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Proportional changes in cephalometric distances during Twin Block appliance therapy

M. J. Trenouth
Department of Oral and Maxillo Facial Surgery and Orthodontics Royal Preston Hospital, Lancashire, UK

SUMMARY The aim of the study was to evaluate the cephalometric changes produced by the Twin Block appliance. Lateral cephalometric radiographs were taken before and after Twin Block appliance treatment on 30 consecutive patients (14 male, 16 female, mean age 12 years 6 months). Published normative data tables were used to produce control data, which were individually matched to the test group for age, sex, and treatment time. Alteration in shape was assessed by measuring percentage change in linear dimensions as opposed to change in cephalometric angles used in previous investigations. The differential average percentage change was calculated by subtracting the control value from the Twin Block value.

Clinically significant changes (2 per cent and greater) were found in lower anterior (6.6 per cent) and posterior (4.6 per cent) face heights, upper incisor to maxillary plane (4.9 per cent), i.e. upper incisor retraction, and increase in mandibular length (Co–B 3.3 per cent, Co–Po 2.6 per cent, Ar–B 3.5 per cent, Ar–Po 2.2 per cent).

Introduction

In morphological terms, an object or its image can be characterized by size and shape. Size is independent of shape because an object can vary in size but retain the same shape and *vice versa*. Size has algebraic magnitude but no direction, being purely relative to some arbitrarily chosen standard of dimensional space, whereas the shape of an object is characterized by its geometry and proportions rather than by reference to a standard.

To demonstrate changes in shape it is necessary to eliminate first the effect of size and secondly variation in position and orientation (Trenouth and Johnson, 1980). The effect of size may be eliminated by normalizing all records to an equal area (Eid, 1978). In fact, Chen *et al*. (2000) characterized shape as the 'residual' or what is left after controlling for size.

In cephalometric analysis, angular changes measure alterations in shape, whereas linear changes tend to measure variations in size (Trenouth, 1981). Muzj (1982), in a comprehensive review, considered that proportion was important in the determination of facial shape and harmony.

If all linear distances increase in equal proportion, then the size will increase but shape will remain unchanged. If, alternatively, linear distances increase in varying proportions then shape must also change as well as size.

Shape changes can be isolated by knowing which linear distances increase proportionally more than others (Figure 1) (Reyment *et al*., 1984; Dryden and Mardia, 1998).

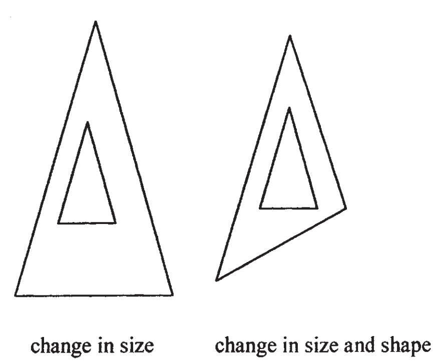

Figure 1 Geometric model demonstrating increase in linear dimensions in equal and unequal proportions.

Thus it is possible to assess changes in shape by measuring the percentage changes in various linear dimensions, i.e. change in proportion. In the present study, this approach was applied to assess the outcome of Twin Block appliance therapy as previously reported for conventional cephalometric analysis (Trenouth, 2000a).

A number of previous authors have reported the outcome of Twin Block appliance therapy using angular and linear measurements. Their results for changes in cephalometric angles are summarized in Table 1. However, no previous cephalometric investigation has used differential average percentage change in linear dimensions to assess alteration in shape.

