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A cephalometric evaluation of skeletal class II patients treated with premolar extraction and fixed functional appliance (Forsus)

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Abstract
Fixed functional appliances have been used for correction of skeletal class II malocclusion for sometime now, with the Forsus being a relatively newer addition. 6 skeletal class II patients were treated with Forsus spring for an average period of 6 months, after decompensation with 1st premolar extraction. The main objective was to evaluate the Skeletal, Dental and Soft tissue profile changes resulting in the correction of the class II malocclusion to either Class I or Super Class I occlusal relationship. Lateral cephalograms were taken before (T1) and after (T2) the fixed functional phase. Results showed significant improvement in soft tissue convexity and both skeletal and dental parameters contributed to the correction of overjet and molar relation. The skeletal contribution for overjet correction was 31.62% whereas the dental was 68.37%. The molar relation was corrected skeletally by 41.91% and dentally by 58.08%. The occlusal plane was rotated by 6.5^0 in a clockwise direction. This study concluded that dental changes contributed more to the correction of the malocclusion.

Keywords: Skeletal class II malocclusion, The Forsus class II corrector

Introduction

Class II malocclusion is one of the most common problems in orthodontics, with an estimated one-third of all orthodontic patients treated for this condition. However, this type of malocclusion is not a single diagnostic entity, but it can result from various skeletal and dentoalveolar components. Many treatment options are available for the correction of Class II malocclusion, depending on what part of the craniofacial skeleton is affected. In general, treatment of Class II malocclusion can include growth modification in terms of mandibular advancement (in patients with mandibular skeletal retrusion) or maxillary retraction (in patients with maxillary skeletal protrusion), and maxillary molar distalization (in patients with maxillary dentoalveolar protrusion) The treatment approaches that can be used, include the use of functional or removable appliances, extraoral traction by means of headgears, and fixed appliances combined with Class II elastics [1].

Many clinicians have used functional appliances developed primarily in Europe in an effort to stimulate mandibular growth. Advocates of functional appliances cite considerable research on experimental animals demonstrating stimulation of the mandibular growth caused by forward positioning of the mandible; Frankel R has suggested that a similar effect can be produced in human beings. Hotz R and Creekmore T.D have proposed that the Class II correction observed with functional appliances were caused by a “Headgear” effect restraining the maxilla along with a combination of dental changes such as retroclination of the maxillary incisors and proclination of the mandibular incisors [2-5].

The lack of success of functional appliances has in some circumstances been attributed to lack of patient compliance in appliance wear. Thus the ideal appliance would eliminate the need for patient co-operation, provide the ability to stimulate the overall amount of mandibular growth, and direct this growth in the appropriate direction. An important breakthrough in the treatment of Class II malocclusion came through the use of fixed functional appliances in adolescent and adult cases, therefore opening a new vista in the clinical management of borderline skeletal discrepancies.

Herbst was the first fixed functional appliance, introduced by Emil Herbst in 1905. However, it was not used until Pancherz reintroduced it in the late 1970s. The studies of Pancherz, Wieslander, and McNamara *et al* have reported both skeletal and dentoalveolar changes with the Herbst appliance. The disadvantages of this appliance were the rigidity of the mechanism and the requirement of complex laboratory stages.

In 1987, a new and more flexible fixed functional appliance, the Jasper Jumper was developed.

The Forsus class II corrector from 3M Unitek is a newer addition. It has a telescopic spring which provides light continuous forces. The Forsus appliance can be installed in a single appointment, it is comfortable and the spring does not bow into the cheek and the open coil spring is easily brushed cleaned and does not trap food, it functions continuously and is compatible for use with multi banded appliance.

Most class II skeletal malocclusions have a dentoalveolar component which requires correction either by retraction or decrowding and alignment of upper and lower anteriors. Extraction therapy is frequently indicated to correct severe crowding or retract the anterior teeth. In this study the Forsus appliance was used after correction of proclination or crowding with first premolar extraction using a multi banded pre adjusted edgewise appliance.

Most of the studies with fixed functional appliances have been conducted on non-extraction patients hence need to study the effect of fixed functional appliance in association with premolar extraction was the motivation behind this study.

