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Research Article

Prediction of Successful Treatment with Clark Twin Block

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Abstract

Introduction: Deficiency in size of the mandible requires functional appliances. To date, several functional appliances have been developed, however the factors which lead to its success in patients is still under scrutiny.

Materials and Methods: A retrospective cohort study using purposive sampling was conducted in the dental clinics. The records of patients were scanned from January 2002 to April 2013. Complete records of patients treated only with twin block therapy were included into the study. Patients with incomplete records or treated with appliances other than twin block were not taken into consideration. Data collected were analyzed using binary logistic regression analysis.

Results: The sample size consisted of 60 subjects, 24 males (12.46 ± 1.41 years) and 36 females (11.02 ± 1.10 years). Binary logistic regression analysis was done to examine the association between outcome and independent variable with p- value ≤ 0.2 in the univariate analysis. The independent variables were examined in the multivariate analysis and treatment duration (OR- 1.202, 95%CI- 1.07 - 1.34, p-value - 0.001) for mandibular length and corrected ANB (OR- 0.13, 95%CI- 0.02 - 0.74, p-value - 0.021) for ANB were independently associated.

Conclusions: Successful prediction for CTB can be done with increased treatment duration for compliant patients. No successful predictor for overjet could be identified.

Keywords*: Clarks Twin Block; Functional Appliances; Class II Malocclusion; Mandibular Deficiency*

Introduction

The Clarks Twin Block (CTB), introduced by Dr. William J. Clark [1] is a favored appliance for clinicians [2]. The appliance can be used in both fixed and removable form. Other advantages include its use with appliances such as high pull headgear or fixed appliances and improved patient compliance [1,3].

A variable response to increased mandibular length is obtained with the CTB. While Mills and Mc Culloch [4] found an annual increase of 5.6 mm during appliance use, Schaefer., *et al*. [5] found a 2 mm greater correction in corpus length in comparison to Herbst Jena., *et al*. [6] and Jena and Duggal [7] found CTB to be more effective than bionator and mandibular protraction appliances. Correction of molar relation and overjet was associated with greater skeletal contribution [7].

However, the question remains, which parameters can be used to successfully identify patients who will have a favorable response to the appliance.

Review conducted by Barton and Cook [8] on activators found that, growing compliant patients with deep overbites and 11 mm overjet may have more successful treatment responses to functional appliance therapy. Other predictors include horizontal growth pattern for bionator and acute condylion-gonion-menton angle at CS39 for functional jaw orthopedics [10,11]. Single prospective research by Caldwell and Cook [12] found overbite as successful predictor for CTB. Although prospective research is favored, the limitation of treatment duration may be insufficient for equal and favorable effects to occur [13].

The influence of growth on CTB was also assessed. Patients at peak pubertal growth spurt produced a better response, however, the total duration of appliance wear was not ascertained [14].

Although the correlation of chronologic age with development status is fair [15], recent studies have found a significant relationship between tooth calcification and maturation of cervical vertebrae [16,17]. Hence, this raises the question if dental age may also be used as a predictor for treatment success. Other than that, literature review showed that no study has used these parameters as a predictor for successful treatment.

Thus, the objective of our study is to determine pretreatment variables which may lead to successful treatment outcomes in CTB patients. Other than the cephalometric and clinical parameters (e.g. overjet and overbite), we also aim to include skeletal, dental and chronologic age along with treatment duration to determine if they may also predict successful treatment response.

Materials and Method

A retrospective cohort study was conducted on data which was obtained from records of patients treated at the dental clinics. An ethical clearance was not obtained due to study design. Records of all patients from the year January 2002 to June 2013 were analyzed. Growing patients of Pakistani origin between the ages of 9 - 14 years with complete orthodontic records who had been treated only by the CTB were considered. Patients with craniofacial disorders and facial asymmetries; complete skeletal growth; incomplete orthodontic records and, those treated by appliances other than CTB were excluded from the study. Thus, sample size was of 60 patients.

