bimaxillary retrusion, with both the upper and lower lip being behind the esthetic plane. Type III, upper lip proversion, was described as having undesirable fullness of the upper lip and it being closer to the E-plane than the lower lip. In contrast, Type IV, lower lip eversion, involved having the lower lip extend beyond the E-plane and being too far forward of the upper lip.

Spiro Chaconas and Jack Bartroff (1975)[29] conducted a study on 46 Caucasian children for whom cephalometric records were taken yearly from the ages of 10-16 years. This study showed that at age 10 years all of the males had profiles that were less convex than the females. The difference in convexity seemed to be

defined by sex rather than classification of occlusion. At 10 years of age the female profile was more convex than that of the male. By age 16 years there was no well defined sex differentiation in facial convexity. The convexity of the females remained relatively stable after 13 years of age. The greatest spurt for the males was between 12 and 15 years of age. They found that the changes in the lip convexity was negligible at 16 years of age relative to the 10 years of age.

Roos (1977)[30] also found similar ratios of incisor retraction to lip retraction in his study of 30 Class II division 1 patients treated with four first premolar extractions. He found the upper incisor to upper lip ratio to be 2.5:1 and the lower incisor to lower lip ratio to be 1.1:1. He found a moderate correlation (r=0.42) for the upper incisor to upper lip ratio and a strong correlation (r=0.82) for the lower incisor to lower lip ratio.

Jacobs (1978)[31] found a ratio of 1:0.7 for upper incisor retraction to upper lip retraction. Pre- and post-treatment cephalometric roentgenograms of eleven male and nine female white patients treated with first premolar extraction for Class II, Division I malocclusions were analyzed to assess lip changes in the vertical dimension relative to orthodontic retraction of maxillary incisors. The following conclusions were drawn from the results obtained: 1. Closure of the interlabial gap occurs predictably when correlated with both horizontal and vertical movement of the maxillary incisors during retraction. 2. The interlabial gap closes vertically at a ratio of approximately 1 mm. for every 2 mm. of horizontal retraction of maxillary incisors if neither extrusion nor intrusion occurs during such retraction. The distance between LS and LI decreases significantly more per millimeter of horizontal movement if the incisors are intruded during retraction, and proportionately more relative to the amount of intrusion

occurring. 4. If maxillary incisors are extruded during retraction, closure of the interlabial gap occurs at a ratio of less than 1 : 2 and proportionately less as the amount of extrusion increases, with the change in distance between Labrale superior (LS) and Labrale Inferior (LI) approaching zero as the amount of extrusion approximates the amount of horizontal movement. 5. The relative decrease in distance between Labrale superior (LS) and stomion and Labrale Inferior (LI) and stomion respectively is not as consistent and, therefore, less predictable than the cumulative decrease in distance between Labrale superior(LS) and Labrale Inferior(LI) when correlated with horizontal and vertical movement of the maxillary incisors during retraction. 6. Pretreatment lip strain of 6 mm. or less does not significantly influence the predictability of the vertical changes observed when correlated with horizontal and vertical movement of maxillary incisors during retraction.

Ketterhagen DH (1979)[32] performed a survey with 25 consecutively treated first or second premolar extraction cases and 25 consecutively treated nonextraction cases. He asked 192 general dentists and orthodontists to identify whether the patient was treated with or without extractions. In the survey, respondents answered correctly 54% of the time. He concluded, the face does not get "ruined" in patients that are properly diagnosed and treated with extractions.

Waldman (1982)[33] only computed a ratio for the upper incisor to upper lip retraction in his study of 41 Class II patients. He found the ratio to be slightly higher than previous studies mentioned at 3.8:1 with a moderate correlation (r=0.42)

Franklin, Lo and Hunter (1982)[34] Changes in the nasolabial angle of the soft-tissue profile were assessed quantitatively in a serial cephalometric study of fifty

treated subjects and forty-three untreated subjects, all of whom had Class II, Division 1 malocclusions. Correlations, simple and multiple regression analyses, and multifactorial analysis of variance were used to examine the changes in the nasolabial angle owing to incisor superius retraction and associated skeletal displacements. There were no significant changes in nasolabial angle because of growth. However, the greater the maxillary incisor retraction, the greater was the increase in nasolabial angle. Increase in the nasolabial angle showed a significant correlation with treatment-related increase in the vertical dimension of the lower face. The soft-tissue profile followed closely the underlying skeletal framework. Extraction and non-extraction treatment procedures did not show significant differences in the changes of the nasolabial angle. Results permit prediction of the changes in nasolabial angle owing to incisor superius retraction in orthodontic treatment.

Rains (1982)[35] conducted a study on 30 post-pubertal females. It included nine Class I patients and 21 Class II Division 1 patients. 26 of the patients had varying extraction patterns: 10 maxillary and mandibular first premolars, nine maxillary first premolars, five maxillary first and mandibular second premolars and one maxillary first molars. The remaining four patients did not have any extractions done. He found a ratio of 8:5 for upper incisor to upper lip retraction. Both maxillary and mandibular incisor retraction had an effect on the upper lip retraction. The upper lip position was also affected by mandibular rotation and the lower lip position. There was no correlation found between lower incisor retraction and lower lip retraction.

Holdaway(1983)[36] defined his H-line as a "line from the chin through the upper lip to extend to a point near the center of the nares." The ideal place of the lower lip was 0-0.5 mm anterior to this line.

Fumio Yogosawa (1990)[37] had done a study related to soft tissue profile change where in first group adults with normal occlusion were compared to adults with maxillary protrusion. Cephalometric radiographs were obtained for all subjects in two positions: with lip relaxed and lips closed. This sample was compared with the post-treatment patients treated for maxillary protrusion and bimaxillary protrusion. Upper lip retraction was about 40% of the maxillary incisor retraction. Maxillary protrusion cases showed slightly less soft tissue changes than the bimaxillary protrusion cases. Lower lip retraction was about 70% of the maxillary incisor retraction. Author concluded with his results that there is a tendency to rely only on the analysis of hard tissue for orthodontic treatment but this does not always offer the best results for soft tissue.

Zylinski, Ram Nanda and Sunil Kapila (1992)[38] had done a longitudinal study to know the growth changes in the soft tissue profile of 40 Caucasians between the ages of 7 and 18 years. Cephalometric radiographs were taken on a yearly basis and the soft tissue thickness measured at the nose, upper lip and lower lip and chin, as well as the length of the upper lip and lower lip. Females acquired more growth as a percentage of their adult size at age 18 than males in all variables except the angle of inclination of the skeletal chin. Upper lip length growth in both males and females was complete by the 15^{th} year. The total gain in the thickness at the labrele superius

was four times as much as in female and continued to increase in males even at age 18.

Luecke and Johnston (1992)[39] looked at 42 Class II division 1 patients treated with only the upper first premolars extracted. They found an average upper lip retraction of -1.4 mm to the mean functional occlusal plane and -2.4 mm to the Esthetic Plane. The average lower lip retraction was -0.1 mm to the mean functional occlusal plane and -1.4 mm to the Esthetic Plane. They concluded the soft tissue profile appears to be more influenced by growth of the nose and chin than by treatment.

Perkins and Staley (1993)[40] also found a similar mean ratio of 2.2:1 for upper incisor to upper lip retraction when looking at 40 adult females. Twenty of the subjects were Class I and 20 were Class II division 1 and showed a variability between the two subgroups. In the subgroup whose upper incisor tip was less than 6 mm to stomion superioris at rest, the ratio was 1.8:1. In the subgroup whose upper incisor tip was greater than 6 mm for stomion superioris at rest, the ratio was 6.0:1.

Bravo (1994)[41] found similar lip retraction to the Esthetic Plane when he studied 16 females who were treated with premolar extractions. He found the upper lips moved -3.4 mm and lower lip -3.8 mm to the Esthetic Plane. He also found the nasolabial angle increased 3.7˚. Despite this amount of movement of the upper and lower lips to the Esthetic Plane and increase in the nasolabial angle, it was found only 12% of patients finished with a flattened profile.

Diels (1995)[42] also assessed pre and post-treatment cephalograms of an adolescent African American sample. It consisted of 30 males and 30 females that were bimaxillary protrusive and had four first premolars extracted. He found a ratio of 1:2.8 for females and 1:3.2 for males for upper lip retraction to upper incisor retraction. For the lower lip to lower incisor ratio he found 1.6:1 for females and 1.2:1 for males.

Steyn et al.(1997)[43] found when four first premolars were extracted, the upper incisor was retracted -4.7 mm and the lower incisor was retracted -4.2 mm. When four second premolars were extracted, they reported the upper incisor to be retracted -2.1 mm and lower incisor to be retracted -1.3 mm.

