Dental and skeletal changes following sagittal split osteotomy for correction of mandibular prognathism

N. S. Vasir, R. T. Thompson, and T. M. Davies

University College and Middlesex School of Dentistry, London, *University Hospital of South Manchester, Didsbury, Manchester, and **Central Middlesex Hospital, Park Royal, London

SUMMARY Skeletal and dental changes were examined in 15 patients presenting with a Class III malocclusion treated by a sagittal split osteotomy. All patients received orthodontic treatment with Straightwire appliances both prior to and following surgery. These appliances were also used for fixation. The lower incisors were proclined by 8.4 degrees before surgery with little change in upper incisor inclination. With surgery, there was a mean reduction of 4.3 degrees in the angle SNB. Following surgery, the relapse in mandibular position was minimal and was not related to the dental changes during this period. Changes in the vertical skeletal parameters were generally small. The individual cases exhibited a wide variation in the changes.

Introduction

The combined approach of surgical and orthodontic treatment has made possible the correction of certain severe skeletal deformities and malocclusions previously not amenable to treatment by surgical or orthodontic means alone. The benefits often quoted are achievement of improved treatment objectives and optimum aesthetic results. Orthodontic correction of tooth malposition and dental arch form before and/or after surgery improves the potential for achieving these goals.

A variable amount of relapse, both in the dentition and in the skeletal structures, often accompanies this form of treatment. The underlying reasons for this are unclear, although variations in the pre- and post-surgical orthodontic treatment, the operative technique, and the period and type of fixation have been implicated. For the same reasons, direct comparison of various studies is difficult.

It was generally assumed that post-surgical changes leading to compromised results occurred after the release of maxillo-mandibular fixation, but Poulton and Ware (1973) showed that skeletal changes can occur during maxillo-mandibular fixation. They demonstrated that the dentition can be bodily re-orientated within the alveolar processes as skeletal equilibrium is being re-established.

However, characteristic relapse immediately following the operation is frequently masked by compensatory changes in axial inclinations of the teeth (McNeill et al., 1973; Ive et al., 1977; Schendel and Epker, 1980).

Because of the number of variables present in most studies, it is difficult to ascertain the relative importance of the factors in the causation of relapse. The present study was confined to assessment of changes with a single surgical approach in patients with Class III malocclusions who received similar pre- and post-surgical orthodontic treatment. The aim was to specifically evaluate the amount and direction of dental and skeletal changes during the various stages.

Subjects and methods

Fifteen patients were selected from a cohort of 37 orthognathic patients. Each selected patient had a Class III malocclusion which had been treated by orthodontics followed by mandibular surgery; this was performed by one surgeon using the sagittal split osteotomy technique. The sample consisted of four males and 11 females with a mean age of 19.3 years at the time of the surgical procedure. The mean age for the four male patients was 22.0 years (range 17.7–25.0 years), while the mean for the female sample was 18.3 years (range 16.9–23.9 years). Any patients presenting with cleft lip and/or palate were excluded from the study.
Orthodontics

This was undertaken by two operators, 13 of the 15 patients being treated by one clinician. Presurgical orthodontic treatment consisted of upper and lower Straightwire 018" Edgewise mechanics for an average period of 1.4 years. During this period, the aims were to eliminate dental compensations, correct transverse discrepancies and achieve arch coordination. In all cases, the fixed orthodontic appliances were used for stabilization at the time of surgery. Post-surgical orthodontic treatment was completed in a mean period of 4.5 months. Class III intermaxillary elastics were worn with removable retainers after the fixed appliances were removed.

Surgical technique

All patients received a bilateral sagittal split osteotomy which was performed as described by Trauner and Obwegeser (1957) and modified by Dal Pont (1961). Wires ligated to the fixed orthodontic appliances provided the intermaxillary fixation for a mean period of 6.7 weeks. Condylar orientation to the glenoid fossa was established by manipulation of the proximal fragment into its most retruded superior position. Interosseous wires were placed to preclude condylar distraction from the glenoid fossa. A radiograph was taken in the immediate postoperative phase to ensure that the condyles were correctly seated in their fossae. The patients were followed up in the post-retention period for an average of 16.3 months (one patient for 36 months, another for 23 months, and the remaining ranged between 12 and 18 months).

Horizontal and vertical displacements of specific points together with a conventional cephalometric analysis was applied to standardized films available at the following stages.

I  Start of orthodontic treatment  
II  Immediately prior to surgery  
III  Following surgery  
IV  At least 1 year out of all retention

Tracing procedure

Under optimum lighting conditions, a tracing of the first radiograph was made on acetate sheet using a 4H pencil.

Cranial base, anterior wall of sella turcica, De Coster’s line, and maxillary and mandibular structures were traced. Cranial base, maxillary, and mandibular reference lines were then drawn. The points identified are shown in Fig. 1.

Registration procedure

The first radiograph was attached to a digitizing table with adhesive tape, the tracing was aligned on the cranial base structures and points 1–12 were digitized. The second radiograph was positioned on the digitizing table, the tracing of the first radiograph was aligned on the cranial base structures, and points 1 and 2 were digitized. The tracing was then repositioned without moving the radiograph so that the maxillary structures were registered, and points 3 and 4 were digitized. The remaining points were digitized in an identical manner. This procedure was repeated for the third and fourth radiograph. One week later, the tracing and registration procedure was repeated on records of eight patients for an assessment of the method error.