All patients were instructed to maximally protrude their mandible while recording the construction. Hence a one-step mandibular advancement was done. In the first week of the appliance delivery, all patients were instructed to wear their appliance full time, except during meal times and brushing. Activation of the appliance by expansion was done one week after delivery. All patients were instructed to quarter turn the expansion screw after every two days.

Pre and post functional appliance treatment lateral cephalograms were manually traced in a dark room on an illuminator by the principal investigator. Skeletal age was assessed on pretreatment cephalograms using the modified cervical vertebrae maturation method, as suggested by Bacetti [9]. Dental age was calculated on pretreatment orthopantomograms (OPG) using the Dmerijian's index [18] modified for Pakistani population [19].

Demographic data for chronologic age, gender, duration of treatment (in months) were recorded from the files. The duration of treatment was assessed from appliance delivery to discontinued wear. Pre and post treatment variables for assessment were; angles SNA [20], SNB [20], ANB [20], corrected ANB [21] [original ANB angle + 0.5 × (81.5^0- SNA angle) + 0.25×(32^0- SNMP angle)], mandibular plane angle (SNMP) [20] and, maxillomandibular plane angle (MMPA) [22] and lower anterior face height (LAFH) [22]. Corrected ANB was used to eliminate the effects of jaw rotation on the sagittal patterns of the mandible. Groups were formed based on sagittal relation for mild- moderate (5 - 8^0) and severe (> 9^0) as per angle ANB. Mandibular body length was assessed as the distance in millimeters between gonion and pogonion. Dental variables were; overjet and overbite in millimeters, and, upper and lower incisor inclinations (UISN, IMPA).

Data Analysis

Data was analyzed using SPSS version 19.0 (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.). Descriptive statistics were calculated for all variables including chronologic age, gender and duration of treatment. Pre and post treatment measurements were recorded except, post treatment readings for dental age. Increase in mandibular length of ≥ 4 mm was assessed by calculating the pre and post treatment difference in mandibular length. This was considered successful treatment for mandibular length. Angle ANB and overjet was considered successful when post treatment values were in the range of 2-40 and 0-2 mm, respectively. Treatment outcomes were categorized as 1 for success and 0 for failure. The values obtained in both the categories were incorporated into the binary logistic regression for analysis.

All independent variables were categorized except for treatment duration and dental and chronologic age. The association between the outcome and a continuous variable was assessed using Univariate Binary Logistic Regression Analysis. The independent categorical variable was assessed using Univariate Chi-square test (p-value ≤ 0.2). Multivariate analysis was used for evaluation of the most likely predictor between outcome and independent variable (p-value ≤ 0.05). Odds ratio and 95% confidence interval were also noted.

Results

Table 1 shows the mean ages and the gender distribution. For a sample size of 60 patients (Mean age- 11.44 ± 1.32 years), there were 24 males (Mean age-12.46 ± 1.41 years) and 36 females (Mean age- 11.02 ± 1.10 years).

	Males- 24	Females-36	P-value
Chronologic Age	12.06 ± 1.41	11.02 ± 1.10	0.004
Skeletal Age	3.08 ± 1.06	2.89 ± 0.88	0.462
Dental Age	11.12 ± 2.31	11.40 ± 1.31	0.599

Table 1: *Descriptive statistics for the sample size.*

Comparison of pre and post treatment mean values (Table 2) showed a statistically significant difference for all variables except angle SNA, SNMP, MMPA and LAFH. The highest mean reduction was obtained in overjet (-6.21 ± 4.15 mm, p-value ≤ 0.001) followed by UISN (-4.63 ± 13.67mm, p- value 0.011). The highest mean increase was obtained in mandibular length (3.43 ± 3.07 mm, p-value ≤ 0.001) followed by IMPA (2.83 ± 10.49°, p-value 0.041).

