Timing of Myofunctional Appliance Therapy

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Objective: *To identify the stage of skeletal maturity, as depicted by the Cervical Vertebrae Maturity Index at which the maximal response to myofunctional therapy could be expected.* ***Design:*** *The soft copies of pre and post treatment lateral cephalometric radiographs of the sample comprising of 48 subjects, on myofunctional therapy, were traced on 'Nemotec Dental Studio NX' software. Three groups were formed based on the stages of skeletal maturity and comparison was done.* ***Results:*** *The treated samples were compared with control samples consisting of subjects with untreated Class II malocclusions, also selected on the basis of stages in cervical vertebrae maturation. Inter-group comparison of the treated samples revealed statistically significant changes in Group II (Stages 3 to 4 of Cervical Vertebrae Maturity Index).* ***Conclusion:*** *Maximum response to myofunctional therapy can be expected in patients during the stages 3 to 4 of cervical vertebrae maturation index, i.e., during or slightly after the pubertal peak.*

Keywords: *Myofunctional appliance, Skeletal maturity, Cervical vertebrae Maturity Index (CVMI), Nemotec Dental Studio NX, Pubertal peak.*

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INTRODUCTION

The form-function debate has been a perpetual one for the orthodontic community. The effect of facial form on the function and vice-versa has been a subject of great interest and controversy for a research oriented orthodontic clinician. Pioneering works by Van der Klaauw and later by Moss[1-2] have substantiated the effects of function in changing facial form.

Altering the sagittal and vertical mandibular position generates the modifications in muscular forces and results in orthopedic and orthodontic changes.[3] Despite a number of cephalometric studies on the treatment effects of myofunctional appliance in growing subjects,[4-6] only a few investigations have dealt with the issue of optimal treatment timing[7–14] for this type of therapy. The issue of optimal timing for dentofacial orthopedics is linked intimately to the identification of periods of accelerated growth that can contribute significantly to the correction of skeletal imbalances in an individual patient.

It has been demonstrated widely that individual skeletal maturity significantly affects the outcomes of functional orthopedics. Myofunctional therapy rendered during the adolescent growth spurt induces greater mandibular skeletal effects than a therapy at a prepubertal stage.[8-14] Björk[15] found that the effectiveness of functional appliances is reduced as a patient gets older. Cohen[16] suggested that treatment should start before the patient achieves peak growth rate in order to take advantage of periods of fast growth, which both precede and follow the peak growth rate itself. In particular, investigations by Petrovic *et al*[17] revealed that the therapeutic effectiveness of the Louisiana State University activator, Fränkel appliance, and Bionator is most favorable when these appliances are used during the ascending portion of the individual pubertal growth spurt.

It may be difficult to predict the precise timing of the peak rate of facial growth before it takes place, but studies have shown a strong correlation between the peak of facial growth and peak height velocity.[18-19] Tanner *et al* [20] found that the peak height velocity occurred, on an average, around 12 years in girls and 14 years in boys.

Kopecky and Fishman[21] attempted to identify optimal timing of cervical headgear treatment based on skeletal maturation (determined from hand-wrist radiographs), and reported more favorable results during maturation periods that were associated with greater incremental velocity.

Hassel and Farman[22] combined the observations of the changes in the hand-wrist and the changes in the cervical

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vertebrae during skeletal maturation and advocated that cervical vertebrae maturation (CVM) can be used as an indicator of skeletal maturity. The obvious advantage of CVM method is that cephalometric radiographs are routinely required for diagnosis and treatment planning; therefore no additional radiograph is needed. A recent study by Fudaleja and Bollenb [23] confirms the fact that CVM method is modestly effective in determining the amount of postpeak circumpubertal craniofacial growth.

Validating the applicability of cervical vertebrae maturation Index (CVMI), a study was designed to analyze the skeletal and dento-alveolar changes produced by the myofunctional appliance in three different groups of skeletal maturation of cervical vertebrae. This could be of immense help for an apt clinician, wherein he can select cases with relatively reliable prognosis by the identification of a particular stage of development at which the most favorable response to myofunctional appliance treatment is possible.

MATERIALS AND METHOD

The study was done on a sample of 48 Class II Div 1 patients, 32 girls and 16 boys, with a mean age of 11.17 years treated with the Clark's 'Twinblock Appliance' for a period of 2 years and an equal amount of control sample put under observation for the same period. The patients were instructed to wear the appliance 24 hours including eating so as to take the advantage of rapid functional correction of malocclusion by transmitting favorable occlusal forces to the inclined planes covering the posterior teeth.

Both the samples were taken up for fixed mechanotherapy after the completion of 2 years depending upon the individual requirements. The soft copies of the pre and post treatment lateral cephalometric radiographs of the sample were traced utilizing Nemotec Dental Studio NX software.

For the error assessment, systematic and random errors were calculated separately as described by Houston.[24] The pre and post treatment tracings were viewed side by side to try and minimize the errors in locating the cephalometric landmarks. Error of magnification was taken care of by placing a radiopaque ruler on the unit's nasal positioner and calculating the percentage increase in the ruler's image length. Systematic errors were controlled by randomising the order in which the records were measured. The cephalograms were traced in a random order whenever any two groups were compared so as to prevent the measurer from knowing as to which group the record belongs to. Reliability of measurements was tested by doing double determinations of all the cephalograms, randomly selected at 15 days interval from the collected sample, by the same operator. The comparison was drawn between the first and second determinations by student's't' test.