Subjects and method

The study was performed retrospectively on consecutive subjects who had successfully completed treatment. The material comprised the lateral cephalometric radiographs of 30 patients, 14 males, 16 females; average age 12 years 6 months (range 9 years 8 months to 17 years 7 months). All the patients were treated by the author using a standardized technique described previously (Trenouth, 1989). This consisted of three phases: first, semi-rapid maxillary expansion and alignment of the upper arch after Mew (1977); secondly, correction of the Class II relationship using a modification of the Twin Block functional appliance introduced by Clark (1982), but with steeper bite blocks and excluding the extra-oral traction and intermaxillary elastics; thirdly, retention with an upper removable appliance with a very steep inclined anterior bite plane. This was a purely passive appliance retaining the anteroposterior correction produced by the functional appliance. Selection bias was minimal because the appliance system had a high level of patient acceptance with only the occasional subject failing to complete treatment.

To assess the effects of factors that influence craniofacial growth other than appliance therapy, it is necessary to have control data. Published normative data were used as a control because they can be matched precisely for age, sex, and treatment time. The normative data group contained a mixture of malocclusions, which are representative of the general population (54 per cent Class I, 41 per cent Class II, 5 per cent Class III). Although Class II patients show a mean size difference in the length of the mandible when compared with Class I, they both have the same longitudinal growth characteristics (Buschang *et al*., 1986; Bishara *et al*., 1997). It must therefore be concluded that the matched normative control data have the same growth characteristics as the Class II division 1 treatment data.

Cephalometric radiographs were taken just before treatment and at the end of full-time

Table 1 Previous cephalometric outcome studies on Twin Block therapy (average changes, control values in parentheses).

Author	Date	*n*	SNA (°)	SNB (°)	ANB (°)	MM (°)	UI (°)	LI (°)	OJ (mm)
Lund and Sandler	1998	36	–0.10 (0.30)	1.90 (0.40)	–2.00 (–0.10)	0.20 (–0.30)	–11.00 (–0.20)	8.20 (0.30)	–7.80 (–0.30)
Mills and McCulloch	1998	28	–0.90 (0.10)	1.90 (0.30)	–2.80 (–0.20)	–0.10 (–0.40)	–2.50 (0.20)	5.20 (1.40)	–5.60 (0.30)
Illing *et al.*	1998	16	–1.40 (0.30)	0.80 (–0.20)	–2.30 (0.40)	–1.50 (–0.40)	–9.1 (–1.9)	2.00 (–1.70)	–5.7 (0.7)
Tümer and Gültan	1999	13	–0.23 (0.15)	1.77 (0.31)	–2.00 (–0.19)	0.58 (–0.89)	UI/S–N –6.65 (0.85)	5.12 (0.81)	–7.46 (0.27)
Toth and McNamara	1999	40	0.2 (0.3)	1.6 (0.3)	–1.8 (0.0)	FMIA 1.8 (–0.3)	UI/S–N –4.3 (0.1)	2.8 (0.2)	–3.6 (0.3)
Trenouth	2000a	30	–0.60 (0.28)	2.00 (0.57)	–2.60 (–0.31)	0.07 (–0.96)	–14.37 (0.06)	1.13 (–0.16)	–7.20 (–0.24)

retention (third phase) prior to a period of night time only wear. The average duration was approximately 2 years.

The date of the pre- and post-treatment cephalometric radiographs was used to calculate the treatment time and age of the patient at the start of treatment. This information was then used to generate control data by matching each individual case from published normative data for age, sex, and observation time. Thus for each set of pre- and post-treatment cephalometric measurements taken from the patient, a matching set was derived from the normative data tables controlled for age, sex, and observation time. The normative data derived from London school children were chosen because of their nearest geographic proximity (Bhatia and Leighton, 1993). However, these data are derived from a longitudinal study taking repeated measures on the same children. The control data are therefore not independent and so not suitable for inclusion in simple statistical tests. They do nevertheless provide information about the average changes that could be expected in a matched control group. The magnification of the cephalometric radiographs was 7.78 per cent, which was close to the 7.76 per cent reported for the normative data (Bhatia and Leighton, 1993).

All the tracings from the radiographs were performed using a sharp pencil on acetate paper over an illuminated opal light box. The following points were recorded (Figure 2): S, sella; A, subspinale; ANS, anterior nasal spine; N, nasion; B, supramentale; PNS, posterior nasal spine; Go, gonion; Me, menton; Ar, articulare; Po, pogonion; Co, condylion; UI, upper incisor edge; LI, lower incisor edge.