	Pre	Post	Difference	p-value
Age (years.months)	11.44 ± 1.32	12.39 ± 1.40	0.95 ± 0.66	0.000**
CVM	2.94 ± 0.88	4.19 ± 1.07	1.24 ± 0.47	0.000**
Sagittal Relationship	2.67 ± 0.85	1.18 ± 0.70	-1.48 ± 1.15	0.000**
SNA	81.54 ± 4.16	81.13 ± 3.81	-0.40 ± 5.17	0.544
SNB	74.58 ± 3.61	76.07 ± 3.64	1.48 ± 4.66	0.017*
ANB	6.99 ± 2.07	5.05 ± 1.89	-1.94 ± 3.00	0.000**
Corrected ANB	6.74 ± 2.03	5.03 ± 1.60	-1.70 ± 2.78	0.000**
Mandibular Length	69.47 ± 4.29	72.90 ± 5.24	3.43 ± 3.07	0.000**
SNMP	32.90 ± 5.23	32.92 ± 5.45	0.01 ± 7.50	0.986
MMPA	23.70 ± 5.60	23.60 ± 5.09	-0.10 ± 8.42	0.927
LAFH	55.98 ± 2.87	55.73 ± 2.50	-0.25 ± 3.79	0.606
Overjet	8.99 ± 2.57	2.77 ± 3.77	-6.21 ± 4.15	0.000**
Overbite	4.73 ± 1.86	1.38 ± 1.47	-3.34 ± 2.17	0.000**
IMPA	101.92 ± 7.56	104.75 ± 7.59	2.83 ± 10.49	0.041*
UISN	110.27 ± 9.544	105.63 ± 9.77	-4.63 ± 13.67	0.011*

Table 2: *Pre and Post Mean for the Sample Size.*
P ≤ 0.05; P ≤ 0.001**; N = 60*
Paired Sample T-test

Prediction of continuous variables for successful treatment outcomes (Table 3) shows treatment duration (OR- 1.18, 95% CI- 1.07 - 1.31, p-value- 0.001) for mandibular length and chronologic age (OR- 0.65, 95% CI- 0.39 - 1.07, p-value 0.091) for ANB as statistically significant predictors. The odds for success are slightly higher with increased treatment duration (Mean ± SD-15.42 ± 8.25 months). The mean chronologic age for ANB is 10.90 ± 1.29 years. The odds of success are lower for younger age groups.

Mandibular length						
Variable	**Groups**	**Total (N = 60)**	**n (%Success)**	**Mean ± SD**	**Crude OR (95%CI)**	**p-value**
Dental Age	Success	60	24 (40)	11.07 ± 1.64	0.89 (0.66 - 1.20)	0.454
	Failure		36 (60)	11.43 ± 1.85	1.00	
Chronologic Age	Success	60	24 (40)	11.57 ± 1.55	1.14 (0.76 - 1.69)	0.516
	Failure		36(60)	11.35 ± 1.16	1.00	
Treatment Duration	Success	60	24 (40)	15.42 ± 8.25	1.18 (1.07 - 1.31)	0.001**
	Failure		36 (60)	8.61 ± 4.56	1.00	
Overjet						
Variable	**Groups**	**Total (N = 60)**	**n (% Success)**	**Mean ± SD**	**Crude OR (95%CI)**	**p-value**
Dental Age	Success	60	47 (78.3)	11.21 ± 1.92	0.873 (0.58 - 1.29)	0.504
	Failure		13(21.7)	11.57 ± 1.03	1.00	
Chronologic Age	Success	60	47 (78.3)	11.46 ± 1.42	1.05 (0.66 - 1.68)	0.823
	Failure		13 (21.7)	11.36 ± 0.94	1.00	
Treatment Duration	Success	60	47 (78.3)	10.91 ± 7.71	0.96 (0.88 - 1.04)	0.386
	Failure		13 (21.7)	12.85 ± 3.99	1.00	
Angle ANB						
Variable	**Groups**	**Total (N = 60)**	**n (%Success)**	**Mean ± SD**	**Crude OR (95%CI)**	**p-value**
Dental Age	Success	60	14 (23.3)	10.90 ± 1.44	0.85 (0.62 - 1.18)	0.354
	Failure		46 (76.7)	11.40 ± 1.85	1.00	
Chronologic Age	Success	60	14 (23.3)	10.90 ± 1.29	0.65 (0.39 - 1.07)	0.091*
	Failure		46 (76.7)	11.60 ± 1.31	1.00	
Treatment Duration	Success	60	14 (23.3)	12.29 ± 9.31	1.02 (0.94 - 1.11)	0.564
	Failure		46 (76.7)	11.04 ± 6.36	1.00	