The criteria for selection of the sample included: growing patients within the age group of 9 to 14 years, Class II skeletal relation of the jaws with relatively normal maxilla and retrognathic mandible, angle ANB 4º or greater, full cusp Class II molar relationship on one side and end-on or greater on the other side, minimum or no dental crowding, normal to horizontal growth pattern with little or no vertical problems.

Oral health of the patients was critically observed and managed by an in-office periodontist from time to time.

On the basis of Cervical Vertebrae Maturation Index, the groups were formed as:

Group I (CVMI Stage 1 to 2) (n=5): Significant amount (65-100%) of adolescent growth expected.

Group II (CVMI Stage 3 to 4) (n=29): Moderate amount (10-65%) of adolescent growth expected.

Group III (CVMI Stage 5 to 6) (n=14): Small amount (≤10%) of adolescent growth expected.

Landmarks used in cephalometric tracings were according to the definitions given by Salzmann[25] and Rakosi.[26]

Thirty-three linear and angular parameters were identified as described by Riolo *et al.*[27] A vertical reference plane *(VRP)* through Sella at *97º* angle to the Sella-Nasion plane was constructed, as described by Burstone *et al,*[28] for the purpose of hard and soft-tissue measurements. The assessment of skeletal age was performed by the evaluation of maturational stages in the cervical vertebrae, according to the method originally developed by Lamparski[29] and successfully implemented by O'Reilly[30] and by Hassel & Farman.[22]

The cephalometric variables used in the study included were those representing the Facial Height, Antero-posterior and Mandibular dimensions along with those depicting Dento-alveolar and Soft-tissue relationships.

RESULTS

In Table I, correlation amongst the different variables was established. Findings revealed that all the variables were influenced in a positive or negative manner except for *ÐAr-Go-Me, LM-MnP* and *VRP-Gb* showing the absence of any correlation.

In Table II, comparison done between the treated and untreated Group I revealed statistically insignificant changes, exhibiting subtle variation produced by the appliance as compared to normal growth phenomenon.

In Table III, treated and untreated Group II were compared and statistically significant differences in lower anterior facial height with improved position of mandible; as revealed by *ÐSNB, ÐANB, VRP-B* and *VRP-Pog*, were obtained. There was significant improvement in mandibular dimensions comprising of ramus height *Cd-Go,* and mandibular lengths *Cd-Gn and Ar-Gn*. There were significant changes in dento-alveolar variables *OB, OJ, UI-MxP, II, LM-MnP* and *VRP-LM*; and the soft-tissue variables *VRP-Li* and *VRP-sPog*.

The results obtained demonstrated noteworthy changes produced by the appliance as compared to normal growth progression.

In Table IV, comparison of the treated and untreated Group III revealed statistically insignificant changes, demonstrating minimum variation produced by the appliance as compared to normal growth trend.

In Table V, inter-group comparison of the three groups was carried out. Comparison of Group I and II revealed significant differences in the magnitude of facial height variables *LAFH* and *PFH*. Statistically significant discrepancy was uncovered when the antero-posterior variables *ĐSNB, ĐANB, VRP-B* and *VRP-Pog* were evaluated. Momentous difference in the ramus height *Cd-Go,* and the mandibular lengths *Cd-Gn and Ar-Gn* was observed as the mandibular dimensions were measured. Group II demonstrated a significant difference over Group I when the dento-alveolar variables *OB, OJ, UI-MxP, LM-MnP* and *VRP-LM*; and the soft-tissue variables *VRP-Li* and *VRP-sPog* were put under comparison.

Comparison of Group II and III showed, yet again, significant changes in Group II as confirmed by facial height variables *UAFH, LAFH, PFH*; antero-posterior variables *ĐSNB, ĐANB, VRP-B, VRP-Pog*; mandibular dimensions *Cd-Go, Cd-Gn, Ar-Gn*; dento-alveolar variables *OB, OJ, UI-MxP, LM-MnP, VRP*-LM; and soft tissue variable *VRP-Li.*

On comparison of Group I and III, *LAFH* as the facial height variable, *Cd-Gn* as the mandibular dimension, Overjet as dento-alveolar variable and *VRP-Li* and *VRP-sPog* as soft-tissue variables revealed greater changes.