Caplan(1997)[44] studied a group 28 adult African American females that had four first premolars extracted and found ratios of 1.2:1 for upper incisor retraction to upper lip retraction and 1.75:1 for lower incisor retraction to lower lip retraction.

James (1998)[45] conducted a study which looked at 170 consecutively treated patients, of which 108 were treated with extractions and 62 were treated non-extraction. He found at pretreatment the non-extraction group was more retrusive than the extraction group. The extraction group presented with a greater soft tissue lip and chin imbalance, but improved with treatment more than the non-extraction group. The lower lip moved -3.3 mm to the Esthetic Plane in the extraction group and moved forward 1.1 mm to the Esthetic Plane in the non-extraction group. He concluded that with extraction of the proper teeth, balanced facial esthetics can be achieved.

Kasai (1998)[46] found similar ratios in his study of Class I and Class II division 1 Japanese women. He found the upper incisor to upper lip ratio to be 2.3:1 and the lower incisor to lower lip ratio to be 0.8:1. He also found the lower lip response to lower incisor retraction to be more predictable than the upper lip response to upper incisor retraction.

Shearn and Woods (2000)[47] measured lower incisor retraction to be -2.4 mm when four first premolars were extracted and -0.5 mm when four second premolars were extracted.

This study was designed to examine lateral cephalometric and arch dimensional changes that occur in the mandibular arch during orthodontic treatment involving the extractions of various premolars. Pre-treatment and post-treatment records of 73 patients were chosen at random from completed cases in the practice of one experienced orthodontist. Eighteen involved the extraction of lower first premolars and 55 involved the extraction of lower second premolars. Of these 55, 29 involved the extraction of upper first premolars. In the lower first premolar group, however, all 18 involved the extraction of upper first premolars. Males and females were evenly represented in the 3 subgroups. Pre-treatment factors that suggested a basis for the extraction choice in this group of patients were found to include incisal overjet, molar relationship, and underlying vertical facial pattern. A wide variety of arch dimensional changes was found with different lower premolar extraction patterns. There was evidence, however, of more intermolar arch width reduction after the extraction of lower second premolars than lower first premolars. Orthodontic treatment with the extraction of premolars did not consistently cause a retrusive effect

on the incisors. In fact, instances of proclination of the incisors occurred within all of the extraction groups. A large amount of individual variation in incisor and molar changes accompanied treatment involving all lower premolar extraction patterns.

Ong and Woods (2001)[48] measured the upper incisor to be retracted -4.2 mm when four first premolars were extracted and -2.3 mm when four second premolars were extracted. The purpose of their study was to examine dimensional changes in the maxillary arch following the extractions of maxillary first or second premolars. Pre- and post-treatment records of 71 patients treated by one experienced orthodontist were randomly selected from completed premolar extraction cases. Forty five patients involved the extraction of maxillary first premolars; of these, 15 also had extractions of mandibular first premolars and 30 had extractions of mandibular second premolars. Twenty-six patients involved the extraction of maxillary second premolars, and all of these also had extractions of mandibular second premolars. Pre-treatment factors that seemed to suggest a basis for the extraction choice in this sample included incisal overjet, molar relationship, and maxillary incisor protrusion. Mean reductions with treatment in the antero-posterior arch dimension were similar within all premolar extraction groups. There was evidence of greater mean maxillary intermolar-width reduction following the extractions of maxillary second premolars than following extractions of maxillary first premolars. Greater mean maxillary incisor retraction was found in the maxillary first premolar extraction group than in the maxillary second premolar group. A wide range of individual variation in incisor and molar changes did, however, accompany treatment involving both maxillary premolar extraction sequences.

Ellie Simpson and Maciej Henneberg (2002)[49] said that the average thickness of soft tisssues on parts of the face is known, but its variation has not been related to cranial morphology. To investigate this relationship, measurements of the facial soft-tissue depths and craniometric dimensions were found, suggesting a relationship between the amount of soft tissue present on the face and the size of the underlying bony skeleton.

Soft-tissue depths were highly positively correlated with each other; craniometric dimensions were correlated but to a lesser extent. Males had thicker soft tissues and larger craniometric dimensions than females; considerable overlap of ranges was also noted. Multiple regression analysis was used to produce equations predicting the soft-tissue depth at specified areas of the face from craniometric dimensions.

Paula Fernandez et al (2003)[50] had done a study to obtain average measurements of the soft tissue facial profile to use them as a guide for aesthetic treatment goals. The soft tissue facial profile of a young adult European Caucasian population (212 individual, 50 males and 162 females, 18–20 years of age) was studied by means of standardized photographic records taken in the natural head position (NHP). Angular measurements were analysed digitally. Sexual dimorphism was found for several angles: nasofrontal, vertical nasal, nasal, nasal dorsum, and mandibular contour. Wide individual variations in nasolabial and mentolabial angles were also observed.

Hanson (2003)[51] also calculated a ratio for incisor retraction to lip response. She looked at 180 orthodontically treated patients. One hundred fifty patients were

treated with various extraction patterns and 30 were treated non-extraction. Her results showed an average upper incisor to upper lip retraction of 2.0:1 and lower incisor to lower lip retraction of 1.3:1. She also found a high degree of correlation for upper lip response (r=0.70) and lower lip response (r=0.73). Her results are similar to the previous studies mentioned. Collectively, all of the studies indicate a high degree of individual variability between upper and lower incisor retraction to upper and lower lip retraction.

Kim et al (2005)[52] also reported more upper and lower incisor retraction when four first premolars are extracted. They found the upper incisors to be retracted -4.71 mm and lower incisors to be retracted -5.13 mm when four first premolars were extracted. They also found the upper incisor retraction to be -2.33 mm and lower incisor retraction to be -3.01 mm when four second premolars were extracted.

Ramos (2005)[53] studied the effect of maxillary first premolar extractions in 16 Class II Division 1 patients. One group was lip incompetent before treatment and the other group had passive lip seal pre-treatment. He measured retraction from the cervical point of the maxillary central incisor because he felt this was more predictable. He found that retraction at the cervical point of the maxillary central incisor "greatly influenced changes in the upper lip." The ratios of upper incisor retraction to upper lip retraction between the two groups were similar. The pre-treatment lip seal group was 1.3:1 and the pre-treatment lip incompetent group was 1.43:1

Brock(2005)[54] conducted a study to see if there was a difference in lip response to incisor retraction between Caucasians and African Americans. The

sample included 88 post-pubertal females, 44 Caucasians and 44 African Americans that had maxillary first premolars only extracted. Pre and post-treatment cephalograms were used and he found a difference existed between Caucasians and African Americans for hard tissue change to upper lip retraction. A significant correlation was found for the change at prosthion to the upper lip response at labrale superius. The ratio of upper incisor retraction to upper lip retraction was found to be 2.6:1 for the African American group and 1.5:1 for the Caucasian group. This shows the African American group having less soft tissue response of upper lip retraction as a result of upper incisor retraction.

Jamilian (2008)[55] looked at pre and post-treatment cephalograms of 20 Class I, female Caucasian bimaxillary protrusive patients that had four first premolars extracted. A ratio of 0.63:1 of upper lip retraction to upper incisor retraction and 0.62:1 for lower lip retraction to lower incisor retraction was found.

Nety Trisnawaty et al (2013)[56] conducted a study to evaluate the effects of orthodontic treatment, involving the extraction of four premolars, on vermilion height and lip area. Twenty-eight female patients (mean 21.9 +-3.1 years) who were diagnosed with bimaxillary protrusion were selected for this study to be treated by extraction of four premolars. The control group consisted of 28 female volunteers (mean 25.0 +-3.0 years) with Angle Class I normal occlusion. Frontal photographs of the patients were taken both before and after the orthodontic treatment in resting position. Thirty-five landmarks on the upper and lower lips were identified for the measurements of vermilion height and lip area. Lateral cephalograms were taken before and after active orthodontic treatment, and linear and angular measurements

were performed. The mean pre-treatment values of vermilion height and lip area were significantly greater in the treatment group than those of the control group and decreased significantly after the orthodontic treatment towards the values in the control group. There were no significant differences in the vermilion height and lip area between the post-treatment and the control groups, except for lower lip area values. Significant correlations found between the changes in incisor position and the changes in vermilion height were few in number for the upper lip but greater in number for the lower lip. Thus, the results of this study show that bimaxillary protrusion cases can be treated by the extraction of four premolars to produce an aesthetic improvement in frontal facial features.