Table 3: *Prediction of continuous variables associated with successful treatment outcomep- value ≤ 0.2 **
*p- value ≤ 0.05**; p- value ≤ 0.001***; N – 60*
Univariate Binary Logistic Regression Analysis

Table 4 shows the analysis for the categorical variables. Statistically significant values were obtained for mandibular length in sagittal relation (OR- 0.46, 95% CI- 0.15 - 1.37, p-value- 0.165), SNB (OR- 3.29, 95% CI- 0.8 - 12.86, p-value- 0.086), and ANB (OR- 0.46, 95% CI- 0.15 - 1.45, p-value- 0.189).

Variable	Groups	Mandibular Length				Overjet				Angle ANB			
		Total N = 60	n (% Success)	Crude OR (95% CI)	p - value	Total (N=60)	n (% Success)	Crude OR (95%CI)	p-value	Total (N=60)	n (%Success)	Crude OR (95% CI)	p-value
Gender	Male	24	11 (45.8)	1.49 (0.52-4.28)	0.452	24	21 (87.5)	2.69 (0.65-11.05)	0.159*	24	6(25)	1.16 (0.34-3.92)	0.803
	Female	36	13(36.1)	1.00		36	26 (72.2)	1.00		36	8(22.2)	1.00	
CVM	Optimal	20	6(30)	0.52 (0.16-1.64)	0.267	20	14 (70)	0.49 (0.14-1.74)	0.268	20	4(20)	0.75 (0.20-2.77)	0.666
	Under/over developed	40	18(45)	1.00		40	33 (82.5)	1.00		40	10(25)	1.00	
Sagittal Relation	Normal-Mild	42	15 (35.7)	0.46 (0.15-1.37)	0.165*	24	20 (83.3)	1.66 (0.44-6.19)	0.443	24	6(25)	1.16 (0.34-3.92)	0.803
	Moderate-severe	18	9(50)	1.00		36	27 (75)	1.00		36	8(22.2)	1.00	
SNA	Normal-Mild	42	15 (35.7)	1.8 (0.58-5.51)	0.301	42	36 (85.7)	3.81 (1.05-13.76)	0.034**	42	8(19)	0.47 (0.13-1.63)	0.231
	Moderate-Severe	18	9(50)	1.00		18	11 (61.1)	1.00		18	6(33.3)	1.00	
SNB	Normal- Mild	11	7(63.6)	3.29 (0.84-12.86)	0.086*	11	7 (63.6)	0.39 (0.09-1.63)	0.190*	11	4(36.4)	2.22 (0.54-9.14)	0.258
	Moderate-Severe	49	17 (34.7)	1.00		49	40 (81.6)	1.00		49	10 (20.4)	1.00	
ANB	Normal- Mild	21	6(28.6)	0.46 (0.15-1.45)	0.189*	21	17 (81)	1.27 (0.34-4.77)	0.718	-	-	-	-
	Moderate-Severe	39	18 (46.2)	1.00		39	30 (76.9)	1.00		-	-	-	
ANB corrected	Normal- Mild	23	8(34.8)	0.70 (0.23-2.05)	0.516	23	17 (73.9)	0.66 (0.19-2.29)	0.512	23	10 (43.5)	6.34 (1.68-23.88)	0.004**
	Moderate-Severe	37	16 (43.2)	1.00		37	30 (81.1)	1.00		37	4(10.8)	1.00	
SNMP	Normal	31	13 (41.9)	1.18 (0.42-3.32)	0.752	31	22 (71)	0.39 (0.10-1.44)	0.152*	31	4(12.9)	0.28 (0.07-1.03)	0.048**
	Low/High	29	11 (37.9)	1.00		29	25 (86.2)	1.00		29	10 (34.5)	1.00	
MMPA	Normal	29	13 (44.8)	1.47 (0.52-4.17)	0.461	29	19 (65.5)	0.2 (0.04-0.83)	0.028**	29	4(20.4)	0.33 (0.09-1.22)	0.099*
	Low/High	31	11 (35.4)	1.00		31	28 (90.3)	1.00		31	10 (32.25)	1.00	
Mandibular Length	Fail	-	-	-	-	36	28 (77.8)	0.92 (0.26-3.24)	0.898	36	8 (22.2)	0.85 (0.25-2.88)	0.803
	Success	-	-	-		24	19 (79.2)	1.00		24	6 (25)	1.00	
Overjet	Normal- Mild	7	2(28.6)	0.56 (0.10-3.17)	0.516	-	-	-	-	7	2 (28.6)	1.36 (0.23-7.95)	0.727
	Moderate-Severe	53	22 (41.5)	1.00		-	-	-		53	12 (22.6)	1.00	
Overbite	Normal- Mild	36	14 (38.9)	0.89 (0.31-2.55)	0.830	36	29 (80.6)	1.38 (0.40-4.76)	0.609	36	9 (25)	1.26 (0.36-4.38)	0.709
	Moderate-Severe	24	10 (41.7)	1.00		24	18 (75)	1.00		24	5 (20.8)	1.00	
LAFH	Normal	44	17 (38.6)	1.23 (0.38-3.93)	0.721	44	34 (77.2)	1.27 (0.30-5.37)	0.741	44	9(20.4)	1.76 (0.48-6.39)	0.385
	Low/High	16	7(43.7)	1.00		16	13 (81.25)	1.00		16	5 (31.25)	1.00	
IMPA	Normal	9	5(55.5)	0.47 (0.11-1.98)	0.308	9	6 (66.6)	2.05 (0.43-9.64)	0.364	9	1 (11.1)	2.73 (0.31-24.02)	0.364
	Retrocline/Procline	51	17(37.7)	1		51	41 (80.4)	1.00		51	13 (25.5)	1.00	
UISN	Normal	15	7(46.6)	0.69 (0.21-2.25)	0.544	15	13 (86.6)	0.47 (0.09-2.44)	0.373	15	1 (6.6)	5.68 (0.67-47.79)	0.109*
	Retrocline/Procline	45	17(37.7)	1.00		45	34 (75.5)	1.00		45	13 (28.8)	1.00	