Table I. Showing Correlation amongst the variables (n=48)

	Variable	'r'	't'	'p'
FACIAL HEIGHT VARIABLES:				
1.	UAFH	0.05	0.36	NS
2.	LAFH	0.17	1.23	NS
3.	PFH	0.33	2.50	NS
4.	ĐS-Ar-Go	0.04	0.29	NS
5.	ĐFMA	–0.13	0.94	NS
6.	Đ"Y" axis	0.21	1.53	NS
ANTERO-POSTERIOR VARIABLES:				
7.	ĐSNA	0.11	0.79	NS
8.	ĐSNB	0.21	1.53	NS
9.	ĐANB	–0.07	0.50	NS
10.	VRP-Cd	–0.19	1.38	NS
11.	VRP-ANS	0.15	1.08	NS
12.	VRP-A	–0.08	0.57	NS
13.	VRP-B	0.16	1.16	NS
14.	VRP-Pog	0.23	1.69	NS
15.	ĐS-N-Pog	0.26	1.92	NS
MANDIBULAR DIMENSIONS:				
16.	Cd-Go	0.001	0.007	NS
17.	Cd-Gn	–0.04	0.29	NS
18.	Go-Gn	0.26	1.92	NS
19.	Ar-Gn	0.32	2.41	NS
20.	ĐAr-Go-Me	–0.12	0.86	<0.05
DENTO-ALVEOLAR VARIABLES:				
21.	OB	0.16	1.16	NS
22.	OJ	–0.18	1.31	NS
23.	UI-MxP	0.03	0.21	NS
24.	LI-MnP	–0.10	0.72	NS
25.	II	–0.03	0.21	NS
26.	UM-MxP	–0.06	0.43	NS
27.	LM-MnP	0.49	4.01	<0.001
28.	VRP-UM	0.23	1.69	NS
29.	VRP-LM	0.21	1.53	NS
SOFT-TISSUE VARIABLES:				
30.	VRP-Gb	0.45	3.60	<0.001
31.	VRP- sN	0.04	0.29	NS
32.	VRP-Sn	–0.19	1.38	NS
33.	VRP- sPog	0.6	1.92	NS

(p value < 0.05 – Significant; > 0.05– Non-Significant)

DISCUSSION

Evaluation of the individual biologic timetable and the identification of periods of accelerated and intense growth, along

Table II. Showing inter-group comparison between Treatment and Control Group I

	Variables	Tt I (N=5) Change (Mean±SD)	C I (N=5) Change (Mean±SD)	t_{cal} ($t_{tab\text{-}2.31}$)	p-value
FACIAL HEIGHT VARIABLES:					
1.	UAFH	1.6±1.52	1.2±0.85	1.45	NS
2.	LAFH	3.66±1.12	3.2±1.06	1.34	NS
3.	PFH	3.20±1.90	2.3±0.72	1.67	NS
4.	ĐS-Ar-Go	–2.40±1.52	–2.0±1.24	1.54	NS
5.	ĐFMA	–0.60±1.14	–0.13±.58	1.43	NS
6.	Đ"Y" axis	1.60±4.04	–1.20±2.03	1.54	NS
ANTERO-POSTERIOR VARIABLES:					
7.	ĐSNA	–0.80±1.10	–0.30±1.06	1.89	NS
8.	ĐSNB	3.20±0.84	2.91±.27	1.78	NS
9.	ĐANB	–4.0±1.22	–3.1±.13	1.45	NS
10.	VRP-Cd	0.20±1.48	0.14±.59	1.23	NS
11.	VRP-ANS	0.20±0.84	.013±1.25	1.34	NS
12.	VRP-A	–1.20±0.84	–0.50±0.48	1.56	NS
13.	VRP-B	4.20±2.77	3.46±2.52	1.83	NS
14.	VRP-Pog	4.80±3.27	4.12±2.20	1.34	NS
15.	ĐS-N-Pog	2.40±0.55	2.25±0.31	1.32	NS
MANDIBULAR DIMENSIONS:					
16.	Cd-Go	3.40±1.52	3.10±1.24	1.84	NS
17.	Cd-Gn	5.20±2.17	4.37±1.85	1.79	NS
18.	Go-Gn	2.80±2.28	2.04±1.40	1.64	NS
19.	Ar-Gn	5.20±2.59	4.24±2.21	1.43	NS
20.	ĐAr-Go-Me	0±1.12	–0.36±0.90	1.54	NS
DENTO-ALVEOLAR VARIABLES:					
21.	OB	–4.0±1.0	–3.04±0.90	1.45	NS
22.	OJ	–6.20±2.60	–5.47±1.80	1.43	NS
23.	UI-MxP	11.20±2.15	10.51±1.82	1.76	NS
24.	LI-MnP	3.0±4.06	2.04±2.29	1.56	NS
25.	II	10.0±6.00	08.0±4.00	1.34	NS
26.	UM-MxP	0.60±1.14	0.85±1.41	1.67	NS
27.	LM-MnP	5.0±1.06	4.54±0.92	1.54	NS
28.	VRP-UM	1.40±4.39	1.29±3.29	1.45	NS
29.	VRP-LM	3.80±1.14	3.12±1.14	1.76	NS
SOFT-TISSUE VARIABLES:					
30.	VRP-Gb	1.40±1.67	1.20±1.31	1.45	NS
31.	VRP- sN	1.0±1.00	0.90±0.10	1.32	NS
32.	VRP-Sn	1.0±2.83	0.85±2.29	1.67	NS
33.	VRP- sPog	5.80±2.77	4.83±2.38	1.43	NS

(p value < 0.05 – Significant; > 0.05– Non-Significant)

with other clinical data, can provide valuable information regarding the treatment planning and retention procedures. This would aid the clinician to ascertain the ideal time to initiate treatment, especially the myofunctional therapy.