Cloward (2013)[57] found similar movement of the lower lip to the Esthetic Plane in his study of 30 Caucasian, Class I, minimally crowded, adolescent patients treated with four first premolar extractions. He found the upper and lower lips moved -2.82 mm and -3.47 mm respectively to the Esthetic Plane.

Anita Bhavnani Rathod et al (2015)[58] conducted a study were to investigate long-term soft tissue profile changes in an extraction sample and to compare them with profile changes in an untreated sample. A premolar extraction-treated sample (n =47) and an untreated control sample (n = 57) were studied. Descriptive statistics were collected, and individual t tests were used for comparison and contrast of the treated and untreated samples. They found that the untreated soft tissue profile changed in the downward and forward direction. The treated soft tissue profile change was similar, but with more of a forward component than in the untreated sample. Most noteworthy was the finding that the soft tissue profiles of both the untreated and

the treated samples were similar at the end point. The following conclusions were derived from the study. (1) There was no substantive difference in the soft tissue profiles of the samples, but there were some differences in the directional changes between them. (2) The changes for the untreated sample were the greatest for the lips and the chin, with the change occurring in the downward and forward direction. (3) The soft tissue profiles of the extraction sample also had the greatest measurable changes in the lips and the chin, but the changes had more of a forward component than they did in the untreated sample. (4) Extraction treatment does not adversely impact soft tissue profile changes over time.

Aniruddh Yashwant V., Ravi K. and Edeinton Arumugam (2016)[59] conducted a study to compare soft tissue changes in Class I borderline cases treated with extraction and non-extraction modalities. A parent sample of 150 patients with Class I dental and skeletal malocclusion (89 patients treated with premolar extraction and 61 patients without extraction) was randomly selected and subjected to discriminant analysis which identified the borderline sample of 44 patients (22 extraction and 22 non-extraction patients). Pretreatment and post-treatment cephalograms of the borderline subsample were analyzed using 22 soft tissue parameters. Upper and lower lips were more retracted and thickness of the upper lip increased more in the borderline extraction cases ($p < 0.01$). The nasolabial angle became more obtuse and the interlabial gap was reduced in the borderline extraction cases ($p < 0.01$). Lower lip, interlabial gap and nasolabial angle showed no changes in the borderline non-extraction cases. It was concluded that the soft tissue parameters which can be used as guideline in decision making to choose either extraction or non-extraction in Class I borderline cases are upper and lower lip protrusion in relation to

the E-plane and Sn-Pg' line, lower lip protrusion in relation to the true vertical line (TVL), upper lip thickness, nasolabial angle and interlabial gap.

Kayoung Kim et al (2017)[60] compared soft and hard tissue responses based on the degree of maxillary incisor retraction using maximum anchorage in patients with Class II division 1 malocclusion. This retrospective study sample was divided into moderate retraction (,8.0 mm; n ¼ 28) and maximum retraction (8.0 mm; n ¼ 29) groups based on the amount of maxillary incisor retraction after extraction of the maxillary and mandibular first premolars for camouflage treatment. Pre- and post-treatment lateral cephalograms were analyzed. There were 2.3 mm and 3.0 mm of upper and lower lip retraction, respectively, in the moderate group; and 4.0 mm and 5.3 mm, respectively, in the maximum group. In the moderate group, the upper lip was most influenced by posterior movement of the cervical point of the maxillary incisor (b ¼ 0.94). The lower lip was most influenced by posterior movement of B-point (b ¼ 0.84) and the cervical point of the mandibular incisor (b ¼ 0.83). Prediction was difficult in the maximum group; no variable showed a significant influence on upper lip changes. The lower lip was highly influenced by posterior movement of the cervical point of the maxillary incisor (b ¼ 0.50), but this correlation was weak in the maximum group. They concluded that posterior movement of the cervical point of the anterior teeth is necessary for increased lip retraction. However, periodic evaluation of the lip profile is needed during maximum retraction of the anterior teeth because of limitations in predicting soft tissue responses.

MATERIALS AND METHOD

SUBJECT SOURCE:

For this study, Pre-treatment and post-treatment lateral cephalograms of 50 patients having Class I bimaxillary dentoalveolar protrusion malocclusion, aged 16-25 years, with good definition of both hard and soft tissue landmarks, molars in maximum intercuspation with lips unstrained in natural position, who were treated at the Department of Orthodontics and Dentofacial Orthopedics, were obtained.

INCLUSION CRITERIA:

- Patients aged 16-25 years.
- Skeletal Class I with Angle's Class I molar relationship
- Full complement of teeth with no history of extractions.
- Well aligned arches with mild to moderate crowding.

EXCLUSION CRITERIA :

- Patients with severe crowding.
- Facial asymmetry.
- Patients with skeletal changes.
- Patients with history of previous orthodontic treatment.
- Patients with extensive caries requiring extraction apart from first premolars.
- Patients with periodontally compromised teeth.

PROCEDURE

The cephalometric measurements were obtained from computerized tracing of direct digital radiographs using Nemoceph software, Version 6.0 Nemotec SRL (Spain).

- Pre-treatment and post-treatment lateral cephalograms of 20 patients were analyzed using the Nemoceph software by two operators to eliminate investigator bias.
- Soft copy of the pre-treatment and post treatment lateral cephalograms were used.
- Lateral cephalograms were standardized and caliberated using the Nemoceph software.
- All patients were treated with 0.018 slot MBT, pre-adjusted edgewise appliance after extraction of all four first premolars.

All patients were treated with critical anchorage following standard treatment protocol.

Analysis for comparison of both pre-treatment and post treatment lateral cephalograms included 8 soft tissue parameters and 10 hard tissue parameters.

The soft tissue parameters include:

1. Nasolabial angle:

The nasolabial angle is formed by drawing a line tangent to the base of the nose and a line tangent to the upper lip. It was given by **McNamara**[61] in **1984**. The average nasolabial angle in adult males and females with well balanced jaws is 102 degress (SD 8 degrees). An acute nasolabial angle may be a reflection of the dentoalveolar protrusion, but it can also occur because of the orientation of the base of the nose.

2. Labiomental angle:

It is the anterior angle formed by the intersection of a tangent to the lower lip (sublabiale to labrale inferius) and a tangent to the upper part of the soft tissue chin pad (sublabiale to soft tissue pogonion). Measure of this angle is influenced both by the position of the lower lip and chin along with the inclination of mandibular incisor teeth.

3. Merrifield's Z angle:

A profile line is established by drawing a line tangent to the soft-tissue chin (Pog') and to the most anterior point of either the lower or upper lip, whichever is protrusive. The angle formed by the intersection of Frankfort horizontal and this

profile line is called Z angle. It was given by **Levin Merrifield**[26] in **1966**. It averages 80+- 8 degrees. Ideally the upper lip should be tangent to this profile line, whereas the lower lip should be tangent or slightly retrusive. In bimaxillary protrusion cases post extraction, there was an increase in the Z angle post treatment.

4. Interlabial gap:

The vertical distance between the upper and lower lip as given by **Burstone**[27] in **1967** ranges between 0 and 3mm.

5. Upper sulcus depth:

The upper sulcus depth is measured from the H-line. The upper lip is in balance when this measurement approximates 5.0 mm. with short and/or thin lips, a measurement of 3mm may be adequate. In longer and/or thicker-lipped individuals, a measurement of 7mm may still indicate excellent balance.

6. Lower sulcus depth:

The lower sulcus depth is measured at the point of deepest curvature between the lower lip and the chin. The ideal value is 5mm.

7. Upper lip strain:

The upper lip strain measurement extends horizontally from the vermilion border of the upper lip to the labial surface of the maxillary central incisor. This measurement is less than the upper lip thickness, the lips are considered to be strained. The lips reached a more unstrained position post treatment similar to that reported by **Holdaway (1983)**[36]**.**

8. Upper lip thickness:

Upper lip thickness is measured horizontally from a point on the outer alveolar plate 2mm below point A to the outer border of the upper lip. It is in the range of 15mm.

The hard tissue parameters include:

1. N perpendicular to point A:

As given by Cephalometric analysis for Orthognathic Surgeries by **Burstone[62] in 1978**, a perpendicular to Horizontal Plane (HP) is dropped from Nasion and the horizontal distance parallel to HP is measured from point A. This measurement describes the position of apical base of maxilla in relation to Nasion and is called N-perpendicular to point A.

2. N perpendicular to point B:

As given by Cephalometric analysis for Orthognathic Surgeries by **Burstone in 1978[36]**, N perpendicular to Point B is obtained by measuring the distance between point B and Nasion perpendicular. This measurement describes the position of apical base of mandible in relation to Nasion.