Table 4: *Prediction of categorized variables for successful treatment outcome p- value ≤ 0.2*
*p- value ≤ 0.05**; p- value ≤ 0.001***; N – 60*
Univariate Chi-square test

The analysis for overjet (Table 5) showed a statistically significant values for gender dimorphism (OR- 2.69, 95%CI- 0.65 - 11.05, p-value 0.159), angle SNA (OR- 3.81, 95%CI- 1.05 - 13.76, p- value 0.034), angle SNB (OR- 0.39, 95 %CI- 0.09 - 1.63, p-value 0.190), SNMP (OR- 0.39, 95% CI- 0.10 - 1.44, p-value 0.152), and, MMPA (OR- 0.20, 95% CI- 0.04 - 0.83, p-value- 0.028). Males are 2 times more responsive to treatment than females for overjet reduction. The odds of success for normal to mild SNA and moderate to severe SNB are higher. The odds of success are higher for a high or low MMPA and SNMP.

The analysis for angle ANB (Table 5) shows statistically significant values for corrected ANB (OR- 6.34, 95% CI-1.68 - 23.88, p-value 0.004), SNMP (OR- 0.28, 95%CI- 0.07 - 1.0, p-value 0.048), MMPA (OR- 0.33, 95%CI- 0.09 - 1.22, p-value- 0.099), and, UISN (OR- 5.68, 95% CI- 0.67 - 47.79, p-value- 0.109). Normal to mild values of corrected ANB and normal upper incisor inclination have higher odds for success. Similarly, the odds of success are also increased for high or low angle SNMP and MMPA.

