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Soft and hard tissue changes in Class III patients treated by bimaxillary surgery

Shiu-Shiung Lin and W. John S. Kerr
University of Glasgow Dental School, Glasgow, UK

SUMMARY A cephalometric study of 17 non-growing dentate Class III subjects treated by bimaxillary surgery was undertaken to assess the results of treatment and to evaluate the correlation between soft and hard tissue change. It was concluded that: (i) the orthognathic profiles achieved were brought about by a combination of maxillary advancement and mandibular setback; (ii) a strong correlation in the horizontal direction occurred between all the selected landmarks of the lower lip and chin, but only between superior labial sulcus and point A in the upper lip; highest intra-group correlations were seen between corresponding soft and hard tissue points; the ratios of soft tissue to corresponding hard tissue movements in lower lip and chin approached 1:1; (iii) in the vertical direction, a strong correlation occurred in the lower lip and chin; highest intra-group correlations were not necessarily with corresponding landmarks; and (iv) vertical movement of landmarks on the nasal base and upper lip generally showed poor or weak correlation with corresponding soft tissue points. The most reliable hard tissue predictors of horizontal and vertical soft tissue change are tabulated for application in bimaxillary surgery for the Class III patient.

Introduction

Due to the improvement in orthodontic and surgical techniques during the last two decades, a combined approach has been widely accepted as the preferred method to correct moderate to severe skeletal deformity. Orthognathic surgery also allows orthodontists to solve the problems for which orthodontic treatment alone would do little to improve facial form.

The recognition of aesthetic factors and the prediction of the final facial profile play an increasingly significant role in orthognathic treatment planning, since the facial profile produced by orthognathic treatment is of great significance for patients. Investigations by Laufer *et al*. (1976), Kiyak *et al*. (1981), and Jacobson (1984) found that the principal motive for the majority of patients seeking orthognathic treatment was aesthetic.

At the same time Ostler and Kiyak (1991) demonstrated that the motive 'improving facial profile' was less fulfilled (70.4 per cent) compared with others. Dunlevy *et al*. (1987) suggested that professionals and lay persons were unaware of all facial changes following surgical treatment, with lay persons being more difficult to impress. Consequently, the relationship between hard tissue surgery and the effect which it has on the overlying soft tissue is extremely important in predicting facial changes.

Proffit and White (1990) emphasized that correcting the occlusal relationship only is not an adequate prescription for successful treatment. Unlike orthodontic treatment, which produces gradual alterations in facial features, orthognathic surgery results in sudden and dramatic changes. The patient unconsciously adapts to the physiognomic changes during orthodontic treatment and slowly integrates them into their self-concept. Orthognathic surgery, on the other hand, requires a rapid integration of the new facial features into their own self-concept (Kiyak *et al*., 1982) and may be more difficult to accept.

The first studies of the effects of surgery on the soft tissues were associated primarily with mandibular reduction procedures (Knowles, 1965; Aaronson, 1967; Hamula, 1970). These studies attempted to quantify the relative changes that occurred in the lower lip and chin in conjunction with the surgery. Based on the cephalometric findings, it was shown that for each 1 mm of distal mandibular skeletal movement, the soft tissue chin moved posteriorly 0.9 to 1 mm, while the soft tissue lip drew back 0.6 to 0.75 mm (Hershey and Smith, 1974; Lines and Steinhauser, 1974).

The study of Jensen *et al*. (1992), which investigated the soft tissue responses of simultaneous maxillary impaction and mandibular advancement with V–Y closure and alar base suture techniques, suggested that the soft tissue responses were similar to those seen in single jaw procedures, with the exception of the changes in the naso-labial angle, and in the area of the lower lip and chin. With maxillary impaction and advancement, the upper lip advanced 90 per cent of the underlying hard tissue change and moved superiorly 20 per cent of the hard tissue movement. The naso-labial angle changed by an amount equal to about 60 per cent of the rotation of the anterior maxilla. The response of the nasal base and subnasale did not show any strong correlation with the hard tissue changes in their study, which were as unpredictable as in previous reports (Mansour *et al*., 1983; Carlotti *et al*., 1986; Rosen, 1988). They implied that this may be due, in part, to variations in the amount of occlusal plane rotation that occurred during surgery and the alar base manipulation, or surgical handling of the anterior nasal spine.