3. Upper incisor to NA linear:

The relative location and axial inclination of the upper incisors are determined by relating the teeth to the N-A line. It is expressed both in degrees and as linear measurement in millimetres. The upper incisor to N-A reading in degrees indicates the relative angular relationship of the upper incisor teeth, whereas the upper central incisor to N-A reading in millimetres provides information on the relative forward or

backward positioning of the incisor teeth to N-A line. Using this method, the upper central incisors should relate to the N-A line in such a way that the most anteriorly placed point of its crown is 4mm in front of the N-A line.

4. Lower incisor to NB linear:

The relative anteroposterior location and angulation of the lower incisor teeth is determined by relating the teeth to the N-B line. The lower incisor to N-B measurement in millimetres shows the relative forward or backward positioning of these teeth to the N-B line. The most labial portion of the crown of the lower incisor teeth should be located 4mm ahead of the N-B line.

6. Interincisal angle:

The interincisal angulation relates the relative position of the upper incisor to that of the lower incisor. If the figure is more acute or less obtuse than the mean of 130 degrees, either the upper or lower teeth or both often require uprighting. Conversely, if the angle is greater than 130 degrees or more obtuse, the upper and/or lower incisors often require advancing anteriorly or correcting of the axial inclination.

7. N perpendicular to U1 distance:

It is the measure of linear distance of upper incisor tip from Nasion perpendicular.

8. N perpendicular to L1 distance:

It is the measure of linear distance of upper incisor tip from Nasion perpendicular.

9. AB plane to Pogonion:

AB plane represents the line formed by joining points A and B. Pogonion (Pog): The most anterior point of the bony chin in the median plane. It is the measure of linear distance from Pogonion to the AB plane.

10. AB plane to Prosthion:

Prosthion (PR) is defined as the point of the maxillary alveolar process in the midline that projects most anteriorly. It is the measure of linear distance from Prosthion to the AB plane.

11. AB plane to Infradentale:

Infradentale (Id): -the most anterior point of the alveolar process of the mandible.

It is the measure of linear distance from Pogonion to the AB plane.

For correlation of the soft tissue and hard tissue landmarks, the True Vertical Line (TVL) was established by passing a line through the subnasale, perpendicular to the natural horizontal head position as given by **G. William Arnett (1999)**[63]

The following hard tissue and soft tissue parameters were considered for correlation:

- Pre-treatment and Post-treatment distance of Upper Incisor tip from TVL.
- Pre-treatment and Post-treatment distance of Lower Incisor tip from TVL.
- Pre-treatment and Post-treatment distance of upper lip from TVL
- Pre-treatment and Post-treatment distance of lower lip from TVL

Change in upper lip relative to change in upper incisor distance was correlated and similarly change in lower lip relative to change in lower incisor distance was correlated.

STATISTICAL METHODS

The descriptive statistics for various hard tissue parameters were obtained before and after treatment for the study sample of 50 specimens. The statistics included mean, standard deviation (SD), minimum and maximum for each parameter. The statistical significance of difference for each parameter between pre and post-treatment was compared using paired t-test. Further, the soft tissue parameters were also summarized using the same statistics, before and after treatment. The statistical significance of difference was evaluated using paired t-test. The distance of upper and lower incisor tip from TVL was measured for all the specimens before and after treatment. The distances were compared statistically using paired t-test. Similar analysis was performed for the distance of upper and lower lip from TVL. Pearson's correlation coefficient was obtained to quantify the relation between change in upper lip position versus change in upper incisor position. Similarly, the relationship was obtained between change in lower lip position versus change in lower incisor position. The measurements by two observers were obtained on a subset of specimens on each parameter before treatment, and analysed for reliability using intra-class correlation coefficient (ICC).

All the analyses were performed using SPSS ver 20.0 (IBM Corp) software and the statistical significance was evaluated at 5% level.

