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An investigation of cephalometric and morphological predictors of successful Twin Block therapy

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Objective: To identify predictors of overjet reduction, changes in mandibular length (Co-Me) and antero-posterior changes in mandibular position (Pog-Vert) during Twin Block therapy.
Methods: Pre- and post-treatment cephalograms of 131 participants were analysed (Mean age 12.73 years ± 1) following Twin Block therapy.
Results: Mean annualised overjet reduction was 7.29 mm (± 2.99) with chin projection improving by 2.66 mm (± 5.37). The magnitude of the initial overjet was a strong predictor (95% CI: 0.30, 0.77, $p < 0.01$) of overjet reduction and change in chin position (95% CI: 0.08, 0.77, $p = 0.02$). Greater forward movement of Pogonion occurred if there was greater retrusion of Pogonion at the outset (95% CI: 0.15, 0.45, $p < 0.01$). No prognostic relationship was noted for other potential cephalometric predictors including pretreatment mandibular lower border morphology and Co-Go-Me angle.
Conclusion: No relationship between mandibular morphology, vertical skeletal pattern and favourable dentoalveolar and skeletal responses to Twin Block therapy could be found. These results require confirmation on an external sample.
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Introduction

Functional appliance therapy has successfully been used to address Class II malocclusions for almost a century. Nevertheless, considerable debate and comment has surrounded the impact of functional appliances on underlying skeletal deformity.[1] On the basis of well-designed prospective studies, it is reasonable to conclude that prolonged skeletal impact of functional appliance therapy is limited.[2-4]

Nevertheless, growth modification is instrumental in achieving successful overjet reduction in the short-term in subjects treated in early adolescence. In particular, 27% of overjet reduction has been attributed to skeletal changes including maxillary restraint and acceleration of mandibular growth.[5]

Factors contributing to the hard and soft tissue response to various functional appliances have previously been assessed. Baccetti et al.[6] have suggested that mandibular shape, specifically Co-Go-Me angulation, was predictive of both hard and soft tissue responses to headgear and Herbst appliance therapy.[6] In addition, skeletal dimensions including overall mandibular length, ramus height, ratio of posterior to anterior facial height, cranial base length and occlusal predictors, chiefly overbite depth, have variously been linked to successful therapy.[7,8]

The aim of the current research was to identify skeletal and occlusal predictors of favourable dental and skeletal response to Twin Block functional appliance therapy.

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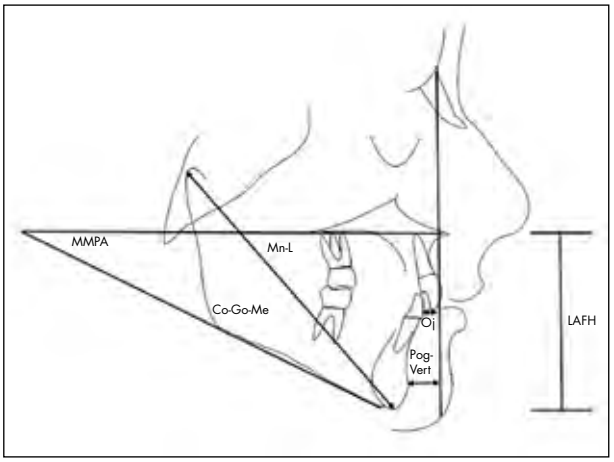

Figure 1. Cephalometric measurements obtained. Mandibular length (Co-Me), lower anterior facial height (LAFH), Co-Go-Me angle, Maxillo-mandibular plane angle (MMPA), antero-posterior projection of chin point relative to the facial vertical though Nasion perpendicular to Frankfort plane (Pog-Vert)

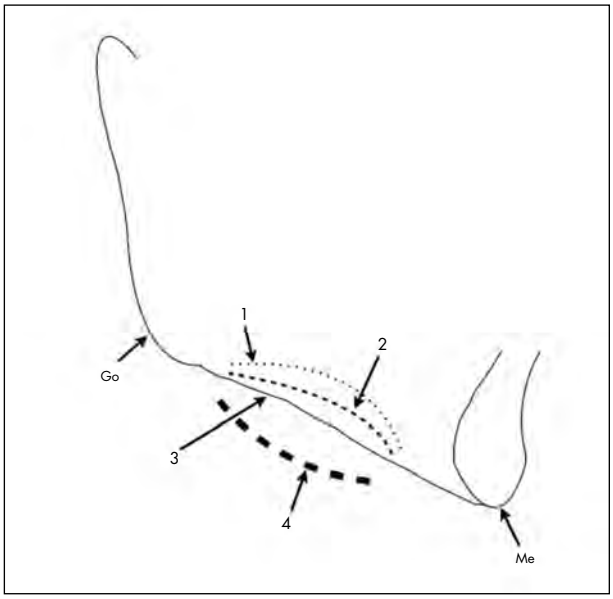

Figure 2. Assessment of lower mandibular border morphology. 1, Deeply convex superiorly; 2, Convex superiorly; 3, Straight; 4, Concave superiorly