Mandibular setback plus maxillary advancement is one of the most common bimaxillary orthognathic surgical manipulations for correcting severe skeletal Class III. Although soft tissue changes in this type of surgery have been considered similar to a combination of the two procedures separately (Proffit, 1991), the details of the relationship between soft and hard tissue response, particularly in the vertical direction, have not been fully clarified.

The aims of this study were to assess cephalometrically the hard and soft tissue response of skeletal Class III patients treated by bimaxillary orthognathic surgery, and to evaluate the correlation between the two.

Materials and methods

Seventeen patients who had undergone two-jaw orthognathic surgery for a Class III relationship (1 male, 16 females) were selected from adult treatment records at Canniesburn Hospital (mean age = 24 ± 8 years). The selection criteria were:

1. Treatment with maxillary Le Fort I advancement osteotomy and mandibular setback osteotomy, either bilateral sagittal split or vertical ramus osteotomy.
2. No additional surgical procedures were performed on the mid-face or chin, such as infra-orbital augmentation, rhinoplasty, or genioplasty.
3. Patients with cleft lip and palate, severe congenital facial deformity, and post-traumatic deformity were excluded.
4. All subjects had available both a lateral cephalogram taken after any pre-surgical orthodontics had been completed (1) and a lateral cephalogram taken 3–6 months post-surgery (2).

Tracings were carried out on acetates for all the radiographs. The 51 landmarks chosen for this study were derived and modified from Rakosi (1982), Phillips *et al*. (1984), and Kerr and Ten Have (1987). The landmarks, shown in Figure 1, comprised 31 points on the soft tissue profile, 16 points on the dentoskeletal structures, and two constructed points for setting up the horizontal and vertical reference lines. The tracings for 13 subjects (26 films) were replicated some months after the original tracing procedure to establish the error of the method.

All the digitizations were executed with a backlit GTCO 15 digitizer interfaced to an IBM P.C. computer, which was used to run a user defined digitization software package: PCDIG (McWilliam, 1989).

A horizontal reference line approaching the true horizontal, modified from Legan and Burstone (1980), was constructed 7 degrees inferior to the sella–nasion line. A vertical reference line, modified from Jensen *et al*. (1992), was set up by PCDIG at right angles to it through reference–sella, which was horizontally 50 mm distal to sella.

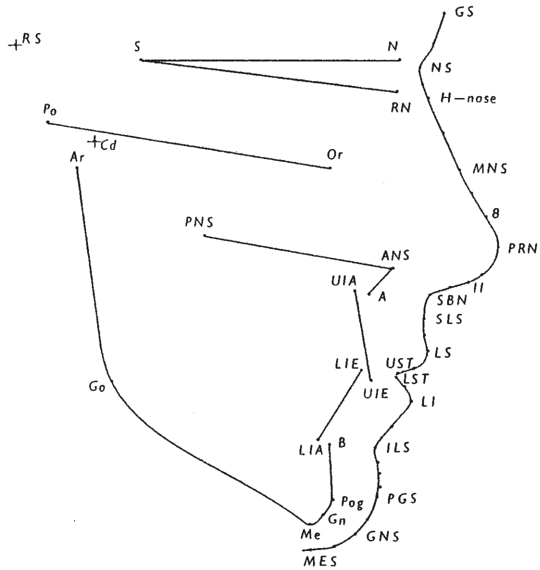

Figure 1 The 51 landmarks utilized in this study. Defined and anatomical points are labelled. Intermediate points represent either bi-, tri-, or quadri-sections of the soft tissue outline between two adjacent labelled landmarks.