COLOUR PLATE I

SOFT COPY OF LATERAL CEPHALOGRAM

PRE-TREATMENT

POST-TREATMENT

COLOUR PLATE II

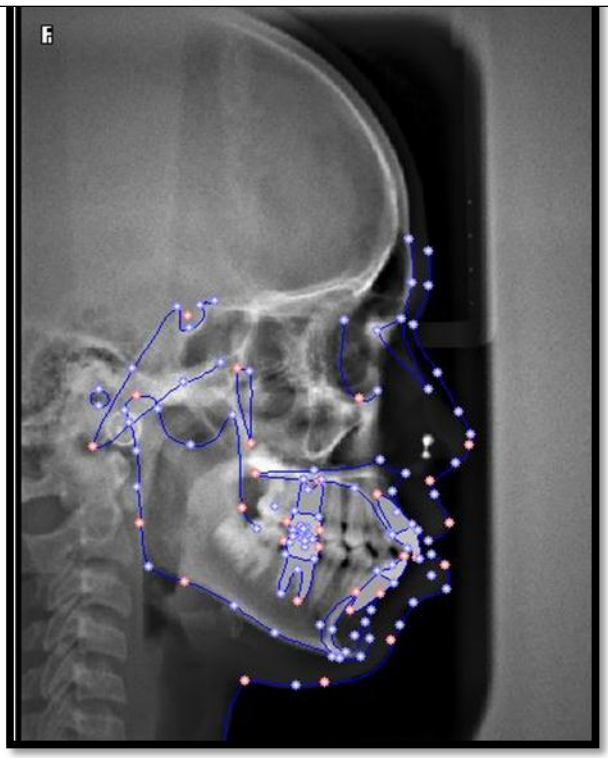
CALIBERATION ON NEMOCEPH SOFTWARE

PRE-TREATMENT

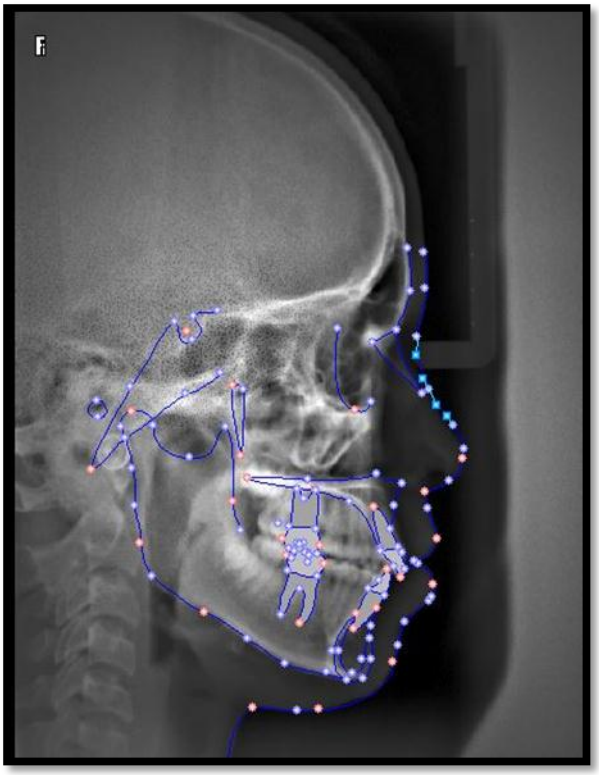
POST-TREATMENT

COLOUR PLATE III

TRACED LANDMARKS ON NEMOCEPH SOFTWARE



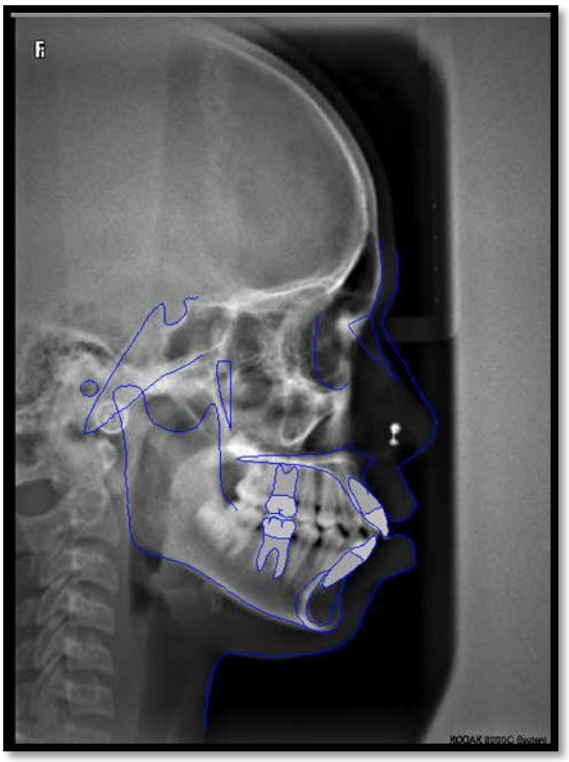
PRE-TREATMENT



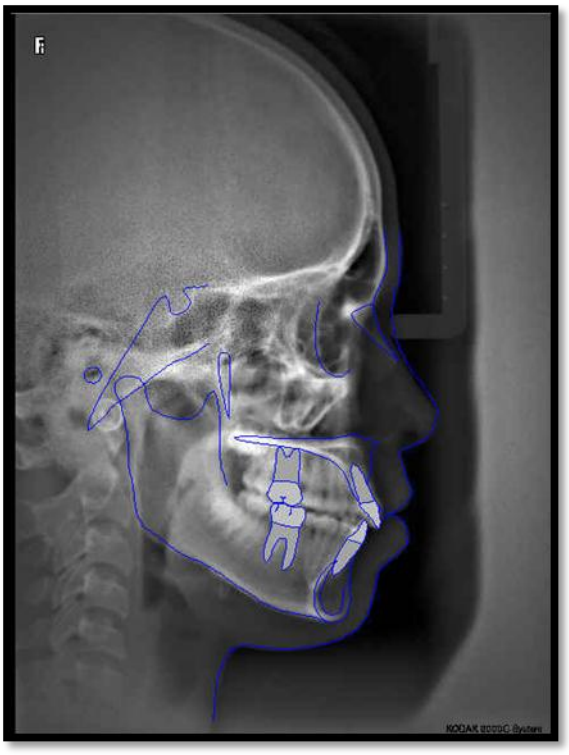
POST-TREATMENT

COLOUR PLATES IV

COMPLETED TRACING ON NEMOCEPH SOFTWARE



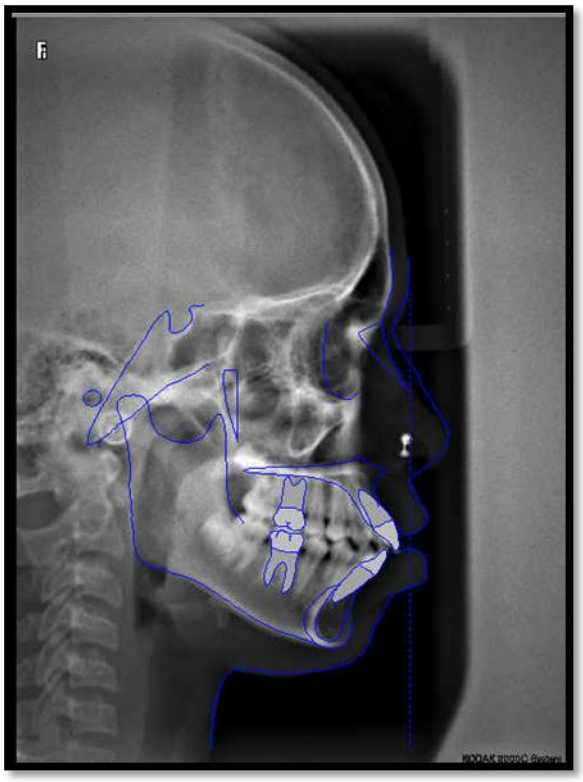
PRE-TREATMENT



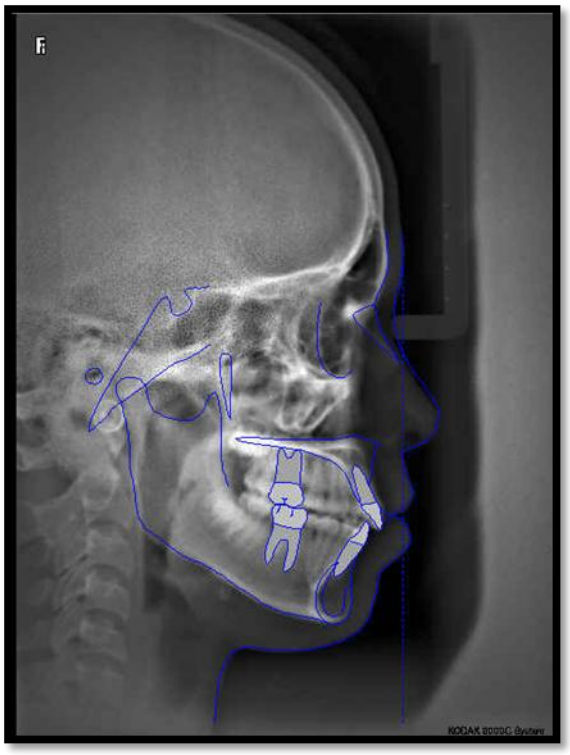
POST-TREATMENT

COLOUR PLATE V

COMPLETED TRACING WITH TVL ON NEMOCEPH SOFTWARE



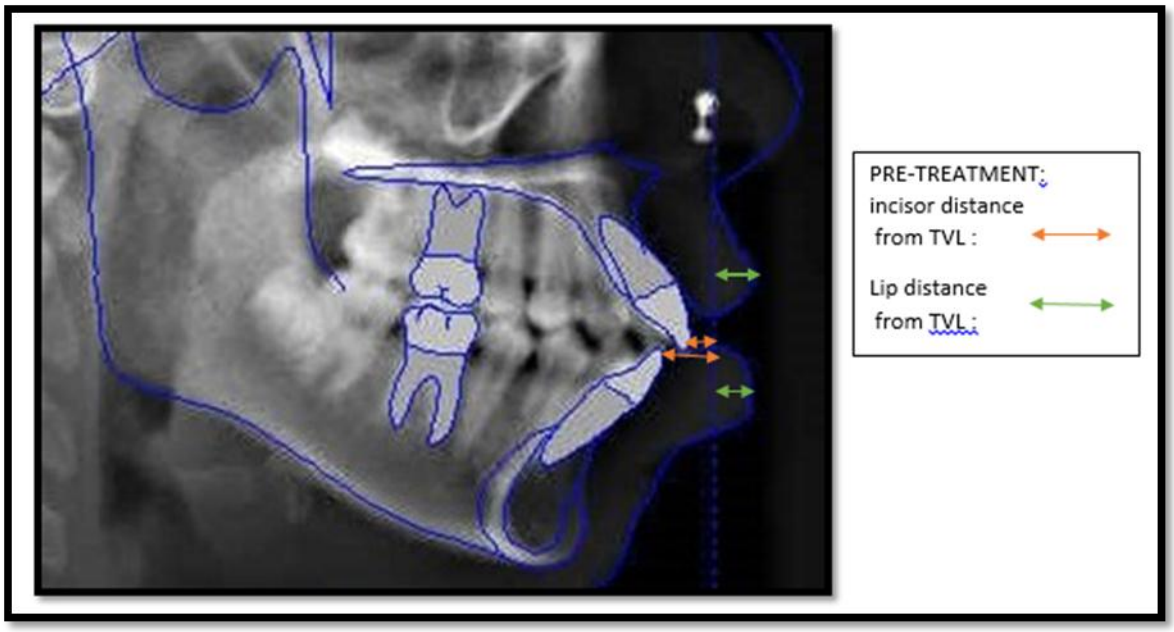
PRE-TREATMENT



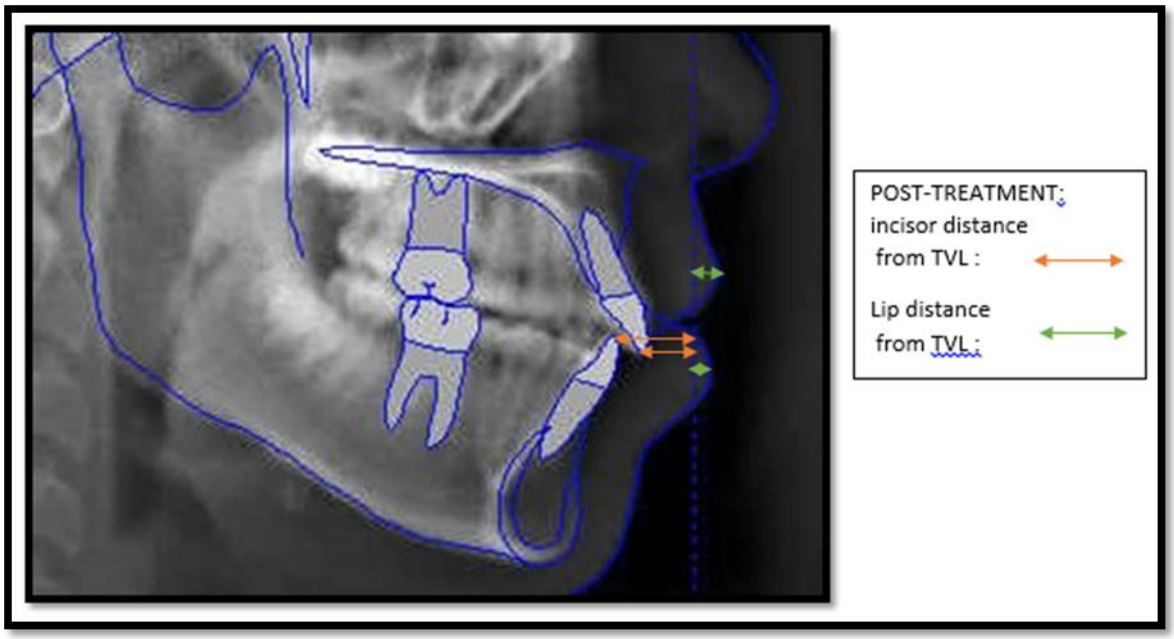
POST-TREATMENT

COLOUR PLATE VI

UPPER AND LOWER INCISOR & UPPER AND LOWER LIP DISTANCE



PRE-TREATMENT



POST-TREATMENT

RESULTS

Table 1: Descriptive statistics for various hard tissue parameters before and after treatment