Materials and methods

This retrospective cohort study was carried out in the Orthodontic Departments at The Royal London Dental Institute and East Kent Hospitals, UK between 2006 and 2010. Institutional approval for the project was obtained from East Kent Hospitals Research and Development Department. Based on previous research, a total of 123 patients was required to demonstrate a clinically meaningful difference of 1 mm in annualised mandibular length change with treatment (Mean = 5.1 mm, SD = 3.7 mm[6]) with a statistical power of 85% and alpha of 0.05.

Subjects included in the study were obtained from departmental clinical databases. The inclusion criteria were as follows: (1) patients aged between 10 and 14 years, (2) a skeletal II discrepancy (ANB > 4°), (3) an overjet in excess of 7 mm, (4) a pretreatment lateral cephalogram taken within 1 month of appliance placement and (5) an interval between repeated cephalograms not less than 9 months or in excess of 18 months. Subjects were excluded from the research if they had a cleft lip and/or palate or other craniofacial anomaly, or had undergone previous orthodontic treatment. A cohort of 131 subjects undergoing Twin Block therapy in the respective units was obtained from an initial sample of 198 patients after application of the selection criteria. The chief reasons for exclusion were incomplete or inappropriate records and inappropriate age.

Twin-block therapy was carried out by postdoctoral students under consultant supervision or directly by one of three consultants. Minor variations were likely in the general design; however, invariably, appliances involved clasping of all first premolars and first permanent molars with mandibular advancement to an edge-to-edge relationship from the outset. Participants were seen routinely at three-monthly intervals. Post-treatment cephalograms were taken following completion of the functional phase (T2) prior to commencement of fixed appliance therapy.

Data collection

Demographic characteristics including age and gender were obtained for each participant. Compiled cephalometric data included pretreatment skeletal characteristics describing mandibular length, lower anterior facial height, Co-Go-Me angle, maxillo-mandibular plane angle (MMPA) and antero-posterior projection of chin point relative to the facial vertical perpendicular to the Frankfort plane (Pog-Vert, Figure 1). Mandibular lower border morphology was also assessed by assigning a grade based on the degree of convexity or concavity (Figure 2). Pretreatment overjet and overbite were also recorded. On the post-treatment cephalogram, overjet, mandibular length, and the antero-posterior projection of chin point relative to

Table I. Demographic and pretreatment clinical characteristics (N =131).

Pretreatment clinical feature	Mean (SD)	N = (%)
Age (years)	12.73	100.00
Gender: Male	66.00	50.40
Gender: Female	65.00	49.60
Mandibular length (Co-Me, mm)	105.70	5.97
Overjet (mm)	9.94	1.81
Overbite (mm)	5.15	1.74
LAFH (mm)	56.13	6.56
MMPA (degrees)	25.19	4.83
Co-Go-Me (degrees)	124.60	5.43
Pog-Facial Vert (mm)	7.23	6.83
Lower border morphology (Grade: N =)	1 = 17	13.00
	2 = 75	57.00
	3 = 35	27.00
	4 = 4	3.00

Table II. Cephalometric variables (pre-, post- treatment and treatment-related changes)

Cephalometric variable	Pretreatment (T1)	Mean (SD)	Post-treatment (T2)	Mean (SD)	Annualised change (T1-T2)	Mean (SD)
Mandibular length (Co-Me, mm)	105.70	5.97	111.13	6.13	5.32	3.64
Overjet (mm)	9.94	1.81	2.69	2.50	7.29	2.99
Pog-Facial Vert (mm)	7.23	6.83	4.52	4.92	2.66	5.37

Table III. Uni- and multivariable linear regression assessing the effects of explanatory variables on overjet reduction.

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
Overjet	0.58	0.35, 0.81	<0.01	0.53	0.30, 0.77	<0.01
Overbite	0.31	0.06, 0.56	0.02	0.17	-0.08, 0.42	0.18
Gender	0.23	-0.67, 1.13	0.62	0.13	-0.98, 0.72	0.76
Start age	0.35	-0.10, 0.79	0.13	0.25	-0.17, 0.67	0.24

the facial vertical (Pog-Vert) were calculated. Changes in linear dimensions were annualised and adjusted for cephalometric magnification. Measurements were repeated on 10 cephalograms at a two-week interval to assess intra-examiner repeatability.