Sixty-four linear and angular measurements (Lin, 1995) were computed with the aim of eliciting the skeletal and dental changes produced by treatment, and the relationship between the behaviour of hard and soft tissue landmarks.

Error of the method

The reproducibility of the reference lines was verified by comparing the angle between sella–nasion and the horizontal line and a calibrated distance 50 mm from sella to reference sella along the horizontal line on cephalograms 1 and 2. No statistical difference was found between the two cephalograms so that all measurements from these reference lines can be considered comparable.

Systematic and random errors in the tracing process were assessed using the method of Houston (1983). The null hypothesis tested showed that there was no difference between the first and the second measurement. The intra-class correlation of all the parameters in this study was greater than 0.90, with the exception of three variables for cephalogram 1, and four variables for cephalogram 2, for which the value was not less than 0.60.

Results

Surgical outcome

Significant angular, horizontal, and vertical changes are shown in Table 1. All horizontal and vertical distances were measured to the corresponding reference lines.

Ratios and correlations between hard and soft tissue movements

These were conducted by applying linear regression procedures to assess the degree of correlation in terms of soft to hard tissue changes between the two cephalograms.

Horizontal parameters. The results can be classified into three groups according to the degree of correlation between soft and hard tissue movement Table 2.

1. Strong correlation ($r > 0.8$*)*: A high correlation was found for all the selected landmarks in the lower lip and chin, whereas only one upper lip comparison fell within this group (superior labial sulcus to point A). Apart from SLS to point A, the ratios of soft to hard tissue movements for corresponding landmarks approached 1 to 1.

2. Moderate correlation ($r = 0.7–0.8$*)*: The landmarks included in this group are all those of upper lip apart from SLS to point A. The ratios of soft to hard tissue movement were generally lower than in the previous group and ranged from 0.61 to 0.82. The moderate correlations of soft to hard tissue response indicate that other factors accounted for a considerable proportion of the soft tissue change (R^2 = 49–61 per cent).

3. Weak or no correlation ($r < 0.7$*)*: This group included the landmarks which were located at the nasal tip and base. The ratios varied from 0.35 to 0.64. The weak correlations imply that other factors contributed more than 55 per cent to soft tissue response.

Table 1 Surgical outcome assessed by skeletal and dental parameters (n = 17, I: Ceph 1, II: Ceph 2, III = III) in mm except where indicated.

Variable	I Mean (SD)	II Mean (SD)	III Mean (SD)	*P*-value
SNA°	78.25 (5.27)	82.22 (4.43)	3.97 (2.62)	0.0000****
SNB°	81.91 (4.16)	79.35 (3.92)	–2.56 (2.93)	0.0024**
ANB°	–3.65 (3.38)	2.88 (2.17)	6.53 (2.80)	0.0000****
ANS HL	120.22 (6.41)	123.14 (5.59)	2.92 (4.10)	0.0098**
A HL	113.26 (6.61)	117.58 (6.28)	4.32 (3.12)	0.0000****
U1E HL	116.31 (8.28)	120.66 (8.23)	4.35 (3.34)	0.0001***
L1E HL	121.80 (8.81)	117.84 (8.14)	–3.96 (4.85)	0.0039**
B HL	116.18 (8.74)	111.86 (8.58)	–4.32 (6.10)	0.01*
Pog HL	118.39 (9.84)	114.08 (9.85)	–4.31 (7.11)	0.024*
Me HL	112.31 (10.01)	108.05 (9.63)	–4.26 (7.18)	0.026*
L1E VL	78.34 (6.75)	74.28 (4.10)	–4.06 (4.02)	0.0007***
B VL	98.86 (8.30)	95.21 (6.06)	–3.65 (4.57)	0.0045**
Pog VL	112.72 (8.34)	108.95 (6.42)	–3.77 (3.56)	0.0005***
Me VL	120.95 (8.55)	117.17 (6.54)	–3.78 (3.48)	0.0004***

****$P < 0.0001$, ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.
HL = horizontal distance of the landmark to the vertical reference line; VL = vertical distance of the landmark to the horizontal reference line.