The Twin-block appliances used were of the standard design as described by Clark.[31] The Twin-Block is a simple, comfortable and esthetically acceptable appliance, worn full time, which achieves rapid functional correction of malocclusion by transmitting favorable occlusal forces to the inclined planes covering the posterior teeth.

The skeletal age was assessed with the use of maturational stages in the cervical vertebrae, according to the method developed by Hassel and Farman.[22] Six stages corresponding to six different maturational phases in the cervical vertebrae can be identified characterized by definite morphologic and dimensional changes of the bodies of the second through the fourth cervical vertebrae (Figure 1). The stages of cervical vertebrae maturation are related to the mandibular growth changes that take place during puberty.

Table III. Showing inter-group comparison between Treatment and Control Group II

	Variables	Tt II (N=29)Change (Mean±SD)	C II (N=29)Change (Mean±SD)	t_{cal} ($t_{tab\text{-}2.01}$)	p-value
FACIAL HEIGHT VARIABLES:					
1.	UAFH	1.44±1.48	1.6±1.02	1.92	NS
2.	LAFH	5.62±1.06	3.76±1.10	3.87	S
3.	PFH	6.30±2.60	4.10±1.20	1.97	NS
4.	ÐS-Ar-Go	–2.21±1.84	–2.10±1.52	1.67	NS
5.	ÐFMA	–0.53±1.78	–3.30±0.14	1.78	NS
6.	Ð"Y" axis	–1.14±2.03	1.20±1.01	2.0	NS
ANTERO-POSTERIOR VARIABLES:					
7.	ÐSNA	–0.30±1.06	–0.30±1.10	1.56	NS
8.	ÐSNB	6.71±1.27	3.30±0.94	3.40	S
9.	ÐANB	–6.1±1.13	–3.0±0.92	2.98	S
10.	VRP-Cd	0.44±3.29	0.38±2.45	1.67	NS
11.	VRP-ANS	–1.03±2.25	–0.90±1.34	1.7	NS
12.	VRP-A	–0.50±1.48	–0.40±1.24	1.69	NS
13.	VRP-B	7.76±1.52	3.20±1.72	2.3	S
14.	VRP-Pog	8.82±1.60	3.50±1.27	2.2	S
15.	ÐS-N-Pog	1.85±1.81	1.60±1.25	1.65	NS
MANDIBULAR DIMENSIONS:					
16.	Cd-Go	6.78±1.14	3.30±1.20	3.0	S
17.	Cd-Gn	8.77±1.54	3.90±1.17	2.5	S
18.	Go-Gn	2.06±2.09	1.90±1.58	1.56	NS
19.	Ar-Gn	8.24±1.41	4.10±1.52	2.45	S
20.	ÐAr-Go-Me	–0.56±1.70	–0.46±1.12	1.89	NS
DENTO-ALVEOLAR VARIABLES:					
21.	OB	–8.64±1.90	–3.02±1.5	2.9	S
22.	OJ	–11.47±1.24	–3.50±1.40	3.2	S
23.	UI-MxP	15.21±1.82	03.50±2.15	3.1	S
24.	LI-MnP	3.94±7.69	3.5±2.05	1.67	NS
25.	II	10.0±7.00	4.80±3.20	3.05	S
26.	UM-MxP	0.85±1.42	0.68±1.14	1.56	NS
27.	LM-MnP	8.74±1.42	3.20±2.02	2.9	S
28.	VRP-UM	–0.59±3.29	–0.40±2.30	1.56	NS
29.	VRP-LM	6.12±1.34	3.30±1.24	3.2	S
SOFT-TISSUE VARIABLES:					
30.	VRP-Gb	0.50±1.31	0.40±1.27	1.98	NS
31.	VRP- sN	–0.10±0.30	–0.50±0.40	1.87	NS
32.	VRP-Sn	0.85±2.39	0.60±2.13	1.76	NS
33.	VRP- sPog	2.83±1.78	2.10±1.37	1.89	NS

(p value < 0.05 – Significant; > 0.05– Non-Significant)