Parameter	Pre-treatment				Post-treatment				P-value*
	Mean	SD	Min	Max	Mean	SD	Min	Max	
N-perpendicular to point A (mm)	- 2.52	0.50	2	3	- 2.50	0.51	2	3	0.3222 (NS)
N-perpendicular to point B (mm)	- 7.54	1.23	3	10	- 7.52	1.31	2	10	0.3222 (NS)
Upper Incisor to NA linear (mm)	8.58	1.74	4	14	3.72	0.67	2	5	< 0.0001 (S)
Lower Incisor to NB linear (mm)	7.46	1.11	4	9	3.72	0.86	2	5	< 0.0001 (S)
Inter-incisal Angle (^{o})	107.76	4.28	100	117	129.1	5.00	120	139	< 0.0001 (S)
N-perpendicular to U1 distance (mm)	5.76	1.68	2	9	2.3	0.93	1	4	< 0.0001 (S)
N-perpendicular to L1 distance (mm)	2.58	0.99	1	4	1.9	0.71	1	3	< 0.0001 (S)
AB Plane to Pogonion (mm)	1.90	0.76	1	3	1.86	0.77	1	3	0.1593 (NS)
AB Plane to Prosthion (mm)	6.22	0.74	5	7	3.54	0.61	2	5	< 0.0001 (S)
AB plane to Infradentale (mm)	4.16	1.00	3	6	2.68	0.87	1	4	< 0.0001 (S)

*Obtained using paired t-test; S: Significant; NS: Not significant

Table 1 provides the descriptive statistics for various hard tissue parameters before and after treatment. For parameter N-perpendicular to point A, the mean pre-treatment distance was -2.52 ± 0.50 mm, while post-treatment distance was -2.50 ± 0.51 mm. The difference between the observations was insignificant as indicated by p-value of 0.3222. On similar lines, the mean pre-treatment distance of N-perpendicular to point B was -7.54 ± 1.23 mm, while post-treatment distance was -7.52 ± 1.31 mm and the difference in values was statistically insignificant with a p-value of 0.3222. The mean distance of upper incisor to NA before treatment was 8.58 ± 1.74mm, while post-treatment, it was 3.72 ± 0.67mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). The mean distance of lower incisor to NB before treatment was 7.46 ± 1.11mm, while post-treatment, the mean was 3.72 ± 0.86mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). The mean pre-treatment inter-incisal angle was 107.76 ± 4.28^{o}, while the post-treatment mean was 129.1 ± 5.00^{o}. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). Further, the distance N-perpendicular to U1 before treatment was 5.76 ± 1.68mm, while post-treatment, the mean was 2.30 ± 0.93mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). The distance of N-perpendicular to L1 before treatment was 2.58 ± 0.99mm, while post-treatment, the mean distance was 1.90 ± 0.71mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). The mean distance of AB plane to Pogonion before treatment was 1.90 ± 0.76mm, while after treatment, the mean was 1.86 ± 0.77mm. The mean difference between the measurements was insignificantly different than zero ($p = 0.1593$).

Further, the mean distance of AB plane to Prosthion before treatment was 6.22 ± 0.74 mm, while after treatment was 3.54 ± 0.61mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$). The mean distance of AB plane to intradentale before treatment was 4.16 ± 1.00mm, while the mean after treatment was 2.68 ± 0.87 mm. The mean difference between the measurements was significantly different than zero ($p < 0.0001$).

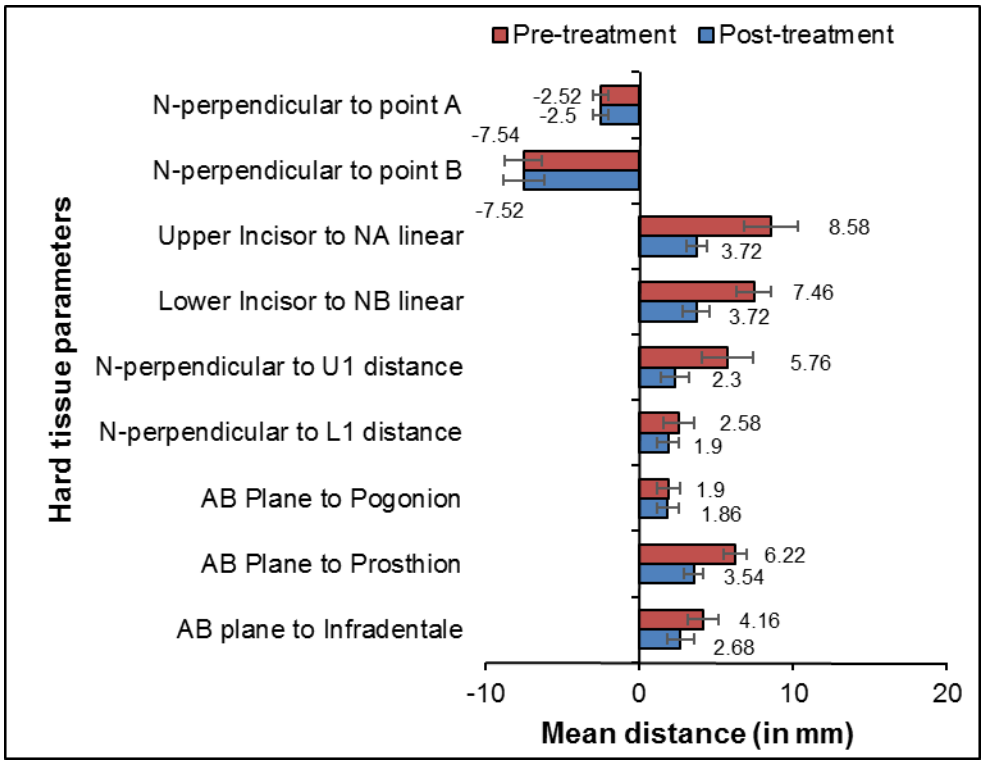


Figure 1: Horizontal bar chart showing mean distance for each hard tissue parameter before and after treatment

Table 2: Descriptive statistics for various soft tissue parameters before and after treatment

Parameter	Pre-treatment				Post-treatment				P-value*
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Nasolabial angle (^{o})	85.80	8.20	75	101	99.28	14.88	13	117	< 0.0001 (S)
Labio-mental angle (^{o})	113.58	11.51	85	132	125.7	9.40	93	139	< 0.0001 (S)
Merrifield's Z angle (^{o})	56.78	4.02	50	64	65.4	5.22	57	77	< 0.0001 (S)
Inter-labial gap (mm)	3.86	0.95	3	6	0.3	0.58	0	2	< 0.0001 (S)
Upper sulcus depth (mm)	8.52	1.05	7	11	5.58	1.43	3	7	< 0.0001 (S)
Lower sulcus depth (mm)	2.68	0.79	1	4	1.68	0.62	0	3	< 0.0001 (S)
Upper lip strain (mm)	8.8	1.54	6	12	7.58	1.65	5	11	< 0.0001 (S)
Upper lip thickness (mm)	10.52	1.22	8	14	12.3	1.27	10	15	< 0.0001 (S)

*Obtained using paired t-test; S: Significant

Table 2 provides the descriptive statistics for various soft-tissue parameters before and after treatment. All the parameters showed statistically significant difference of means between pre- and post-treatments. The mean nasolabial angle before treatment was 85.80 ± 8.20^o, while after treatment, the mean was 99.28 ± 14.88^o. The mean difference of angles before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean labio-mental angle before treatment was 113.58 ± 11.51^o, while after treatment, the mean angle was 125.7 ± 9.40^o. The mean difference of angles before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean Merrifield's Z angle before treatment was 56.78 ± 4.02^o, while the mean after treatment was 65.4 ± 5.22^o. The mean difference of angles before and after treatment was significantly different than

zero as indicated by $p < 0.0001$. The mean inter-labial gap before treatment was 3.86 ± 0.95mm, while after treatment, it was 0.3 ± 0.58 mm. The mean difference of measurements before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean upper sulcus depth before treatment was 8.52 ± 1.05mm, while after treatment was 5.58 ± 1.43mm. The mean difference of measurements before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean lower sulcus depth before treatment was 2.68 ± 0.79mm, while after treatment was 1.68 ± 0.62mm. The mean difference of measurements before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean upper lip strain was 8.8 ± 1.54mm before treatment, while after treatment, the mean was 7.58 ± 1.65mm. The mean difference of measurements before and after treatment was significantly different than zero as indicated by $p < 0.0001$. The mean upper lip thickness was 10.52 ± 1.22mm before treatment, while after treatment, the mean was 12.3 ± 1.27mm. The mean difference of measurements before and after treatment was significantly different than zero as indicated by $p < 0.0001$.