Table 2 Correlation on horizontal parameters (*r* value in bold indicates the highest intra-group soft tissue correlations to corresponding hard tissue landmark).

Variable S	Variable H	(S:H)	Regression equation	*r*	R^2(adj)
Strong correlation group on horizontal parameters					
SLS	Point A	0.756	SLS = *–0.242* + *0.756* Point A	**0.837**	68.1%
LST	L1E	0.901	LST = *2.720* + *0.901* L1E	**0.891**	77.9%
LI	L1E	0.990	LI = *0.220* + *0.990* L1E	**0.956**	90.9%
LI	Point B	0.769	LI = *–0.374* + *0.769* Point B	0.934	86.5%
LI	Pog	0.652	LI = *–0.889* + *0.652* Pog	0.924	84.3%
ILS	L1E	1.240	ILS = *0.446* + *1.24* L1E	0.956	90.9%
ILS	Point B	1.020	ILS = *–0.043* + *1.02* Point B	**0.991**	98.2%
ILS	Pog	0.869	ILS = *–0.711* + *0.869* Pog	0.984	96.6%
ILS	Me	0.844	ILS = *–0.859* + *0.844* Me	0.964	92.5%
PGS	Point B	1.150	PGS = *0.314* + *1.15* Point B	0.992	98.3%
PGS	Pog	0.989	PGS = *–0.408* + *0.989* Pog	**0.992**	98.3%
PGS	Me	0.968	PGS = *–0.544* + *0.968* Me	0.980	95.8%
MES	Point B	1.150	MES = *0.649* + *1.15* Point B	0.984	96.5%
MES	Pog	0.994	MES = *–0.031* + *0.994* Pog	0.992	98.4%
MES	Me	0.992	MES = *–0.088* + *0.992* Me	**0.999**	99.8%
Moderate correlation group on horizontal parameters					
SLS	U1E	0.609	SLS = *0.374* + *0.609* U1E	0.722	48.9%
LS	Point A	0.819	LS = *–0.491* + *0.819* Point A	0.796	60.9%
LS	U1E	0.735	LS = *–0.153* + *0.735* U1E	0.765	55.8%
UST	U1E	0.824	UST = *–2.240* + *0.824* U1E	0.747	52.8%
Weak or no correlation group on horizontal parameters					
PRN	ANS	0.348	PRN = *–0.159* + *0.348* ANS	0.629	35.5%
SBN	ANS	0.368	SBN = *1.460* + *0.368* ANS	0.523	22.5%
SBN	Point A	0.638	SBN = *–0.225* + *0.638* Point A	0.690	44.1%

Table 3 Correlation on vertical parameters (*r* value in bold indicates the highest intra-group soft tissue correlations to hard tissue landmark).