Table IV. Showing inter-group comparison between Treatment and Control Group III

	Variables	Tt III (N=14) Change (Mean±SD)	C III (N=14) Change (Mean±SD)	t_{cal} ($t_{tab\text{-}2.06}$)	p-value
FACIAL HEIGHT VARIABLES:					
1.	UAFH	–0.10±2.95	–0.12±1.25	1.56	NS
2.	LAFH	1.06±1.52	0.90±1.12	1.64	NS
3.	PFH	2.0±1.40	1.8±1.20	1.22	NS
4.	ÐS-Ar-Go	–1.79±4.41	–1.50±2.41	1.45	NS
5.	ÐFMA	–1.14±1.61	–1.24±2.21	1.43	NS
6.	Ð"Y" axis	–1.21±2.56	–0.91±1.42	1.62	NS
ANTERO-POSTERIOR VARIABLES:					
7.	ÐSNA	–0.50±2.79	–0.50±1.29	1.34	NS
8.	ÐSNB	2.79±0.80	2.39±0.60	1.32	NS
9.	ÐANB	–3.30±1.20	–2.80±0.80	1.76	NS
10.	VRP-Cd	–0.50±2.77	–0.40±1.28	1.34	NS
11.	VRP-ANS	0.21±1.05	0.23±0.85	1.33	NS
12.	VRP-A	0.0±0.88	0.2±0.80	1.45	NS
13.	VRP-B	3.64±2.37	2.94±1.32	1.29	NS
14.	VRP-Pog	3.57±2.21	3.02±2.07	1.78	NS
15.	ÐS-N-Pog	2.29±1.20	1.90±1.10	1.67	NS
MANDIBULAR DIMENSIONS:					
16.	Cd-Go	2.21±1.37	2.21±1.25	1.54	NS
17.	Cd-Gn	4.71±1.83	3.33±0.90	1.32	NS
18.	Go-Gn	2.07±2.89	1.82±1.47	1.65	NS
19.	Ar-Gn	4.21±1.26	3.80±0.79	.123	NS
20.	ÐAr-Go-Me	0.07±0.42	0.00±0.52	1.47	NS
DENTO-ALVEOLAR VARIABLES:					
21.	OB	–3.36±2.06	–2.84±1.84	1.78	NS
22.	OJ	–4.21±1.46	–3.43±1.23	1.34	NS
23.	UI-MxP	9.79±1.18	7.57±1.10	1.72	NS
24.	LI-MnP	4.21±5.82	3.72±4.23	1.23	NS
25.	II	10.3±7.23	08.6±5.13	1.45	NS
26.	UM-MxP	1.93±3.54	1.46±2.46	1.23	NS
27.	LM-MnP	4.21±1.82	4.21±1.82	1.1	NS
28.	VRP-UM	–0.71±1.82	–0.43±0.89	1.2	NS
29.	VRP-LM	3.64±1.17	3.23±0.81	1.56	NS
SOFT-TISSUE VARIABLES:					
30.	VRP-Gb	0.14±0.86	0.12±0.53	1.76	NS
31.	VRP- sN	0.50±2.38	0.30±1.27	1.43	NS
32.	VRP-Sn	0.57±1.65	0.48±1.23	1.74	NS
33.	VRP- sPog	3.36±3.03	3.12±2.08	1.03	NS

(p value < 0.05 – Significant; > 0.05– Non-Significant)

Facial height variables

Significant changes were observed in Group II in comparison to other groups, particularly the lower anterior facial height (LAFH), 5.92±1.06 mm/year and posterior facial heights (PFH), 6.3±1.60 mm/year suggesting that the maximum effects of the appliance therapy were seen during this stage of growth. This finding is in accordance with those of Ahlgren and Laurin[32] who observed significant changes in the post normal and pre normal subjects during activator therapy.

Similarly, Cohen[16] investigated the growth of intermaxillary space and the timing of orthodontic treatment in relation to growth and established the fact that, to achieve success, treatment should be instituted early, well before the growth rate peak occurs.

O'Reilly and Yanniello[30] assessed the relationship of cervical vertebrae maturation and mandibular growth changes in annual lateral cephalometric radiographs and found statistically significant increase in the ramus height associated with similar maturation stages in the cervical vertebrae as found in our study.