The following distances were measured in mm: ANS–Me, UI–(ANS–PNS) Ar–Go, Ar–B, Co–B, Co–Po, Ar–Po, Go–Me, N–ANS, LI–(Go–Me), S–N, Co–A, Ar–A, S–Ar.

For each cephalometric distance the average actual change during treatment was calculated for both the control and Twin Block data. The average percentage change was then calculated as the percentage of the original length at the start of treatment.

The tracings were repeated on 20 of the original 60 cephalometric radiographs selected

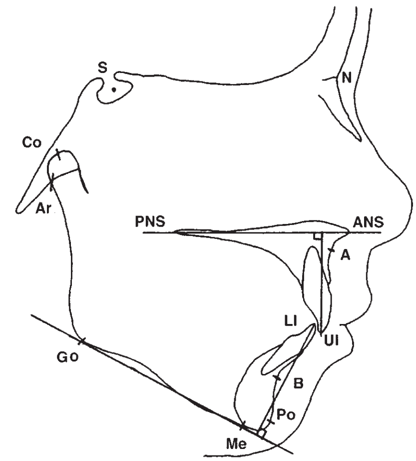

Figure 2 Cephalometric points and distances recorded. N, nasion; S, sella; A, subspinale; B, supramentale; ANS, anterior nasal spine; PNS, posterior nasal spine; Go, gonion; Me, menton; Ar, articulare; Po, pogonion; Co, condylion; UI, upper incisor edge; LI, lower incisor edge.

by random number tables. The error of the method was determined by the formula:

$$ME = \sqrt{\Sigma d^2/2n}$$

where d is the difference between measurement pairs and n is the number of pairs.

The error variance was then compared with the biological variation of the total material and expressed as a percentage (Table 2). It was concluded that the error of the method was comparable to that of other cephalometric studies and was less than 10 per cent of the biological variation.

Results

The linear measurements before and after treatment in the Twin Block and control data are shown in Table 3.

The results for actual and percentage change in cephalometric distances are shown in Table 4. The values for the percentage change for the control data (column 3) were a median of 3.3 per cent, range 4.2 per cent. The values for percentage change for the Twin Block patients (column 4) showed a greater variation, median 5.6 per cent, range 8.5 per cent.

Table 2 Experimental error of cephalometric measurement.

Variable	Method error	Error variance	Sample mean	Standard deviation	Total variance	Error variance/ total variance (%)
ANS–Me	0.89	0.79	61.92	5.10	26.01	3.04
UI–(ANS–PNS)	0.69	0.48	27.97	2.82	7.84	6.12
Ar–Go	0.89	0.79	47.47	5.52	30.47	2.59
Ar–B	0.71	0.50	97.48	5.61	31.44	1.59
Co–B	0.93	0.87	104.93	13.33	177.79	0.49
Co–Po	1.21	1.46	113.78	6.64	44.17	3.31
Ar–Po	0.54	0.29	108.18	13.30	176.76	0.16
Go–Me	0.61	0.37	68.62	5.38	28.94	1.28
N–ANS	0.81	0.66	54.12	4.48	20.07	3.29
LI–(Go–Me)	0.51	0.26	40.97	2.79	7.78	3.34
S–N	0.40	0.16	74.70	4.04	16.32	0.98
Co–A	1.16	1.35	93.47	6.50	42.19	3.20
Ar–A	0.69	0.48	91.88	5.55	30.78	1.56
S–Ar	0.61	0.37	36.67	4.49	20.16	1.84

Table 3 Cephalometric distances before and after treatment.