Variable S	Variable H	(S:H)	Regression equation	*r*	R^2(adj)
Strong correlation group on vertical parameters					
LST	L1E	0.920	LST = *1.960 + 0.920* L1E	0.831	66.9%
LI	L1E	0.882	LI = *1.310 + 0.882* L1E	**0.876**	75.3%
LI	Point B	0.771	LI = *0.555 + 0.771* Point B	0.869	74.0%
ILS	L1E	0.985	ILS = *1.350 + 0.985* L1E	**0.851**	70.6%
ILS	Point B	0.824	ILS = *0.372 + 0.824* Point B	0.809	63.1%
PGS	Me	1.010	PGS = *0.846 + 1.01* Me	**0.810**	63.3%
MES	Point B	0.666	MES = *–1.360 + 0.666* Point B	0.901	79.8%
MES	Pog	0.891	MES = *–0.435 + 0.891* Pog	0.937	87.0%
MES	Me	0.961	MES = *–0.166 + 0.961* Me	**0.989**	97.7%
Moderate correlation group on vertical parameters					
LS	U1E	0.596	LS = *0.723 + 0.596* U1E	**0.745**	52.6%
LI	Pog	0.853	LI = *0.951 + 0.853* Pog	0.750	53.2%
ILS	Pog	0.976	ILS = *1.040 + 0.976* Pog	0.746	52.8%
ILS	Me	1.070	ILS = *1.390 + 1.070* Me	0.797	61.2%
PGS	Point B	0.717	PGS = *(0.335 + 0.717* Point B	0.757	54.4%
PGS	Pog	0.889	PGS = *0.390 + 0.889* Pog	**0.730**	50.2%
Weak or no correlation group on vertical parameters					
PRN	ANS	0.146	PRN = *–0.385 + 0.146* ANS	0.251	0.0%
SBN	ANS	0.162	SBN = *–0.782 + 0.162* ANS	0.394	9.9%
SBN	Point A	0.090	SBN = *–0.760 + 0.090* Point A	0.245	0.0%
SLS	Point A	0.326	SLS = *–0.324 + 0.326* Point A	0.491	19.1%
SLS	U1E	0.437	SLS = *–0.040 + 0.437* U1E	0.630	35.6%
LS	Point A	0.430	LS = *0.337 + 0.430* Point A	0.562	27.0%
UST	U1E	0.437	UST = *1.530 + 0.437* U1E	0.644	37.6%
LST	U1E	0.871	LST = *–1.290 + 0.871* U1E	0.516	21.7%

Vertical parameters (Table 3).

*1. Strong correlation (*r *> 0.8)*: Similar to the findings for horizontal parameters, the highest correlations occurred for the landmarks in the lower lip and chin. Soft tissue landmarks did not necessarily show the strongest correlation with their corresponding hard tissue point. Movement of soft tissue pogonion, for example, was more closely correlated with movement of menton than with pogonion.

The ratios of soft to hard tissue movements in this group varied from 0.67 (soft tissue menton to point B) to 1.01 (soft tissue pogonion to menton). This indicates that the vertical response of soft tissue is not so uniform as that of horizontal response. R^2(adj) values for this group are generally smaller than those for the horizontal group.

*2. Moderate correlation (*r *= 0.7–0.8)*: This group included soft tissue pogonion with its corresponding hard tissue landmark. The ratios showed a wide range from 0.60 (labrale superius to incisor superius) to 1.07 (inferior labial sulcus to menton). The moderate correlations of soft to hard tissue responses indicate that other factors contributed nearly 40–50 per cent to soft tissue changes.

*3. Weak or no correlation (*r *< 0.7)*: This group generally included the landmarks located in the nasal region and upper lip. The ratios varied from 0.09 to 0.87. R^2(adj) for pronasale to anterior nasal spine and subnasale to point A showed almost no correlation. The poor correlation found in this group indicated that other factors contributed most to soft tissue changes.

Discussion

Surgical outcome

The Class III subjects selected for this study all presented a combination of maxillary retrognathism and mandibular prognathism confirmed by the presurgical mean values for SNA (78.25 degrees) and SNB (81.91 degrees), and hence the reason for the bimaxillary approach to surgery. The post-surgical values showed that an orthognathic profile had been achieved by movement of both jaws antero-posteriorly and vertically.

Some Class III patients possess a prognathic chin which may exaggerate the dental base discrepancy. The position of pogonion is not suitable for representing the anterior part of the mandible in these patients. The distance of pogonion from the nasion–point B line has been used in the Steiner analysis (1953) to assess the relationship of lower incisor to chin. This line was applied in this study to define the degree of chin prominence antero-posteriorly. The mean distance from pogonion to NB line before and after surgery (2.24 and 3.00 mm) indicated that the position of pogonion was within the normal range. The mean change (0.76 mm) was significant ($P = 0.0002$). It is, however, possible that this change may be partly the result of alteration of mandibular orientation: distal movement of the mandible tends to upright the NB line and orientate pogonion slightly away from it.