	B	S.E.	Wald	df	p-value	Odds Ratio	95% Confidence Interval
Mandibular Length							
Treatment Duration	0.184	0.057	10.518	1	0.001**	1.202	1.07- 1.34
Sagittal Relation	1.934	1.472	1.726	1	0.189	6.920	0.38-123.93
SNB	0.690	0.685	1.017	1	0.313	1.994	0.52-7.63
ANB	-1.049	1.537	0.466	1	0.495	.350	0.01-7.12
Overjet							
Gender	-0.942	0.785	1.442	1	0.230	0.39	0.08- 1.81
SNA	-1.257	0.806	2.431	1	0.119	0.28	0.05- 1.38
SNB	0.225	0.948	0.056	1	0.812	1.25	0.19- 8.02
SNMP	0.586	0.827	0.501	1	0.479	1.79	0.35- 9.09
MMPA	1.076	0.838	1.646	1	0.199	2.93	0.56- 15.16
ANB							
Chronologic Age	-0.136	0.329	0.170	1	0.680	0.87	0.45- 1.66
ANB corrected	-1.977	0.857	5.329	1	0.021*	0.13	0.02-0.74
UISN	1.917	1.098	3.050	1	0.081	6.80	0.79-58.47
SNMP	0.322	0.918	0.123	1	0.726	1.38	0.22- 8.33
MMPA	1.523	1.021	2.224	1	0.136	4.58	0.62- 33.91

Table 5: *Multivariate Logistic Regression Analysis for factors associated with successful treatment outcome.*
p- value ≤ 0.05; p- value ≤ 0.001**; N – 60*
Multivariate logistic regression analysis

Further analysis was done for the most likely predictor of the three outcomes (Table 5) the model for mandibular length contained four independent variables. The full model containing all predictors was statistically significant, χ^2 (2, N = 60) = 17.518 ($p \leq 0.001$) indicating that the model was able to identify the predictors successfully. The model as a whole explained between 25.3% (Cox and Snell R square) and 34.2% (Nagelkerke R Square) of the variance in predictors and correctly classified 76.7% of cases. As shown in the table, only treatment duration made a unique statistically significant contribution to the model and it was highly statistically significant (p-value- 0.001) with an odds ratio of 1.20 recorded (95% CI- 1.07- 1.34).

The model for overjet (Table 5) contained five independent variables. The full model containing all predictors was statistically insignificant χ^2 (4, N = 60) = 56.44 (p- 0.115) indicating that the model was unable to identify any successful predictor. The model as a whole explained between 9% (Cox and Snell R square) and 13.8% (Nagelkerke R Square) of the variance in prediction and correctly classified 78.3% of the cases. As shown in the table, none of independent variables were able to successfully predict the overjet.

The model for ANB (Table 5) contained five independent variables. The full model containing all predictors was statistically significant χ^2 (2, N = 60) = 73.71 (p- 0.025) indicating that the model was able to identify the predictors successfully. The model as whole explained between 11.6% (Cox and Snell R square) and 17.4% (Nagelkerke R Square) of the variance in prediction and correctly classified 76.7% of the cases. As shown in the table, only normal to mild forms of corrected ANB made a unique statistically significant contribution to the model and it was statistically significant (p-value- 0.021) with an odds ratio of 0.13 recorded (95% CI- 0.02 - 0.74).

Discussion

The present study is a retrospective cohort study because our study took treatment duration into consideration. Hence, a retrospective design was preferred. All treated patients (successfully and otherwise) were included into the research after fulfilling the inclusion criteria.

Mills and McCulloch [4,23] in two separate studies found that the mandibular body length increased 3.0 ± 1.7 mm and 4.2 mm, respectively. Similarly, Jena., *et al*. [6] found a mean increase of 5.02 ± 1.78 mm (95% CI 4.66 - 6.14 mm) of mandibular body length at CVMI3 [24]. Considering these findings, our study took an increase of 4 mm and above in mandibular body length as a measure of successful treatment outcome. Comparison of pre and post treatment mean showed the highest reduction for sagittal correction for ANB (Δ -1.94 ± 3.00, p-value ≤ 0.000) cephalometrically and clinically for overjet (Δ -6.21 ± 4.15, p-value ≤ 0.000). Hence, these were also taken as success parameters. As no statistically significant change was obtained for vertical parameter in our sample size, it could not be taken as measure of successful outcome.