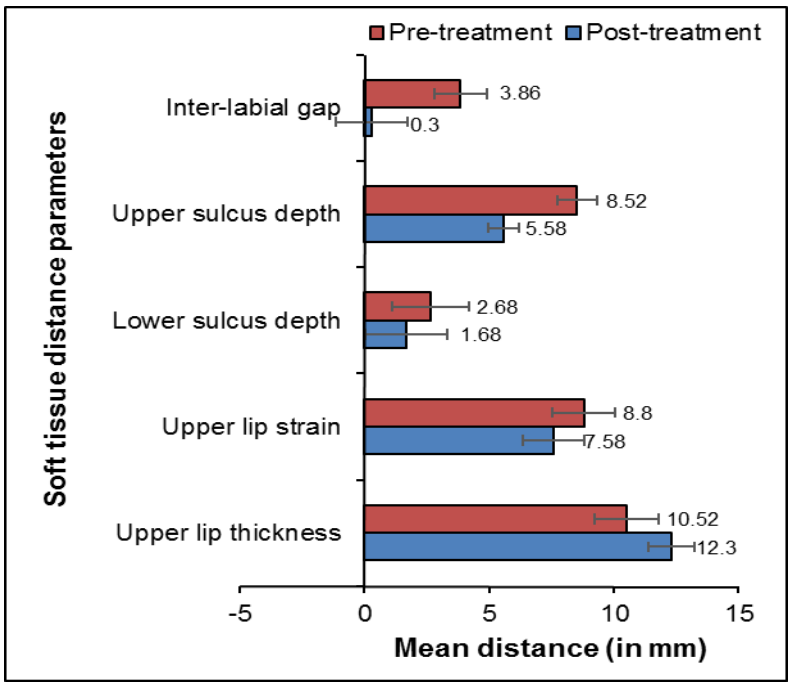


Figure 2A: Horizontal bar chart showing mean distance for each soft tissue parameter before and after treatment

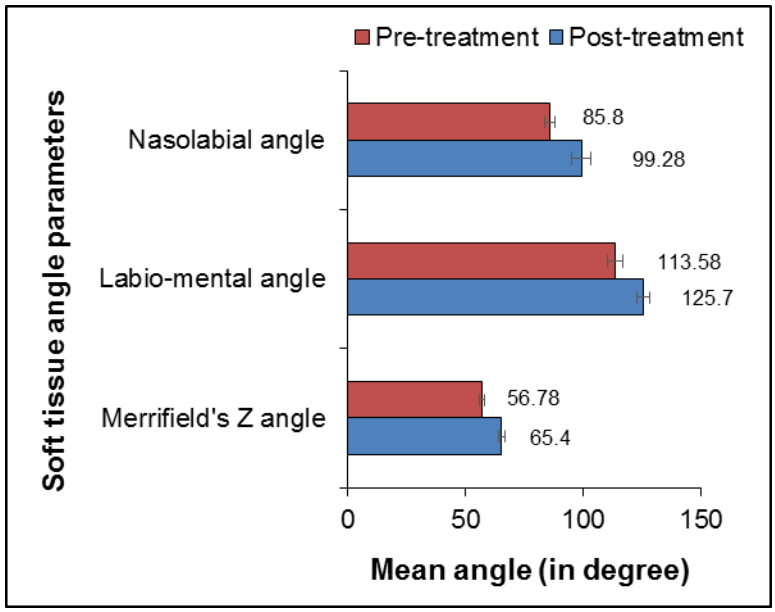


Figure 2B: Horizontal bar chart showing mean angle for each soft tissue parameter before and after treatment

Table 3: Descriptive statistics for distance of incisor tip from TVL before and after treatment – Hard tissue parameters

Position	Pre-treatment				Post-treatment				P-value*
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Upper Incisor tip (mm)	4.46	2.18	1	10	6.92	2.25	3	13	< 0.0001 (HS)
Lower Incisor tip (mm)	8.80	2.11	6	14	11.92	1.91	9	17	< 0.0001 (HS)

HS: Highly Significant; *Using paired t-test

Table 3 provides the descriptive statistics for distance of incisor tip from TVL for hard tissue parameters before and after treatment. The mean upper incisor tip distance before treatment was 4.46 ± 2.18mm, while post-treatment, the mean was 6.92 ± 2.25 mm. The mean difference of measurements was significantly different than zero, as indicated by $p < 0.0001$. Similarly, for lower incisor tip distance, the mean before was 8.8 ± 2.11mm, while after was 11.92 ± 1.91 mm. The mean difference of measurements was significantly different than zero, as indicated by $p < 0.0001$.

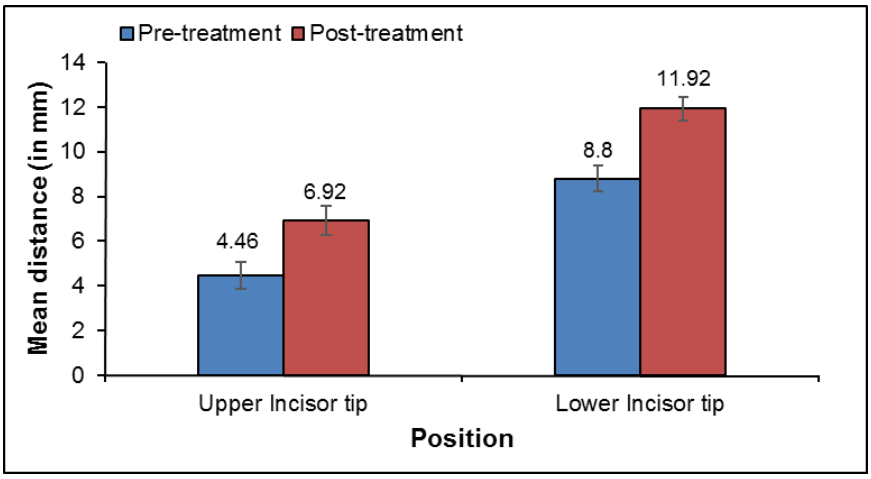


Figure 3: Column chart showing mean distance of upper and lower incisor tip from TVL

Table 4: Descriptive statistics for distance of lip from TVL before and after treatment – Soft tissue parameters

Position	Pre-treatment				Post-treatment				P-value*
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Upper lip (mm)	3.22	0.73	1	5	1.96	0.67	0	3	< 0.0001 (HS)
Lower lip (mm)	- 2.98	0.74	1	4	- 4.60	0.75	3	6	< 0.0001 (HS)

HS: Highly Significant; *Using paired t-test

Table 4 provides the descriptive statistics for distance of lip from TVL for soft tissue parameters before and after treatment. The mean upper lip distance before treatment was 3.22 ± 0.73mm, while post-treatment, the mean was 1.96 ± 0.67 mm. The mean difference of measurements was significantly different than zero, as indicated by $p < 0.0001$. For lower lip, the mean distance before treatment was -2.98 ± 0.74mm, while after treatment, it was - 4.60 ± 0.75 mm. The mean difference of measurements was significantly different than zero, as indicated by $p < 0.0001$.