The severity of Class III malocclusion meriting orthognathic surgery has been investigated by Kerr *et al.* (1992). They found that threshold values of orthognathic treatment for angle ANB and lower incisal inclination were 4 and 83 degrees. The mean ANB angle presurgically in this study was 3.65 degrees, but no pre-orthodontic data of incisal inclination were available.

The superimposed mean plot on cephalogram 1 and cephalogram 2 groups also confirmed the improvement in facial profile (Figure 2). The resultant plot showed clearly that the mandible was repositioned posteriorly parallel with the mandibular plane. Posterior movement of the mandible produced the upward vertical change of the position of the anterior mandibular landmarks, although no surgical procedure specifically designed to induce anterior vertical change had been carried out. This may be ignored by clinicians, when they concentrate on horizontal changes, and may influence the accuracy of profile prediction.

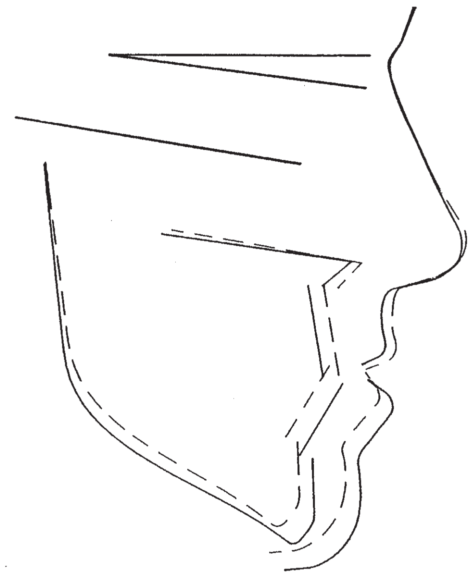

Figure 2 The mean plots of cephalogram 1 (presurgical ——) and 2 (post-surgical – – –) superimposed on the SN line holding at sella.

Soft tissue response

Adjusted coefficient of determination R^2(adj) was selected to explain the degree of contribution of hard tissue movement to soft tissue change. R^2(adj) is adjusted for degrees of freedom and is an approximately unbiased estimate of the population R^2 (Minitab for Windows, 1994).

Horizontally, the results of this study are similar to historical reports of mandibular setback surgery (Robinson *et al.*, 1972; Mansour *et al.*, 1983; Hernández-Orsini *et al.*, 1989) in terms of 1:1 horizontal ratio at pogonion and point B, but slightly greater than that reported by Hershey and Smith (1974), and Lines and Steinhauser (1974) which was 0.9:1. The lower lip in this study responded at a ratio between 0.9 and 1 to the corresponding hard tissues. This is much greater than the ratio found in previous investigations (Hershey and Smith, 1974; Lines and Steinhauser, 1974), which ranged from 0.6–0.75 to 1. Whether or not the horizontal ratio of the present result is related to vertical change in the anterior part of mandible would require further study.

The ratio of superior labial sulcus to point A was less than that of lower lip and chin. It has been reported that the ratio of upper lip advancement varied from 0.4:1–0.82:1 to maxillary advancement which did not involve soft tissue manipulation (Dann *et al.*, 1976; Freihofer, 1976; Araujo *et al.*, 1978; Mansour *et al.*, 1983; Rosen, 1988). The correlation between soft to hard tissues was also weak. The factors which may contribute to the behaviour of upper lip movement in terms of the poor correlation and limited ratio include:

(1) The maxillary bony landmarks being destroyed during surgery and becoming blurred (Houston *et al.*, 1987), particularly ANS with Le Fort I surgery. This is likely to reduce the soft to hard tissue ratio and influence the correlation horizontally and perhaps vertically.
(2) Subnasale is located at the junction of the soft and hard tissue over the maxilla and the nasal base. Firm attachment to the base of the nose prevents it from moving horizontally and vertically in a proportional way with corresponding hard tissue movement (Lines and Steinhauser, 1974).