Material and methodology

Data Selection

6 patients with skeletal class II malocclusion were selected from the patients attending Orthodontic clinic at the Department Of Orthodontics and Dentofacial Orthopedics, College Of Dental Sciences, and Davangere. All the patients were decompensated with extraction of all 1st premolars followed by fixed functional appliance (FORSUS) for correction of class II skeletal relation with an average treatment period of 6 months. The average age of the patients at the time of insertion of Forsus was 13.16 years. All the patients were treated to either Class I or overcorrected to a super Class I molar relation. Pre-treatment lateral cephalogram (Fig.1) before placement of Forsus appliance (T1) and post treatment lateral cephalogram (Fig.2) immediately after removal of Forsus appliance (T2) were collected.

Criteria for selection of patients

Inclusion criteria

1. Skeletal class II malocclusion patients, with retrognathic mandible with class II molar relation age group between 12-16 years.
2. Overjet exceeding 5mm.
3. ANB angle of at least 5^0.
4. All patients with positive VTO.
5. Horizontal growth pattern.
6. Extraction patients treated with fixed functional appliances FORSUS selected.

Exclusion criteria

1. Skeletal class I malocclusion patients and patients with classI molar relation
2. Overjet less than 5mm.
3. Non extraction cases treated with fixed functional appliance (Forsus).
4. ANB angle less than 5^0.
5. Severely periodontally compromised patients.

Analysis of lateral cephalograms

Standard lateral cephalograms were analyzed. Metric analysis was carried out with reference to the pancherz [6], with all registrations being measured to the reference line OLP. The occlusal line OL is defined by the incisal point of the upper central incisor and the distobuccal cusp of the upper first molar. The perpendicular to OL through the sella point defines the OLP (occlusal line perpendicular). The occlusal line OL, the perpendicular OLP, and the sella –nasion line SNL of the cephalogram before treatment (Fig.1) with the spring serve as the reference lines for evaluation of the post treatment cephalogram (Fig.2).

Linear parameters for hard tissue evaluation (Fig. 3)

1. Occlusal line: A line through *Is*and the distobuccal cusp of the maxillary permanent firstmolar.
2. Occlusal line perpendicular: A line perpendicular to *OL* through *S*.
3. Is_OLp: Position of maxillary central incisor
4. Ii_ OLp: Position of mandibular central incisor
5. Ms_OLp: Position of maxillary molar
6. Mi_OLp: Position of mandibular molar
7. Ss_OLp: Position of Maxillary jaw base
8. Pg_OLp: Position of mandibular jaw base
9. Ar_OLp: Position of condyle
10. Pg_OLp plus Ar_OLp: Mandibular length
11. Is_OLp minus Ii_ OLp: Over Jet
12. Ms_OLp minus Mi_OLp: Molar relationship
13. Ii_OLp minus Pg_OLp: Changes in position of mandibular incisor with in mandible
14. Ms_OLp minus SS_OLp: Changes in position of maxillary 1st molar with in maxilla
15. Mi_OLp minus Pg_OLp: Changes in position of mandibular 1st molar with in mandible

Angular parameters for hard tissue evaluation (Fig. 4)

1. SNA
2. SNB:
3. ANB:
4. Mandibular plane angle (Rakosi):
5. Y-axis angle
6. L1-Mandibular plane angle:

Angular parameters for soft tissue evaluation (Fig. 5)

1. Naso labial angle
2. Angle of facial convexity

Linear parameters for soft tissue evaluation

Esthetic Line (E-Line): It is formed by joining tip of the nose and soft tissue pogonion.

E line -Labialis superior

E line - Labialis inferior

Statistics

Means and standard deviations (SD) were calculated for each variable at pre, post, and differences. The paired *t* test was performed to detect any statistical significant changes during the Forsus period. Significance was determined at the 0.05, 0.01 and 0.001 levels of significance.

1. Arithmetic mean = $\frac{\text{Sum of all the values}}{\text{No. of values n}} = \frac{\Sigma X}{n}$

2. Standard deviation, $SD = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}}$

3. Standard Error, S.E= SD / square root of ‘n’

4. Paired T test: T= $\frac{\text{Mean of paired differences}}{\text{S.E of paired differences}}$

Value of <0.05 and 0.01 was statistically significant (s), p value <0.001 highly significant (HS) and p-value more than 0.05 to be statistically insignificant (NS).

Results

Lateral Cephalograms were analyzed and comparison of values between pre-Treatment (T1) i.e. before placement of Forsus and post Treatment (T2) after removal of Forsus, were done by paired T-test. Value of less than 0.05 was statistically significant (s), p value less than 0.01 highly significant (HS) and p value more than 0.05 to be statistically insignificant (NS).