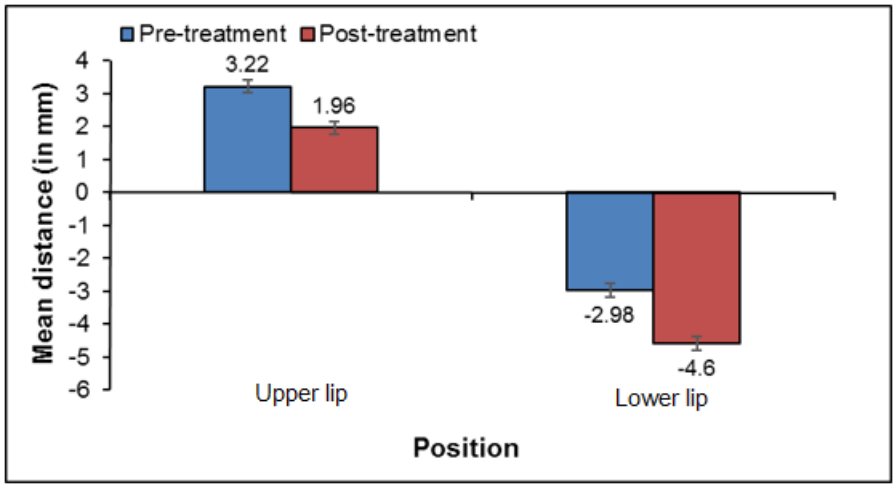


Figure 4: Column chart showing mean distance of upper and lower lip from TVL

PRE & POST-TREATMENT SOFT TISSUE PARAMETERS - COMPARISON

Sr. No.	pre Nasolabial Angle	post Nasolabial Angle	pre Labiomental Angle	post Labiomental Angle	pre Merrifield's Z Angle	post Merrifield's Z Angle	Pre interlabial gap	post interlabial gap	pre Upper sulcus Depth	post Upper sulcus Depth	pre Lower sulcus Depth	post Lower sulcus Depth	pre Upper lip strain	post Upper lip strain	pre upper lip thickness	post upper lip thickness
1	100	112	122	128	60	71	3	0	8	3	3	2	10	8	13	12
2	84	105	129	138	63	77	4	0	9	7	3	2	10	8	14	9
3	80	93	120	126	56	60	3	0	7	7	4	2	6	8	11	10
4	78	90	85	93	64	70	5	1	8	4	3	2	7	5	12	9
5	87	110	115	124	56	64	3	0	7	5	3	1	8	6	11	10
6	92	103	132	138	51	58	6	2	9	6	1	1	8	7	12	11
7	77	93	112	127	57	68	4	0	10	6	3	2	8	7	11	10
8	87	103	110	128	60	70	3	0	9	7	3	3	12	11	15	14
9	78	89	118	130	50	57	4	0	10	7	2	1	10	9	12	11
10	100	111	120	131	57	58	4	0	8	5	2	2	9	8	14	12
11	97	13	119	129	59	66	3	0	9	4	3	2	11	9	10	9
12	84	105	113	124	52	61	5	0	7	3	3	2	9	8	11	10
13	81	93	100	121	57	63	3	0	8	3	2	1	9	7	14	11
14	78	97	120	128	61	69	4	0	8	3	3	2	7	6	12	9
15	87	110	129	137	63	70	6	2	9	7	1	1	8	5	14	10
16	93	103	118	124	54	60	5	1	7	7	3	2	7	6	13	11
17	77	95	100	110	61	72	3	0	8	4	3	2	8	7	11	10
18	85	103	86	101	56	64	4	0	7	5	4	2	8	5	12	9
19	78	90	129	136	52	59	4	0	9	6	3	2	11	10	15	11
20	101	114	110	125	53	66	3	0	10	6	3	1	12	11	10	8

21	99	113	111	128	60	70	3	0	9	7	1	1	10	8	13	9
22	86	105	121	130	54	63	5	1	10	7	3	2	8	6	14	11
23	81	93	119	131	52	59	3	0	8	5	3	3	8	7	13	12
24	78	94	111	129	61	69	3	0	9	7	2	1	10	8	11	10
25	83	98	109	123	59	67	4	0	7	4	2	2	9	8	12	11
26	91	104	114	129	56	63	4	0	8	3	3	2	7	7	12	10
27	84	104	91	110	54	67	6	2	9	7	2	1	8	5	11	9
28	78	96	89	110	59	69	3	0	7	7	3	1	8	6	13	10
29	78	89	121	134	63	76	4	1	8	4	3	2	8	7	14	13
30	96	109	115	126	55	60	5	1	7	5	2	1	8	6	12	10
31	83	105	100	121	62	70	3	0	9	6	1	0	9	11	13	11
32	100	115	115	126	56	64	3	0	10	6	3	2	10	9	11	10
33	78	94	129	138	53	62	4	0	9	7	3	2	9	8	12	10
34	82	97	111	127	55	64	3	0	10	7	4	2	11	10	11	10
35	86	99	108	126	62	70	4	0	8	5	3	2	8	7	13	12
36	90	104	117	129	51	61	4	1	9	7	3	1	7	6	14	13
37	76	95	123	131	54	61	6	1	8	6	1	1	8	6	12	10
38	100	117	121	130	61	70	3	0	9	4	3	2	10	8	11	9
39	78	89	119	128	54	61	3	0	11	6	3	3	9	8	13	12
40	79	91	100	121	53	61	3	0	9	7	2	1	6	8	13	11
41	100	115	121	129	59	69	4	0	8	3	2	2	7	6	13	12
42	88	105	120	127	61	75	3	0	9	7	3	2	7	6	12	10
43	80	95	109	124	57	68	3	0	7	7	2	1	8	7	11	10
44	75	90	90	101	63	70	5	1	8	4	4	1	9	7	14	12
45	87	110	114	124	56	63	3	0	7	5	3	2	12	11	11	10
46	94	103	132	139	50	58	3	0	9	6	2	1	11	10	13	11
47	77	98	113	127	57	70	5	0	10	6	4	2	10	8	11	10
48	82	103	111	128	58	70	4	1	9	7	3	2	11	10	12	11
49	78	91	120	130	50	59	4	0	10	7	3	2	8	7	11	10
50	99	111	118	131	52	58	4	0	8	5	3	2	8	7	12	11

CORRELATION - PRE & POST -TREATMENT - HARD & SOFT TISSUE PARAMETERS

Sr. No.	DISTANCE FROM TVL CORRELATION							
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	Upper incisor Tip	Upper incisor Tip	Lower incisor Tip	Lower incisor Tip	Upper Lip	Upper Lip	Lower Lip	Lower Lip
1	7	11	10	14	2	0	-3	-5
2	2	6	7	10	3	2	-2	-4
3	3	7	6	10	4	3	-1	-3
4	1	5	8	9	4	2	-1	-3
5	2	7	7	11	4	1	-3	-5
6	6	11	8	13	4	2	-2	-4
7	5	7	9	11	5	2	-3	-5
8	6	8	11	13	2	2	-2	-4
9	5	9	10	12	7	3	-3	-5
10	10	14	14	17	3	1	-2	-4
11	6	11	9	14	2	2	-3	-4
12	4	7	8	10	4	1	-3	-4
13	3	7	6	10	2	2	-3	-5
14	4	5	8	11	3	1	-3	-5
15	2	7	7	11	3	2	-2	-4
16	3	9	8	13	3	1	-3	-5
17	4	7	8	11	4	2	-4	-6
18	5	8	10	13	4	3	-3	-5
19	5	9	9	11	3	3	-4	-5
20	9	13	14	17	2	1	-3	-5
21	8	11	10	13	5	2	-2	-4
22	3	6	6	10	3	1	-3	-5

23	3	7	6	11	4	2	-3	-4
24	2	5	7	9	3	1	-3	-5
25	4	7	7	11	3	2	-4	-6
26	6	11	8	13	5	2	-2	-4
27	3	7	8	11	3	1	-3	-5
28	3	8	11	15	3	2	-4	-5
29	4	9	10	12	4	3	-3	-5
30	8	14	12	17	4	2	-3	-4
31	5	7	9	12	5	2	-3	-4
32	4	8	11	13	3	2	-3	-5
33	5	9	9	11	4	1	-4	-6
34	9	12	14	17	3	2	-3	-4
35	7	11	10	13	4	1	-2	-4
36	3	6	6	10	3	2	-3	-5
37	3	7	6	11	2	2	-3	-5
38	2	5	6	10	4	3	-4	-5
39	4	7	7	11	2	1	-3	-4
40	6	11	8	13	2	3	-4	-5
41	3	6	6	10	3	1	-3	-5
42	3	7	7	11	2	2	-3	-5
43	3	5	8	10	4	1	-3	-4
44	2	8	7	11	3	2	-4	-6
45	5	10	8	13	5	3	-3	-5
46	6	7	8	11	3	3	-4	-5
47	3	8	9	12	2	3	-4	-5
48	4	8	10	13	3	2	-4	-6
49	8	13	13	15	3	2	-3	-5
50	2	7	6	12	3	1	-3	-5