Statistical methods

Descriptive statistics were used to summarise the demographics of the sample and to assess annualised changes in linear dimensions and overall change in angular measurements with Twin Block therapy. Inferential statistics were used to isolate variables which may predict overjet reduction, increases in mandibular length and improvement in sagittal mandibular projection (Pog-Vert). Observation of data curves confirmed that the data for overjet and sagittal mandibular projection were normally distributed, whereas data for mandibular length were appropriately transformed to follow a normal distribution, and a linear regression analysis was performed. A general linear model (GLM) was used allowing transformed data to be presented in the original scale. Possible predictors included: pretreatment mandibular length, lower anterior facial height, Co-Go-Me angle, maxillo-mandibular plane angle (MMPA), antero-posterior projection of chin point relative to the facial vertical (Pog-Vert), lower border morphology and overjet and overbite. The dependent variables were mandibular length, Pog-Vert and overjet. Variables found to be significant predictors ($p < 0.10$) were included in the multivariable model. Both bivariate assessment and backward elimination excluded the same variables at the 10% level of significance. Starting age and gender were included in the model as they were considered to be important outcome predictors *a priori*. Pretreatment values for outcome measures were also accounted for in the statistical model when correlation between T1 and T2 values exceeded r = *0.5*.

Acceptable levels of intra-observer agreement of continuous cephalometric measurements were demonstrated using Lin's concordance correlation coefficient (r = 0.89 - 0.98).[9] Similarly, excellent agreement between categorical measurement of lower border morphology was confirmed using a weighted kappa statistic (k = 0.83). Analyses were performed with the STATA® version 12.0 software (Stata Corporation, College Station, TX, USA) with a two-tailed p value of 0.05 considered statistically significant.

Results

From an initial sample of 198 participants, full data could be obtained on a total of 131 patients who satisfied the inclusion criteria. This cohort comprised 66 males (50.4%) and 65 females (49.6%), with an average age of 12.73 (± 1.00 years). All participants had a Class II division 1 incisor relationship. Mean pretreatment clinical characteristics are provided in Table I. The mean duration of treatment was slightly in excess of 1 year (1.02 years, SD = 0.18). The mean pretreatment overjet was 9.94 mm (SD = 1.81). Lower border morphology was slightly convex superiorly (Grade 2) in the majority of subjects (57.3%). The appliance-related annualised overjet reduction was in excess of 7 mm (7.29 mm, SD = 2.99). Annualised change in mandibular length was 5.57 mm (SD = 3.79) contributing to considerable improvement in relative chin point projection (2.66 mm, SD = 5.37; Table II).

The univariate analysis showed the pretreatment overjet value was the only significant predictor ($p < 0.10$) of overjet reduction. In the adjusted model, the magnitude of the initial overjet remained a strong outcome predictor ($\beta = 0.23$, 95% CI: -0.10, 0.56, $p < 0.01$); the larger the initial overjet, the greater the expected reduction during treatment. However, the variance explained by the multivariate model was low (Adjusted $R^2 = 0.16$) indicating that overjet reduction was influenced by other unidentified factors (Table III, Figure 3).

In the adjusted model, initial mandibular length and gender were found to be strong predictors of a change in mandibular length during treatment. Males underwent 0.48 mm more increase in mandibular

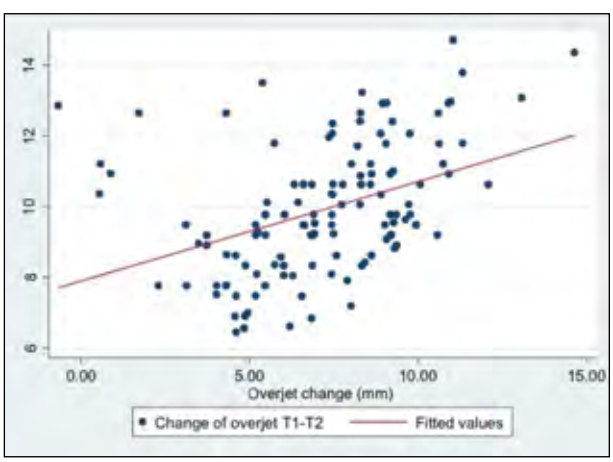

Figure 3. Plot of overjet reduction with increasing initial overjet.