Variable	Twin Block data (mm)				Control data (mm)			
	Before		After		Before		After	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ANS–Me	58.9	3.7	64.9	4.5	58.3	1.8	60.4	1.8
UI–(ANS–PNS)	27.0	2.6	29.0	2.7	26.3	0.7	27.0	0.6
Ar–Go	45.1	4.6	49.8	5.4	40.7	2.0	43.1	1.9
Ar–B	94.3	4.9	100.7	4.3	88.5	2.5	91.5	2.4
Co–B	100.2	5.2	106.7	5.4	93.4	2.6	96.4	2.2
Co–Po	110.2	5.4	117.3	5.9	103.3	3.3	107.3	2.9
Ar–Po	103.5	5.3	109.9	5.8	97.5	3.2	101.4	2.9
Go–Me	67.0	5.3	70.3	5.1	66.2	2.0	68.5	2.2
N–ANS	53.0	4.1	55.3	4.6	48.8	1.3	50.4	1.4
LI–(Go–Me)	40.5	2.8	41.4	2.8	36.0	1.0	37.0	1.1
S–N	73.8	3.9	75.6	4.0	66.2	1.4	67.4	1.5
Co–A	92.1	6.2	94.6	6.6	80.8	2.0	83.0	1.8
Ar–A	90.7	5.8	93.1	5.1	79.9	1.9	82.1	2.2
S–Ar	36.3	5.3	37.0	3.5	31.8	1.0	32.8	1.1

The differential average percentage change was calculated (column 5) by subtracting the control value (column 3) from the Twin Block value (column 4). For the differential average percentage change, the median was 1.8 per cent, range 7.3 per cent.

Clearly some cephalometric distances show a substantial differential average percentage change, whilst other distances show little or no change. An arbitrary level of 2 per cent and above was chosen to be considered as clinically significant.

The greatest differential average percentage change occurred in lower anterior face height (ANS–Me), 6.6 per cent, with substantial change in lower posterior face height (Ar–Go), 4.6 per cent.

The next greatest differential percentage change was in UI–(ANS–PNS), 4.9 per cent,

Table 4 Actual and percentage changes in cephalometric distances during Twin Block therapy.

Variable	Average actual change		Average percentage change		Percentage difference
	Control (mm)	Twin Block (mm)	Control (%)	Twin Block (%)	
ANS–Me	2.10	5.70	3.70	10.34	6.64*
UI–(ANS–PNS)	0.71	2.13	2.72	7.62	4.90*
Ar–Go	2.44	4.67	6.00	10.60	4.62*
Ar–B	3.00	6.40	3.40	6.96	3.53*
Co–B	3.00	6.40	3.24	6.56	3.31*
Co–Po	4.00	7.20	3.93	6.54	2.61*
Ar–Po	3.90	6.60	4.05	6.30	2.25*
Go–Me	2.35	3.17	3.49	4.83	1.34
N–ANS	1.69	2.63	3.42	4.54	1.12
LI–(Go–Me)	1.03	0.87	2.89	2.22	0.67
S–N	1.25	1.80	1.84	2.38	0.53
Co–A	2.20	2.80	2.74	3.09	0.35
Ar–A	2.20	2.40	2.73	2.78	0.05
S–Ar	0.97	0.73	3.08	3.08	0.00

*Clinically significant, i.e. differential average percentage change of 2 per cent and above.

reflecting dento-alveolar retraction of the upper incisors, this distance increasing as they tipped back. Substantial differential percentage changes also occurred in overall mandibular length measured as 3.3 per cent (Co–B), 2.6 per cent (Co–Po), 3.5 per cent (Ar–B), and 2.2 per cent (Ar–Po).

However, mandibular body length (Go–Me) did not show any substantial differential percentage change (1.3 per cent), nor did maxillary length (Co–A = 0.4 per cent) (Ar–A = 0.1 per cent).

The cranial base parameters remained stable (N–ANS = 1.1 per cent; S–N = 0.5 per cent; S–Ar = 0.0 per cent), as did lower incisor position (LI–Go–Me = –0.7 per cent).