The parameters used in this study have been divided into 3 categories;

1. Skeletal changes
2. Dental changes.
3. Soft tissue changes.

Skeletal changes

Linear and angular values were studied to measure the skeletal effects. All the linear measurements showed a non-significant change with a maxillary restriction of 0.08mm, mandibular advancement of 2.33mm, and forward movement of the condyle by 0.67mm and increase in mandibular length by 2.17mm Of the angular measurements SNA, ANB, NAPog and Occlusal plane inclination showed significant change whereas SNB, Y-axis, Mandibular plane angle and Basal plane angle changes were non-significant. SNA decreased by 1^0 and ANB by 1.75^0, the angle of convexity decreased by 2.17^0 and occlusal plane inclination increased by 6.5^0 (Table. 1).

Dental changes

All dental parameter showed significant change, Upper incisors were retruded by 2.33 mm; lower incisors were proclined by 6.33mm with an overjet correction of 7.67mm which was highly significant. The maxillary molar was distalised by 1.08mm while the mandibular molar mesialised by 4.83mm with an improvement in molar relationship of 5.75mm.Inclination of the upper incisors relative to the SN plane reduced by 7.67^0 and inclination of lower incisor to the mandibular plane increased by 10.83^0 showing significant uprighting of the upper incisors and highly significant proclination of the lower incisors (Table. 2).

Soft tissue changes

All the soft tissue parameter showed significant change with a nasolabial angle significantly increased by 4.5^0 and the angle of convexity showing highly significant decrease of 2.83^0. The relationship of the upper and lower lip to the E-line also improved significantly by 0.83mm (Table. 3).

Fig 1: Before placement of Forsus appliance

Fig 2: After removal of Forsus appliance

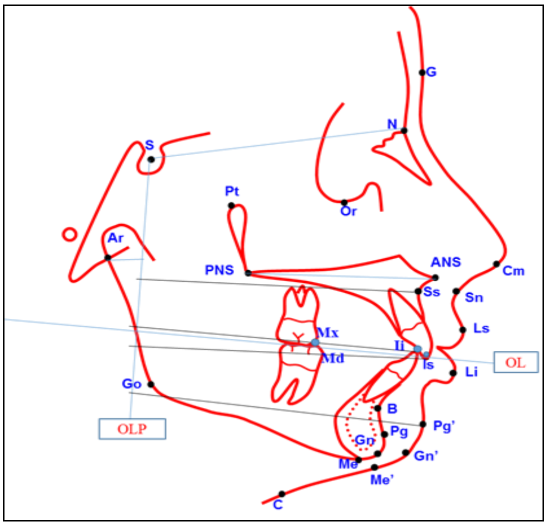

Fig 3: Linear parameters for hard tissue evaluation.

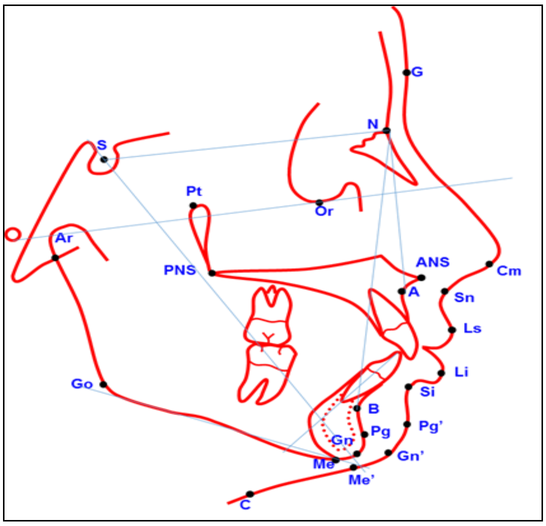

Fig 4: Angular parameters for hard tissue evaluation.

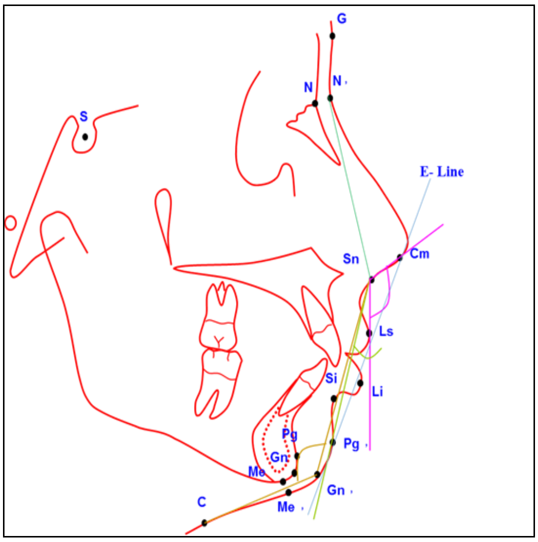

Fig 5: Angular parameters for soft tissue evaluation:

Table 1: Comparison between pre (T1) and post (T2) functional skeletal changes:

Skeletal							
Variable	**Particulars**	**T1**	**T2**	**Diff.(T1-T2)**	**% change**	**t value**	**P value**
ss-Olp (position of max jaw base)	Mean	76.75	76.67	0.08	0.1	0.15	0.88 NS
	SD	3.06	4.18	1.36			
Pg-Olp (position of mand jaw base)	Mean	75.17	77.50	-2.33	-3.1	3.5	0.01 NS
	SD	5.19	5.79	1.63			
Ar/Olp (position of condyle)	Mean	12.83	12.17	0.67	5.2	0.87	0.42 NS
	SD	2.04	3.43	1.86			
Pg/olp+ar/olp (mandibular length	Mean	87.83	90.00	-2.17	-2.5	5.39	0.003 NS
	SD	3.71	3.63	0.98			
SNA (deg)	Mean	81.00	80.00	1.00	1.2	2.73	0.041 S
	SD	1.79	1.67	0.89			
SNB(deg)	Mean	75.33	76.08	-1.42	-1.9	5.2	0.003 NS
	SD	1.21	1.36	0.66			
ANB(deg)	Mean	5.67	3.92	1.75	30.9	7	00.001 HS
	SD	1.51	1.80	0.61			
NAPog (deg)	Mean	11.17	8.83	2.17	19.4	4.54	0.006 S
	SD	4.62	4.07	1.17			
Y-axis (deg)	Mean	69.67	68.83	0.83	1.2	1.38	0.22 NS
	SD	3.39	2.40	1.47			
Mand plane angle (Rak) (deg)	Mean	36.33	34.83	1.50	4.1	1.24	0.26 NS
	SD	5.43	3.31	2.95			
Basal plane angle (deg)	Mean	26.17	26.67	-0.50	-1.9	1	0.36 NS
	SD	3.76	3.67	1.22			
SN-Occlusal plane angle (deg)	Mean	15.50	22.00	-6.50	-34.5	4.69	0.005 S
	SD	6.34	5.80	3.39			

Table 2: Comparison between pre (T1) and post (T2) functional dental changes.

Dental							
Variable	**Particulars**	**T1**	**T2**	**Diff. (T1-T2)**	**% change**	**t value ***	**P value**
Is-Olp (position of max CI) (mm)	Mean	85.67	83.33	2.33	2.7	5.5	0.003 S
	SD	5.09	5.54	1.03			
Ii-Olp (postion of mand CI) (mm)	Mean	75.83	82.17	-6.33	-8.4	7.51	0.001 HS
	SD	4.31	6.18	2.07			
ms-Olp (Position of max molar) (mm)	Mean	57.83	56.75	1.08	1.9	5.39	0.003 S
	SD	3.97	4.19	0.49			
mi-Olp (position of mand molar)(mm)	Mean	55.17	60.00	-4.83	-8.8	6.8	0.00 HS
	SD	4.22	5.18	1.72			
Is/olp-ss/olpchanges in position of max incisor with in max	Mean	8.58	7.00	1.58	18.4	2.71	0.042 S
	SD	1.50	2.19	1.43			
Is/olp-ii/olp (overjet)	Mean	9.17	1.50	7.67	83.6	18.18	0.00 HS
	SD	0.41	0.84	1.03			
Ms/olp-mi/olp (molar relationship)	Mean	2.67	-3.08	5.75	215.6	7.9	0.00 HS
	SD	0.52	2.01	1.78			
Ii/olp-pg/olp (change in position of mand incisor with in mandible	Mean	1.67	4.67	-3.00	-180.0	3.87	0.012 S
	SD	1.21	1.63	1.90			
Ms/olp-ss/olp (changes in position of max per Ist molar with in maxilla	Mean	19.25	19.83	-0.58	-3.0	3.79	0.013 S
	SD	0.42	0.68	0.38			
Mi/olp-pg/olp (changes in position of mand per Ist molar with in mand	Mean	19.67	17.00	2.67	13.6	4	0.01 S
	SD	2.94	3.58	1.63			
U1 SNdeg	Mean	101.50	93.83	7.67	7.6	4.05	0.01 S
	SD	9.59	8.11	4.63			
IMPA(deg)	Mean	92.83	103.67	-10.83	-11.7	19.95	0.00 HS
	SD	1.83	0.82	1.33			
* Paired t test			- ve sign indicates increase at T2				

Table 3: Comparison between pre (T1) and post functional (T2) soft tissue changes.