Mandibular length: Evaluation of predictors for mandibular length did not show cervical vertebrae maturation as a predictor for treatment success. Literature states that peak mandibular growth occurs in pubertal growth spurt [15]. Although Baccetti., *et al*. [14] found greater skeletal effects with CTB at optimum CVM [25], previous studies [26-31] state that the mandible does not grow at a constant rate through the adolescent period and individual variation does occur. Hence, CVM is not a likely predictor for successful treatment outcome and patients can be treated at CS 2 and 4 as well.

Increased treatment duration has marginally higher odds for success (Mean ± SD-15.42 ± 8.25 months). Although this is an important finding, the compliance of patients in such situations was not assessed. We recommend that compliant patients with longer treatment durations become better candidates for successful treatment. A retention phase in which eruption of posterior teeth through incremental reduction of bite blocks is recommended [32]. Normal to mild forms of SNB are three times more likely to succeed than moderate to severe SNB. This group had less participants and they had mostly responded well. Caldwell and Cook [12] also found low values of SNB to produce a better treatment response. This is due to favorable muscle stretch with small SNB [12]. Unfavorable stretching of the muscles can deprogram them and the jaw assumes a new posture. As the muscles are not activated, no active growth occurs. Thus, further analysis did not show SNB as the most likely predictor for success for mandibular length.

Moderate to severe forms of sagittal relation and ANB are two times more likely to succeed than normal to mild forms and this was statistically significant. The cause for increased severity was not ascertained whether it was reduced mandibular length with normal maxilla or vice versa. Hence, further analysis did not show them as likely predictors for successful increase in mandibular length.

Vertical dimensions had no influence on improvement in mandibular length, despite marginally higher odds, they were statistically insignificant. Hence our findings support those by Lau., *et al* [33].

Overjet reduction: Analysis of the continuous variables did not obtain any predictor for success. Hence we concluded that they do not impact treatment success for CTB.

Among the categorized variables; gender, SNA, SNB, SNMP and MMPA were predictors for success. Males predominantly have a better treatment response than females. A probable cause for this response could not be isolated as they were neither younger in age nor at peak developmental age. Had males been in the optimum skeletal developmental age, an increase in mandibular length would also have been noted, which did not occur.

Normal to mild forms of SNA were three time more likely to succeed in overjet reduction than moderate to severe. Prognathic maxilla with retrognathic mandibles present as severe forms of Skeletal Class II profiles. Treatment of such conditions is difficult with functional jaw orthopedics alone and patients require orthognathic surgeries in the long term. Hence, the odds of success with CTB alone are reduced. Thus normal to mild SNA are more likely to succeed than moderate to severe forms.

Moderate to severe forms of SNB are more likely to succeed than milder forms. This is in stark contrast for increase in mandibular length where normal to mild forms are more likely to succeed. The mean pretreatment overjet was 8.99 ± 2.57 mm. No pre functional orthopedics was done to reduce the overjet. All patients were encouraged to bring their jaw forward using their musculature strength and flexibility. Increase in overjet increased the range of forward mandibular protrusion. Thus moderate to severe forms had higher odds of success. However, keeping in consideration the results of mandibular length, we conclude that the SNB reduced due to the new position acquired by the mandible and not skeletal growth.

Low/high values of SNMP and MMPA are also predictors of success with MMPA (p-value- 0.028, 95%CI- 0.04 - 0.83) being more statistically significant than SNMP (p-value- 0.152, 95%CI- 0.10 - 1.44). This is a notable finding. Caldwell and Cook12 did not find any relation between vertical facial dimension and overjet reduction. Pancherz [34] did not obtain any relation between size of MMPA and treatment outcome either. However, he did state that direction of growth rotation does influence stability and that forward growth produces more stable results than backward growth rotation. The CTB can be used effectively in high angle patients as its bite blocks cause intrusion of the posterior dentoalveolar segments and mandibular autorotation occurs [15,32]. Although marked differences in vertical relationships have been noted [3,4,23], Lau., *et al*. [33] did not find occurrence of mandibular rotations with CTB. Our study did not take into consideration whether which growth pattern predominantly contributed to success. Nonetheless, keeping in consideration the effect of CTB on vertical relations, we concluded that it worked effectively for all patients.