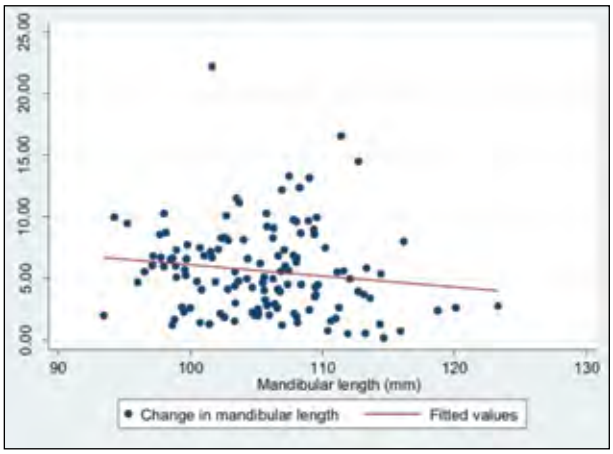

Figure 4. Inverse relationship between mandibular length change with treatment and increasing initial mandibular length.

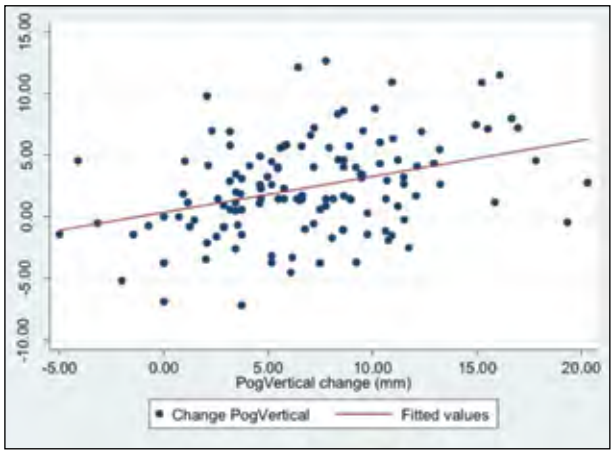

Figure 5. Greater sagittal mandibular projection occurs during treatment with greater initial mandibular retrusion.

Table IV. Uni- and multivariable linear regression analysis assessing the effects of explanatory variables on annualised change in mandibular length.

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
LAFH	-0.01	-0.03, 0.00	0.09	-0.01	-0.03, 0.00	0.11
Overjet	0.06	-0.01, 0.13	0.10	0.05	-0.02, 0.12	0.14
Gender	0.33	0.08, 0.59	0.01	0.48	0.21, 0.75	<0.01
Start age	-0.02	-0.16, 0.11	0.73	-0.04	-0.16, 0.09	0.55
Initial mandibular length	-0.02	-0.04, 0.00	0.12	-0.03	-0.05, -0.00	0.03

Table V. Uni- and multivariable linear regression analysis assessing the effect of explanatory variables on annualised change in sagittal mandibular position (Pog-Vert).

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
Co-Go-Me	0.18	0.01, 0.36	0.04	0.04	-0.11, 0.20	0.61
LAFH	0.13	-0.01, 0.28	0.07	0.03	-0.08, 0.15	0.55
Overjet	0.44	0.08, 0.80	0.02	0.42	0.08, 0.77	0.02
MMPA	0.20	0.01, 0.40	0.04	-0.09	-0.29, 0.12	0.39
Start Pog-Vert	0.29	0.16, 0.42	<0.01	0.30	0.15, 0.45	<0.01
Gender	1.46	-0.42, 3.34	0.13	0.43	-0.83, 1.69	0.50
Start age	-0.07	-1.02, 0.89	0.89	0.14	-0.49, 0.78	0.66

length than females (95% CI: 0.21, 0.75, $p < 0.01$) after adjusting for overjet and starting age. Changes in mandibular length reduced with increasing initial mandibular length (β = -0.03, 95% CI: -0.05, -0.00, $p = 0.03$). The variance explained by this multivariate model was also low (Adjusted R^2 = 0.09; Table IV, Figure 4).

Pretreatment Co-Go-Me angle, initial LAFH, overjet, MMPA and Pog-Vert values were all found to be significant predictors ($p < 0.10$) for Pog-Vert change during Twin Block therapy. However, in the adjusted model, only initial values for overjet and sagittal chin position (Pog-Vert) remained strong predictors. Greater forward projection of Pogonion was also noted with larger initial overjet values ($\beta = 0.42$, 95% CI: 0.08, 0.77, $p = 0.02$). The variance explained by this model was also low (Adjusted R^2 = 0.14; Table V, Figure 5).