Soft Tissue							
Variable	**Particulars**	**T1**	**T2**	**Diff.(T1-T2)**	**% change**	**t value**	**P value**
Nasolabial angle	Mean	100.83	105.33	-4.50	-4.5	5.08	0.004 S
	SD	2.56	3.20	2.17			
Angle of facial convexity	Mean	23.17	20.33	2.83	12.2	9.22	0.000 HS
	SD	3.19	3.27	0.75			
E-line Labialis superior(mm)	Mean	0.67	-0.17	0.83	125.0	6.7	0.001 HS
	SD	3.27	4.26	1.47			
E-line Labialis inferior(mm)	Mean	2.33	1.50	0.83	-92.0	5	0.004 S
	SD	0.52	0.55	0.41			

Discussion

Skeletal class II malocclusion is a frequently occurring malocclusion with retrognathism of the lower jaw being the cause in most cases. Headgear and functional appliances are valuable means of treating sagittal discrepancies between upper and lower jaws. Fixed functional appliances are welcome aids when patient compliance is low [7]. They can be used to treat dental and skeletal class II malocclusion with or without extraction therapy. The most popular appliances are Herbst and Jasper jumper with the Forsus spring rapidly increasing in popularity. Majority of skeletal Class II malocclusion patients also require correction of upper and lower incisors for proclination or crowding. These corrections may be undertaken before or after the fixed functional phase. Decompensation of the incisors position before the fixed functional phase has multiple advantages.

1) Retroclination of the upper incisor with improvement in soft tissue profile.
2) Retraction of lower incisors with increase in overjet allowing greater mandibular advancement.
3) Uprighting of lower incisors over the basal bone occupying a more stable position.
4) Retroclination of the lower incisors helps to counter the protrusive effect of fixed functional appliances.
5) Inherent restriction to mandibular advancement offered by the incisor position is effectively eliminated.
6) Upper and lower arches are leveled and aligned facilitating the placement of 0.021x0.025 stainless steel wire which is a prerequisite for the proper functioning of fixed functional appliance.
7) Labial root torque can be effectively incorporated in a well aligned lower anterior segment.

The only disadvantage being delay in starting the fixed functional phase. However Pancherz have shown that fixed functional appliances work effectively even in young adults[8] and treatment is more successful when carried out at the end of the growth period.

The results of this study show that dental parameters contributed significantly to the correction of the class II malocclusion compared to the skeletal parameters. Dental factors contributed 68.37% and skeletal 31.62% to the correction of overjet and 58.08% and 41.91% respectively to the correction of molar relation.

The maxilla distalised by 0.08mm (Ss-OLP) and SNA angle reduced by1^0 which is statistically significant. Forsus^{TM} were effective in restraining the forward growth of the maxilla. In contrast, the study by Nina Heing, Gernot Goz [9] showed advancement of maxilla. Whereas, Seinz Karacay [10] showed decrease in SNA angle which was statistically significant. Studies on Herbst appliance all mention inhibition of maxillary growth [2, 11].

The mandible displaced forwardly as evident by SNB difference of 1.42^0 and the mandibular length increased by 2.17mm which was statistically insignificant. Nina Heinig and Göz [7], Weiland *et al.* [3] have reported increases in the mandibular length. Similar effects on the mandible were detected also in the studies with Herbst appliance [12-16] Sabine and Pancherz also observed an effective increase in mandibular length. In contrast to present study, studies by Cope *et al.* [4] and Covell *et al.* [6] concluded that the Jasper Jumper had no orthopedic effect on the mandible. Overall increase in mandibular length is due to remodeling process in glenoid fossa as well as due to remodeling process along the anterior and posterior surface of the ramus of mandible. Change in condyle position anteriorly, evident by mean value of 0.67 mm was similar to that of Sabine and Pancherz.