The V–Y closure technique and the alar base cinch suture procedure are reported to demonstrate consistent ratios of nearly 0.9:1 between the soft and hard tissues (Schendel and Williamson, 1983; Carlotti *et al.*, 1986). Jensen *et al.* (1992) reported that with V–Y closure techniques, the maxillary soft tissues moved forward 90 per cent of the hard tissue change and showed 20 per cent shortening of the upper lip in Class II division 1 orthognathic patients with maxillary impaction. Application of these soft tissue manipulating methods to maxillary advancement in Class III patients still needs further investigation to assess their effectiveness.

Vertically, the responses of the nasal base and subnasale after surgery show poor or weak correlation to the hard tissue changes in this study, which is similar to previous reports (Mansour *et al.*, 1983; Carlotti *et al.*, 1986; Rosen, 1988; Jensen *et al.*, 1992). In the upper lip, the best, but moderate, correlation (r = 0.745) occurred between labrale superius and incisor superius.

Table 4 Ideal predictors for soft tissue movements.

Variable S	Variable H	(S:H)	Regression equation	r	R^2(adj)
Horizontal					
SLS	Point A	0.756	SLS = *–0.242 + 0.756* Point A	0.837***	68.1%
LS	Point A	0.819	LS = *–0.491 + 0.819* Point A	0.796**	60.9%
UST	U1E	0.824	UST = *–2.240 + 0.824* U1E	0.747**	52.8%
LST	L1E	0.901	LST = *2.720 + 0.901* L1E	0.891***	77.9%
LI	L1E	0.990	LI = *0.220 + 0.990* L1E	0.956***	90.9%
ILS	Point B	1.020	ILS = *–0.043 + 1.02* Point B	0.991***	98.2%
PGS	Pog	0.989	PGS = *–0.408 + 0.989* Pog	0.992***	98.3%
MES	Me	0.992	MES = *–0.088 + 0.992* Me	0.999***	99.8%
Vertical					
LS	U1E	0.596	LS = *0.723 + 0.596* U1E	0.745**	52.6%
LST	L1E	0.920	LST = *1.960 + 0.920* L1E	0.831***	66.9%
LI	L1E	0.882	LI = *1.310 + 0.882* L1E	0.876***	75.3%
ILS	L1E	0.985	ILS = *1.350 + 0.985* L1E	0.851***	70.6%
PGS	Me	1.010	PGS = *0.846 + 1.01* Me	0.810***	63.3%
MES	Me	0.961	MES = *–0.166 + 0.961* Me	0.989***	97.7%

***Strong correlation ($r > 0.8$).
**Moderate correlation (r = 0.7–0.8).

The vertical correlation coefficients of the soft to hard tissue movement are not so strong as those for horizontal change. The ratios are also more variable. Lin (1995) found that these may account for the increased difficulty in predicting change in this dimension accurately.

In the lower lip and chin area the correlation was stronger, however, the highest intra-group correlation was not necessarily between corresponding hard and soft tissue points. The ratios for the high correlation group varied from 0.67 to 1.0 and it is therefore important to distinguish which are the best hard tissue predictors of soft tissue response.

The data are arranged in Table 4 indicating the soft and hard tissue points which relate well to one another in terms of response and which can be utilized in surgical planning and prediction. Moss *et al*. (1988) have pointed out that the various types of operation and morphology of the anatomic structures must be considered in predicting the outcome of facial surgery.

Further investigations on other types of malocclusion and methods of surgical correction are essential to widen the database for planning prediction.

Address for correspondence

Professor W. J. S. Kerr
Glasgow Dental School
378 Sauchiehall Street
Glasgow G2 3JZ, UK

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