Discussion

Various dento-alveolar and skeletal parameters may be used to assess the effectiveness of functional appliance therapy. The more common of these include overjet, mandibular length and a sagittal assessment of chin projection, such as Pog-Vert. In this retrospective study, the magnitude of overjet reduction during treatment was in excess of 7 mm. This figure is in keeping with prospective studies with O'Brien et al.[5] reporting a mean overjet reduction of 6.93 mm. Similarly, the mean increase in mandibular length was in excess of 5 mm; this compares favourably with both treated and untreated adolescent groups.[10] Given the retrospective nature of this study, the present study is likely to overstate the likely effectiveness of the appliance. Prospective studies, particularly randomised trials, are less susceptible to selection and performance bias, and other confounding issues. The advantage of randomisation is maintained throughout using an 'intention to treat' analysis. In the present study, unsuccessful cases were likely to have been omitted, as these individuals were less likely to have returned for follow-up radiographs. Consequently, the findings obtained may be considered a best-case scenario; the failure to identify significant predictors is therefore arguably more instructive.

Efforts were made to assess outcomes by relating the mandible to other structures (LAFH, MMPA, Pog-Vert) and by examining the mandible in isolation (Co-Go-Me, lower border morphology). While a previous study found a significant relationship between Co-Go-Me angulation and response to functional appliance therapy,[6] this relationship was not corroborated in the present study. The previous study was prospective in design and involved a phase of functional appliance therapy followed by refinement with fixed appliances; the present study investigated the duration of functional appliance therapy in isolation, with a shorter follow-up period. While it has been suggested that the Co-Go-Me angle may give an indication of mandibular morphology,[6] it is composed of only 3 points, and further elaboration of mandibular morphology would be of benefit. The present study therefore was the first to attempt to predict a response to functional appliance therapy on a purely morphological basis.

A grading system for lower border morphology was devised to permit more detailed analysis of the influence of mandibular shape in isolation on successful appliance therapy. The system devised was reproducible but failed to demonstrate a causal relationship. This outcome may reflect the absence of a clear relationship between a vertical growth pattern and the results of functional appliance therapy. Confirmation of a possible association may, however, have been hampered by the preponderance of subjects with straight or mildly convex lower border morphology. Additionally, morphological assessment was confined to a two-dimensional radiographic assessment. In the future, the application of three-dimensional imaging modalities including Cone-Beam Computed Tomography may permit more detailed morphological and volumetric assessment of the mandible[11,12] and therefore the outcome of growth modification treatment.

No relationship was demonstrated with respect to vertical dimensions and treatment outcome with appliance therapy in the present study. While this outcome may be slightly surprising, it is in keeping with previous prospective[6,8] and retrospective[7,13] research. The mean MMPA of participants was slightly reduced (25.2°) reflecting operator preferences and convictions. Significant vertical excess is likely to have been managed without recourse to the Twin Block in many cases due to concerns of increasing the vertical dimension further. Consequently, significant vertical discrepancy is likely to have been absent in this sample, making identification of significant relationships less likely. An assessment of the influence of a vertical discrepancy on the outcome of Twin Block therapy would therefore necessitate prospective follow-up, irrespective of the vertical skeletal pattern.

In the present study, overjet reduction and changes in mandibular projection were positively correlated with the extent of the initial discrepancy. Moreover, forward movement of the chin during Twin Block therapy was also found to be predicated on the initial overjet. Findings of this nature are common in orthodontic research; for example, the magnitude of transverse expansion has been shown to be related to the initial transverse dimension.[14] In this retrospective study, the final desired outcome was likely to be the elimination of the initial overjet during the functional appliance phase. Consequently, overjet reduction merely reflects the success of this treatment. However, given that the primary objective of treatment was typically overjet reduction rather than skeletal change, the relationship between mandibular retrognathia and treatment changes in the mandibular position may be of greater relevance. This finding is also in keeping with Baccetti et al.[10] who reported 2.7 mm of relative forward movement of Pogonion in their prospective study involving two-phased treatment commenced with bonded Herbst therapy.

The objective of the present study was not to assess the effectiveness of Twin Block appliances to an alternative as this objective would best be fulfilled with a randomised controlled trial, but was to identify parameters associated with successful outcomes. In epidemiological research, predictive models are best developed and piloted using observational designs. Potential relationships between dento-alveolar and skeletal parameters on both overjet reduction and change in mandibular position during Twin Block therapy have been identified; however, further research is necessary to confirm the validity of these results.[15,16] Specifically, given the relatively low strength of the relationships demonstrated, it is possible that important predictors may have been overlooked. Further analysis on an external sample is warranted to confirm these relationships. In particular, prospective follow-up research on a treated sample investigating sagittal skeletal responses with varying degrees of mandibular projection over a predefined treatment period would be of value.

Conclusions

No relationship between mandibular morphology and vertical skeletal pattern, and favourable dento-alveolar and skeletal responses to Twin Block therapy was found in this retrospective cohort study.

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