Forward displacement of the mandible leads to elongation of the muscle fibers and tendons. The pull of the muscle attachments at the bone surface is intensified by the modified function and induces bone remodeling processes. For example, stimulation of the lateral pterygoid muscle increases cell proliferation at the condyle. Through simultaneous bone adaptive, bone deposition in the posterior area of glenoid fossa and bone resorption in the anterior area, the glenoid fossa is relocated in the forward and downward direction, ultimately resulting in an improved jaw relationship [2, 12].

The ANB angle reduced by1.75^0 showing statistically high significance. Studies by Nina Heinig, Gernot Goz [9], Seinz Karacay [10] also showed decrease in ANB. Studies with Herbst appliance [12-16] showed similar results with a statistically significance.

The occlusal plane became significantly steeper with treatment. Similar results were detected by Nina Heinig, Gernot Goz [9] and Seinz Karacay [10] in studies on the Herbst appliance and the Jasper Jumper. Mandibular plane angle, basal plane angle, and Y-axis showed non-significant change. Similar results were seen in studies [2, 4, 11].

In the present study, overjet reduced by 7.62 mm, (100%) of which 2.41 mm (31.62%) being contributed by skeletal changes (Ss plus Pg) and 5.21 mm (68.37%) by dental changes (Is-Ss plus Ii-Pg). Study by Nina Heinig, Gernot Goz [9] using Forsus showed 33% overjet reduction was skeletal and 66% dental. Study by Ernest L Stromeyer Joseph [6] showed 10% skeletal and 90% dental reduction of overjet with Eureka springs. Studies by Seinzkaracay *et al.* [10, 17] showed similar results. Study by Frank J. Weiland, Hans-Peter Bantleon [18] using Jasper Jumper showed reduction in overjet of 38% by skeletal and 62% by dental changes. Study by Sabine Ruf [8] using Herbst appliance showed overjet reduction in young adults of 22% by skeletal changes and 78% by dental changes and in early adolescent of 39% by skeletal changes and 61% by dental changes. Hans pancherz [12] showed 56% skeletal and 44% dental changes in overjet correction which makes the Herbst appliance more efficient than the Forsus for skeletal correction.

Maxillary incisor retroclination was statistically significance; Mandibular incisor proclination was highly significant (Table 2). IMPA increased by a mean of 10.83^0 showing high significance. Study by Nina Heinig, Gernot Goz [9] showed similar results [2, 4, 12-16].

The improvement in molar relationship is 5.75 mm (100%) of which 2.41 mm (41.91%) is by skeletal changes and 3.34mm (58.08%) is by dental changes showing statistical significance. Study by Nina Heinig, Gernot Goz [11] using Forsus showed 39% due to skeletal changes and 61% due to dental changes. Study by Ernest L Stromeyer *et al.* [6] showed molar correction 100% (skeletal 7% and dental 93%). Study by Hans Pancherz [12] showed molar correction 100% (skeletal 43% and dental 57%) and the correction was primarily by forward growth of mandible. Study by Sabine Ruf [8] showed in young adult's molar correction of 100% (skeletal 25% and 75% dental) in early adolescents 100% (skeletal 41% and dental 59%). Similar results were seen in other studies also [2, 4, 12-16].

The Nasolabial angle increased by 4.50^0 showing statistical significance. Increase in nasolabial angle is the result of upper lip fall due to retroclination of maxillary incisors. Improvement in Soft tissue profile was statistically significant as evident by decrease in Gl-Sn-Pog[1] of 2.83^0. The profile improvement in the present study is because of the changes observed in the lower lip and soft tissue pogonion which is influenced from the forward displacement of the mandible and protrusion of the mandibular incisors. This finding was similar with those of Weiland *et al.* [3] and Pancherz [12]. The distance between the E-line to labialis superior and Labialis inferior were increased by 0.83mm showing statistically significant value. Increase in E-line to Labialis superior length is mainly due to upper lip fall on retraction of maxillary incisors. Similar results were seen in other studies also [2, 4, 12-16].

Conclusion

The Forsus appliance in the present study showed:

1) Stimulation of the mandibular growth and inhibition of the maxillary growth.
2) Significant incisor and molar movements, and dentoalveolar changes were more effective than the skeletal changes in attaining Class I molar relationship.
3) Changes in the inclination of the occlusal plane.
4) Significant change in soft tissue profile.
5) Effective as an alternative to orthognathic surgery in borderline skeletal class II cases.
6) Comparable treatment effects to those published for Herbst and Jasper Jumper
7) Decompensation of the dentoalveolar component before the fixed functional phase did not interfere with the Class II correction.

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