Although further analysis did not show any likely predictor for CTB, we conclude that MMPA does present as a likely predictor for overjet reduction.

ANB: Variables associated with success for ANB showed that younger patients (Mean ± SD- 10.90 + 1.29 years) are more likely to give a better treatment response than older patients (Mean ± SD- 11.60 + 1.31 years). The multivariate analysis showed that chronologic age is not a reliable predictor for success. This is attributed to the weak correlation of chronologic age with skeletal age [15].

The odds of success are higher for high/low angle SNMP and MMPA. This is significant. Franchi and Baccetti [11] found horizontal growth patterns at CS3 of the mandible as predictors of success for CTB. Patel., *et al*. [35] also favored low angle patients as successful candidates for functional appliance therapy. Kumar., *et al*. [36], in their research also using ANB as a predictor for all functional appliances found low mandibular plane angle, low basal plane angle and high Jarabak ratio as predictors of success. Preliminary analysis showed them as statistically significant. Hence, we also recommend that they can be considered as predictors for success.

Normal to mild forms of corrected ANB are 6 times more likely to succeed than moderate to severe forms. This is an important finding. Corrected ANB was incorporated to nullify the effects of jaw rotations on sagittal growth patterns. Although there is a minor difference in values of ANB and corrected ANB (Table 2), we still recommend that patients with vertical discrepancies should be further evaluated for the correct sagittal patterns. High angle patients present with reduced ANB while low angle patients have increased ANB values. These disparities occur due to jaw rotations which may either reduce or aggravate the severity of the presenting complaint. Elimination of vertical disparities shows a true picture of sagittal relations. Hence, a better selection of patients by clinicians can be anticipated. Further analysis of this variable showed it to be a better predictor for ANB.

Although normal incisor inclinations have higher odds of success, they eventually became statistically insignificant. Skeletal points A and B change their positions with tooth movements [37]. CTB causes proclination of lower anterior teeth and retroclination of upper anterior teeth. Points A and B alter to a new position. The overall effect is insignificant. Thus, upper incisor inclination was not a likely predictor of success.

Dental Age: Our study took dental age into consideration. However, its influence was not noted in any of the treatment outcomes. This is a significant finding. Several studies have moderately correlated dental age with skeletal maturity [38,39]. Basaran., *et al*. [40] found dental age as a reliable indicator of facial growth. Our research found reduced odds of success in younger age groups for prediction of increased mandibular length and subsequently reduced overjet and ANB. The odds of failure were comparatively higher in older age groups. This is in concordance with Sukhia and Fida [41] and Surendran and Thomas [42]. They did not find dental age effective in the assessment of skeletal maturity. Hence, dental age could not be established as an effective predictor of successful treatment outcome.

Gender Predilection: An overall better treatment response was noted for males than females in all outcomes groups despite their increased chronologic age. The CVM stages was not ascertained. A better treatment response can be attributed to delay in growth spurt with a longer duration. Hence, higher odds of successful treatment were obtained.

Limitations

The present study despite its limitations, recommends prospective research with inclusion of multiple centers with large sample sizes. Furthermore, patients who have completed their fixed appliance phase should be incorporated in such research. This will allow evaluation of variables which will be better predictors of long term stability.

Conclusions

Removable appliances require patient compliance for effective treatment. Thus compliant patients with longer treatment duration can be expected to produce a favorable response. Such a response cannot be anticipated in non compliant patients and extended treatment durations can become cumbersome for the patient and the doctor. Although normal to mild forms of corrected ANB were found to be a better predictor of treatment success for ANB, it is not clinically significant as there was a mild difference in mean values.

Conflicts of Interest

None to declare.

Author's Contribution

The contribution of all authors has been as follows:

1) Dr. Tania Arshad Siddiqui- Data collection and manuscript write up
2) Dr. Attiya Shaikh- Data proforma preparation and manuscript write up
3) Dr. Mubassar Fida- Editing and reviewing of manuscript
4) Dr. Khabir Ahmed- Statistical analysis

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