Table V.. Showing inter-group comparison amongst Groups I, II & III

	Variables	I (N=5) Change (Mean±SD)	II (N=29) Change (Mean±SD)	III (N=14) Change (Mean±SD)	I vs II		I vs III		II vs III	
					't'	'p'	't'	'p'	't'	'p'
FACIAL HEIGHT VARIABLES:										
1.	UAFH	1.6±1.52	1.44±1.48	–0.10±2.95	0.23	NS	1.22	NS	2.42	<0.05
2.	LAFH	3.66±1.12	5.62±1.06	1.06±1.52	4.41	<0.001	2.75	<0.01	11.34	<0.001
3.	PFH	3.20±1.90	6.30±2.60	2.0±1.40	3.91	<0.001	1.51	NS	11.29	<0.001
4.	ÐS-Ar-Go	–2.40±1.52	–2.21±1.84	–1.79±4.41	0.22	NS	0.30	NS	0.47	NS
5.	ÐFMA	–0.60±1.14	–0.53±1.78	–1.14±1.61	0.08	NS	0.69	NS	1.10	NS
6.	Ð"Y" axis	1.60±4.04	–1.14±2.03	–1.21±2.56	2.45	<0.05	1.81	NS	0.10	NS
ANTERO-POSTERIOR VARIABLES:										
7.	ÐSNA	–0.80±1.10	–0.30±1.06	–0.50±2.79	0.98	NS	0.23	NS	0.36	NS
8.	ÐSNB	3.20±0.84	6.71±1.27	2.79±0.80	5.26	<0.001	0.97	NS	10.64	<0.001
9.	ÐANB	–4.0±1.22	–6.1±1.13	–3.30±1.20	3.85	<0.001	1.12	NS	7.67	<0.001
10.	VRP-Cd	0.20±1.48	0.44±3.29	–0.50±2.77	0.16	NS	0.53	NS	0.94	NS
11.	VRP-ANS	0.20±0.84	–1.03±2.25	0.21±1.05	1.20	NS	0.02	NS	1.97	NS
12.	VRP-A	–1.20±0.84	–0.50±1.48	0.0±0.88	1.03	NS	2.65	<0.05	1.18	NS
13.	VRP-B	4.20±2.77	7.76±1.52	3.64±2.37	4.38	<0.001	0.43	NS	7.21	<0.001
14.	VRP-Pog	4.80±3.27	8.82±1.60	3.57±2.21	4.52	<0.001	0.94	NS	9.24	<0.001
15.	ÐS-N-Pog	2.40±0.55	1.85±1.81	2.29±1.20	0.67	NS	0.20	NS	0.83	NS
MANDIBULAR DIMENSIONS:										
16.	Cd-Go	3.40±1.52	6.78±1.14	2.21±1.37	5.94	<0.001	1.67	NS	13.61	<0.001
17.	Cd-Gn	5.20±2.17	8.77±1.54	4.71±1.83	4.61	<0.001	2.59	<0.05	7.85	<0.001
18.	Go-Gn	2.80±2.28	2.06±2.09	2.07±2.89	0.73	NS	0.51	NS	0.01	NS
19.	Ar-Gn	5.20±2.59	8.24±1.41	4.21±1.26	4.02	<0.001	0.61	NS	9.62	<0.001
20.	ÐAr-Go-Me	0±1.12	–0.56±1.70	0.07±0.42	0.70	NS	0.20	NS	1.36	NS
DENTO-ALVEOLAR VARIABLES:										
21.	OB	–4.0±1.0	–8.64±1.90	–3.36±2.06	5.33	<0.001	0.66	NS	8.57	<0.001
22.	OJ	–6.20±2.60	–11.47±1.24	–4.21±1.46	7.60	<0.001	2.12	<0.05	17.46	<0.001
23.	UI-MxP	11.20±2.15	15.21±1.82	9.79±1.18	4.51	<0.001	1.83	NS	10.28	<0.001
24.	LI-MnP	3.0±4.06	3.94±7.69	4.21±5.82	0.27	NS	0.43	NS	0.12	NS
25.	II	10.0±6.00	10.0±7.00	10.3±7.23	0	NS	0.08	NS	0.14	NS
26.	UM-MxP	0.60±1.14	0.85±1.42	1.93±3.54	0.37	NS	0.81	NS	1.52	NS
27.	LM-MnP	5.0±1.06	8.74±1.42	4.21±1.82	3.79	<0.001	0.92	NS	9.15	<0.001
28.	VRP-UM	1.40±4.39	–0.59±3.29	–0.71±1.82	1.21	NS	1.52	NS	0.13	NS
29.	VRP-LM	3.80±1.14	6.12±1.34	3.64±1.17	3.67	<0.001	0.26	NS	6.06	<0.001
SOFT-TISSUE VARIABLES:										
30.	VRP-Gb	1.40±1.67	0.50±1.31	0.14±0.86	1.39	NS	2.19	<0.05	0.94	NS
31.	VRP- sN	1.0±1.00	–0.10±0.30	0.50±2.38	4.33	<0.001	0.45	NS	0.98	NS
32.	VRP-Sn	1.0±2.83	0.85±2.39	0.57±1.65	0.12	NS	0.41	NS	0.40	NS
33.	VRP- sPog	5.80±2.77	2.83±1.78	3.36±3.03	3.24	<0.01	1.58	NS	0.76	NS

(p value < 0.05 – Significant; > 0.05– Non-Significant)

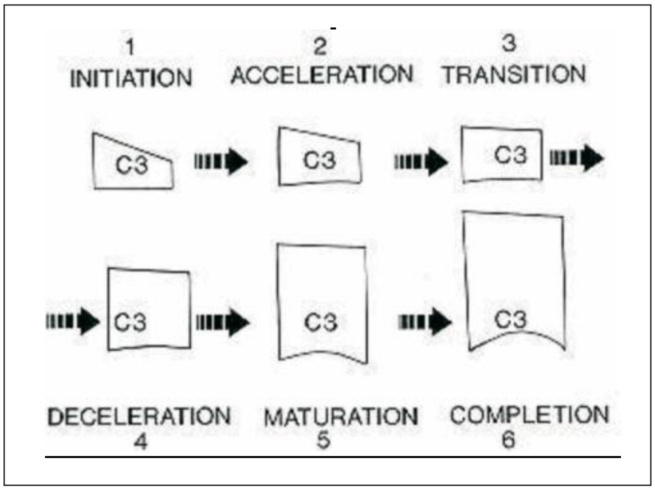

Figure 1. Cervical vertebrae maturation indicators using C3 as guide.

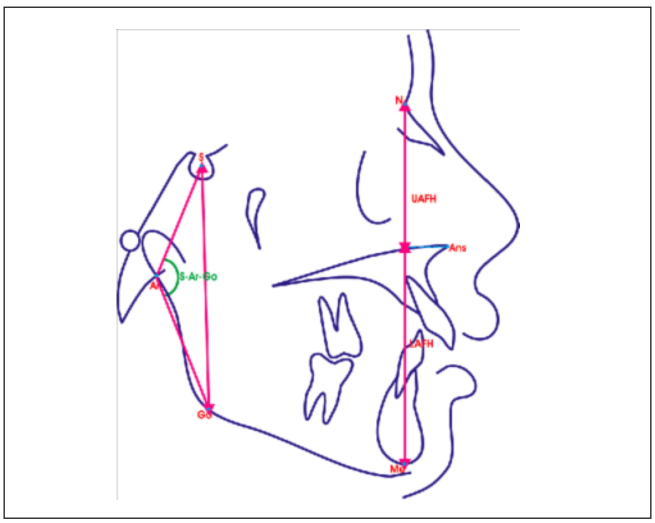

Figure 2. Facial Height Variables.