The percentage change in mandibular length (Co–B) was plotted against the percentage change in maxillary length (Co–A) (Figure 3). Nearly all the points lay above the line where percentage change in Co–B was equal to Co–A, indicating two to three times greater mandibular growth.

This suggests that the skeletal correction was due to mandibular growth rather than maxillary restraint, especially as there were no clinically significant changes in the maxilla with relative or absolute lengths.

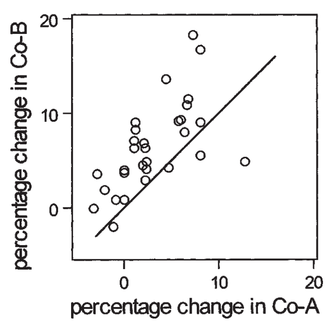

Figure 3 Plot of percentage change in Co–B against percentage change in Co–A for the treatment group. The line represents equal percentage changes for Co–B and Co–A.

Discussion

The use of differential average percentage change in linear dimensions provides an alternative method to the use of cephalometric angles to assess change in shape. Both methods appear to yield comparable results. The cephalometric distances, which showed a differential average percentage change of 2 per cent and above corresponded with clinically significant equivalent average angular changes reported previously (Trenouth, 2000a). In that study a clinically significant change was indicated where the treatment effect was greater than twice the method error. The treatment effect was calculated by subtracting the control value change from the Twin Block change. Clinically significant changes occurred in angles SNB (2.0 degrees), ANB (–2.6 degrees), and UI (–14.37 degrees). By identifying average proportional changes of 2 per cent or above in excess of the control group, it is possible to locate the areas where shape is likely to change.

The cephalometric data seem to support current understanding of the *modus operandi* of the Twin Block appliance (Trenouth, 2000b). This first involves reflex forward posturing of the mandible (McNamara, 1973; Miller and Vargervik, 1978), which, if persistent, is followed by second growth adaption of the condylar cartilage and subsequent remodelling of the glenoid fossa (Ruf and Pancherz, 1998, 1999; Pancherz, 2000). If this correction is retained for a sufficient length of time, then differential tooth eruption and remodelling of bone and muscle attachments will occur (Voudouris and Kuftinec, 2000).

The largest apparent contribution to reduction in overjet was from retraction of the upper incisors [UI–(ANS–PNS) = 4.9 per cent] with a lesser but significant contribution from forward mandibular growth (Co–B = 3.3 per cent, Ar–B = 3.5 per cent). These findings are in general agreement with previous studies (Table 1). However, Mills and McCulloch (1998) achieved a smaller amount of upper incisor retraction (–2.5 degrees), but significant reduction in SNA (–0.90 degrees). Because mandibular body length showed little change, the increase in overall mandibular length must occur in the region of the ramus and condyle.

In the present study, maxillary growth did not differ from the control group to any significant degree, and therefore there was no evidence of maxillary restraint making any contribution to the reduction in overjet. Also, there was no significant proclination of the lower incisors during treatment, in contrast to the findings of previous studies.

The greatest proportional increase was in lower face height. This is explained by forward repositioning of the mandible to reduce the overjet with subsequent eruption of the molars and premolars. Initially, this produces distraction of the condyle from the glenoid fossa. The condylar cartilage is unloaded and proliferated, inducing endochondral ossification. Also the bone of the glenoid fossa is subsequently remodelled. The increase in length of the mandible occurs mainly in the region of the condyle and ramus.

Conclusions

The Twin Block appliance produced a combination of mandibular skeletal and maxillary dentoalveolar responses. The Class II relationship was corrected by anterior bodily movement of the mandible with elongation in the region of the condyle and ramus, together with posterior tipping of the upper incisors.

Differential average percentage change in linear distances provides an alternative method to angular changes as a measure of alteration in shape. Both methods produce comparable results.

Address for correspondence

Dr M. J. Trenouth
Royal Preston Hospital
Sharoe Green Lane
Fulwood
Preston PR2 9HT
Lancashire, UK

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