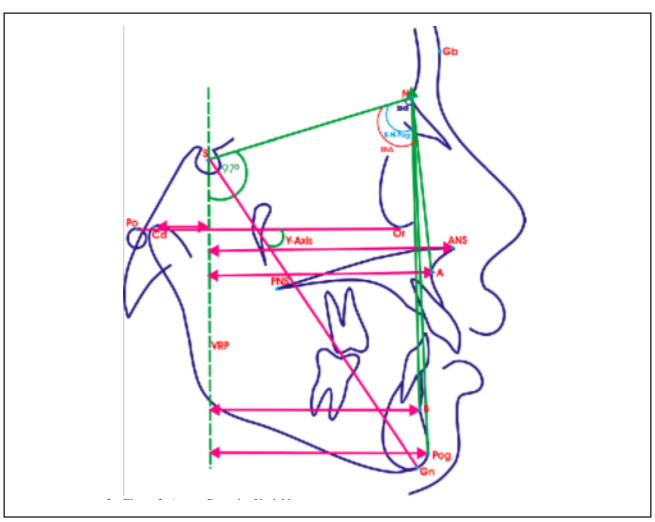

Figure 3. Antero-Posterior Variables.

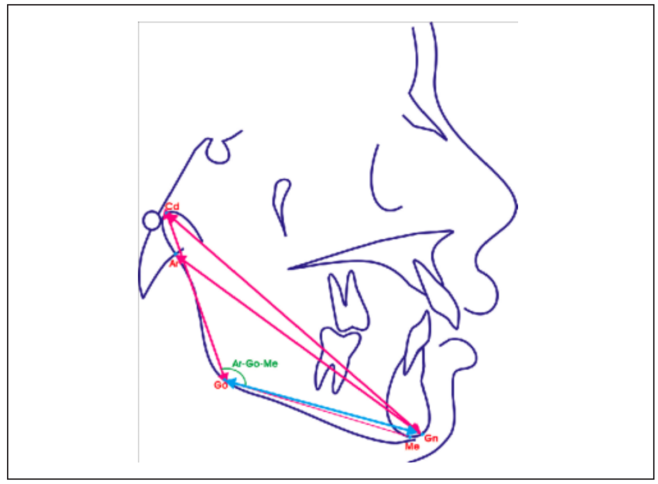

Figure 4. Mandibular Dimensions.

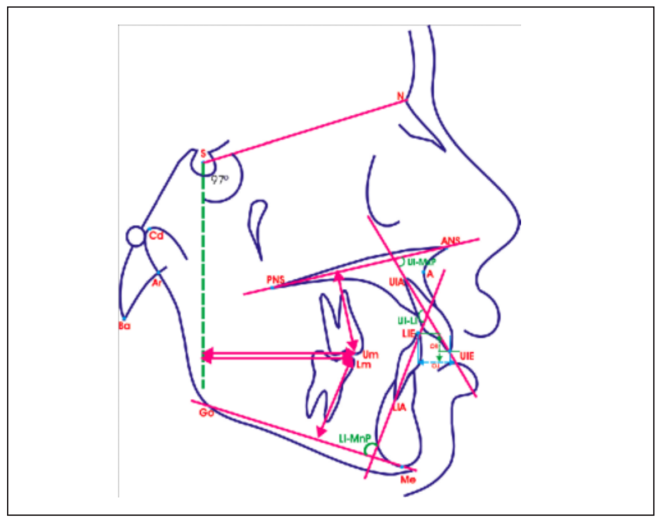

Figure 5. Dento-Alveolar Variables.

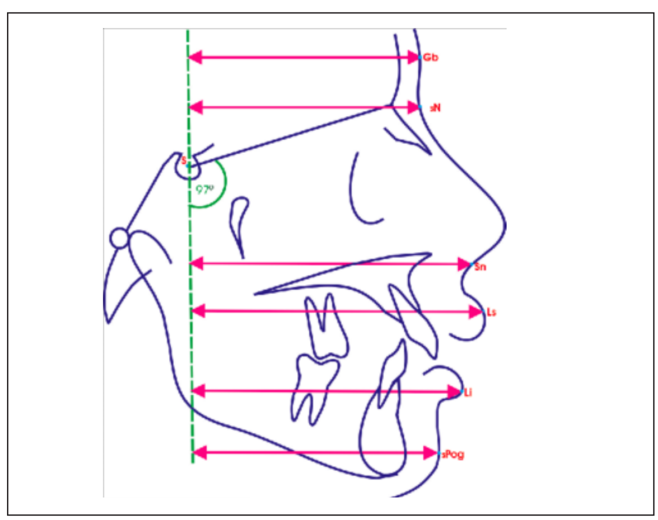

Figure 6. Soft-Tissue Variables.

Baccetti, Franchi and McNamara[7] evaluated skeletal and dento-alveolar changes induced by the Twin-block appliance in two groups of subjects, where Class II malocclusion was treated at different skeletal maturational stages, and found that optimal timing for Twin-block therapy is during or slightly after the onset of pubertal peak, a finding corresponding to our research. Similarly, a recent study by Fudaleja and Bollenb[23] says that boys in CVM stage 4 showed significant differences compared with girls in CVM stage 4 for only 2 variables (sella to gonion and condylion to gonion; $P < 0.001$ and $P = 0.012$, respectively) during the assessment of circumpubertal growth.

Antero-posterior variables

The reduction in *ANB* angle was significantly incompatible between the groups. This was due to a greater forward movement of the mandible in *Group II*, demonstrated by the significant increase in SNB, 6.71±1.27 degrees/year (p<0.001); VRP-B, 7.76±1.52 mm/year, (p<0.001); VRP-Pog, 8.82±1.60 mm/year, (p<0.001) and ÐS-N-Pog, 2.85±1.81 degrees/year (p<0.001). This finding is analogous to that of O'Reilly and Yanniello[30] who also found significant forward movement of mandible in the similar maturation stages of cervical vertebrae.

Baccetti *et al* [7] found that the amount of supplementary elongation of mandible in the late-treated group (4.75mm/year) was more than twice that of the early-treated group (1.88 mm/year). There was greater increase in total mandibular length (co-pg) associated with significant increases in the height of the mandibular ramus (co-go, 2.73 mm/year) and the length of the mandibular body (go-pg, 1.66 mm/year) in the group treated at the peak of puberty; a finding matching our research.

Mandibular Dimensions

The change in mandibular lengths (Cd-Gn), 8.77±1.54 mm/year; (Ar-Gn), 8.24±2.41 mm/year; and ramal height (Cd-Go), 6.78±1.14 mm/year were statistically significant (p<0.001) in the Group II. This has been observed earlier in a study done by McNamara *et al*.[33] who reported a supplementary bi-annualized increment in mandibular length *(Co-Gn)* of 3.6mm and in ramus height *(Co-G0)* of 3.1mm in patients treated in the late mixed and early permanent dentitions stage.

Also, O'Reilly and Yanniello[30] observed statistically significant increase in mandibular and corpus lengths in specific maturation stages of cervical vertebrae.

Baccetti *et al*[7] found that the chin point at pogonion shows an advancement of about 2.5mm/year in the late treatment group.

Similarly, the study by Fudaleja and Bollenb[23] shows that boys and girls show similar i.e. greater changes in mandibular lengths, Condylion to Gnathion and Gonion to Gnathion in stages 3 and 4 of CVMI.

Dento-alveolar Variables

A significantly higher (p<0.001) reduction in the Overjet i.e 11.47±1.24 mm/year and Overbite 8.64±1.90 mm/year was achieved in Group II, possibly reflecting a greater forward movement of the mandible, similar to the results of Baccetti *et al* [7] who observed efficient reduction in the overjet (ranging from about 4.5 mm/year in an early-treated group and up to about 6 mm/year in a late-treated group) and a remarkable correction in the molar relation (about 4.8 mm/year in both groups).

A significant reduction (p<0.001) in the inclination of upper incisors, 15.21±1.82 degrees/year in Group II was observed as compared to other groups.

A noteworthy decrease in the upper incisor to maxillary plane angle (ÐUI-MxP) i.e., 15.21±1.82 degrees/year in Group II was also found in the study.

At the end of treatment, *LM-MnP* and *VRP-LM* increased suggesting the maximum effects of appliance during the peak of puberty. This agrees with the findings of Patel *et al*.[34]

Soft-tissue Variables

At the end of treatment the only two variables showing statistical significance (p<0.001) amongst the groups, with a higher change in Group II, were the linear measurements from vertical reference plane to Labrale-Inferioris (Li), 2.65±1.99 mm/year and soft tissue pogonion (sPog), 2.83±1.78 mm/year. This again confirms the forward movement of mandible.[34]

Singh and Clark,[35] in their finite element study described that Twin-block therapy may produce a rapid but stable change in facial appearance. In their study, the crests of the upper and lower lips invariably showed a decrease in local size; which approves the result achieved in our study.

Though the present study has provided conclusive evidence regarding the effects of Twin block appliance in growing patients, it is by no means complete. Further work to distinguish the effects of growth, genetics and metabolic influences over the outcome of functional appliance therapy would be required to develop an unbiased prognosis.

CONCLUSIONS

The findings of the present study on skeletal and dentoalveolar effects of Twin-block therapy strongly suggest that optimum timing for myofunctional therapy of Class II malocclusion is during or slightly after the pubertal growth spurt. From the point of view of occlusal development, this period correlates in most patients with the late mixed or early permanent dentition. The clinical consequence is that active treatment of skeletal disharmony with the myofunctional appliance can be followed almost immediately by a phase of fixed appliance therapy to refine occlusion and to give stability to the newly established intermaxillary relationship.

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