Figure 1  Cephalometric landmarks used in the investigation (x0y0 denotes point of superimposition). (1) S, Sella. (2) N, Nasion. (3) PNS, Posterior nasal spine. (4) ANS, Anterior nasal spine. (5) PT A, Point A. (6) UIA, Upper incisor apex. (7) UIT, Upper incisor tip. (8) LIT, Lower incisor tip. (9) LIA, Lower incisor apex. (10) Pt B, Point B. (11) Me, Menton. (12) Go, Gonion.
Digitization and analysis were undertaken using programmes developed for this purpose. Results were calculated by superimposing the images from the four radiographs upon one another, using as baseline the sella nasion line which was rotated to be horizontal. The horizontal and vertical displacements of points 3–12 in relation to the mid-point of the sella nasion line (marked as x0y0 on Fig. 1) were calculated.

Repeated measures analysis of variance (Dixon, 1983) was used to assess change over time. Where a significant difference was found, a pair-wise comparison was made using Student’s t-test. Bonferroni’s inequality (Fleiss, 1986) was applied to the following four comparisons which were prospectively considered to be of experimental interest, reducing the significance level from 0.05 to 0.0125.

1. Presurgical change (X-ray 2 minus X-ray 1).
2. Surgical change (X-ray 3 minus X-ray 2).
3. Postsurgical change (X-ray 4 minus X-ray 3).
4. Net change (X-ray 4 minus X-ray 1).

Error of measurement

Large method errors add to the variability of the reported changes when groups of cases are compared, and so method errors reduce the statistical significance of real differences between means. Gravely and Benzie (1974) showed that in the context of serial cephalometric measurements of single cases, one cannot be confident at the 5 per cent level that changes in measurements reflect real changes in the individual unless the differences are greater than twice the method error for that measurement. In the present study, a number of changes were small and fell within these 95 per cent confidence limits. The mean error of the method was 1.05 degrees for angular measurements, 1.05 mm for horizontal displacement and 1.1 mm for vertical displacement.

Results

Changes in the presurgical period

Decompensation of the lower incisors, the primary aim of this phase of treatment was clearly achieved. The incisors were proclined from an initial mean value of 82.8–90.9 degrees (P < 0.001; Table 1). Although the mean upper incisor inclination remained unchanged at 116 degrees, there was substantial change in some patients (range —5.9–6.1 degrees). The reverse overjet increased by a mean value of 2 mm (range 2.3 to —5.7 mm). Unintended effects of the mechanics resulted in a 2 mm increase in lower anterior face height (P < 0.002). There was a significant amount of movement in the same direction of both upper and lower incisor tips (UITy and LITy, P < 0.003 and 0.01, respectively; Table 2). Similar vertical changes were also found at point B and Menton, but not at Gonion.

Table 1  Cephalometric values for the four stages (T1 to T4) and comparison of differences between the stages (values presented as mean ± SD, etc., denotes statistical significance at the 5 per cent level between the values.

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<th></th>
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<th>T4</th>
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<th>T3-T2</th>
<th>T4-T3</th>
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<td>(Surgical)</td>
<td>(Posturgical)</td>
<td>(Presurgical)</td>
<td>(Surgical)</td>
<td>(Posturgical)</td>
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<td>83.6 ± 3.3</td>
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<td>0.2 ± 0.5(*)</td>
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Table 2  Horizontal and vertical changes for cephalometric points, and comparison of the differences between the stages (values given as mean ± SD; *(a,b), etc., denotes a statistical difference at the 5 per cent level between the values.

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<td>-1.6±2.6(a)</td>
<td>-0.7±2.8(b)</td>
<td>3.1±4.9(ab)</td>
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</table>
The slight reduction in the overbite during this phase was not significant.

**Changes attributed to surgery**

As the surgery was confined to the mandible, certain parameters were not affected by the treatment, e.g. SNA and UFH. The primary intention of surgical setback of the mandible was clearly achieved in that the mean overjet was changed from $-3.6$ to $+3.6$ mm ($P < 0.0001$; Table 1).

The mean reduction in mandibular prominence, measured as angle SNB was $4.2$ degrees (range $-0.9$ to $-7.8$ degrees) as illustrated in Table 1. The horizontal changes at specific points on the mandible are listed in Table 2. The horizontal setback of the mandible with surgery, measured at point B was $6.6$ mm (range $-1.2$ to $-12.9$ mm). None of the vertical changes achieved with surgery were statistically significant, as shown in Table 2.

**Changes in the post-surgical period**

Mean horizontal change at point B following surgery was $0.7$ mm (range $3.3$ to $-4.6$ mm; Table 2), and $0.5$ degrees for the angular change (SNB; Table 1), both indicating a small degree of forward relapse. However, there was considerable variation in the response (SNB range $+2.3$ to $-2.2$ degrees). The individual changes in both the horizontal and vertical planes for point B are shown in Fig. 2. The mean overjet of $3.6$ mm following surgery relapsed to $2.7$ mm during the post-surgical phase. The final overjet achieved ranged from $1.4$ to $3.5$ mm. The lower incisors retroinclined slightly in relation to the mandibular base, but proclined by $1.1$ degrees in the face (LISN)—a related change is an increase in the craniomandibular planes angle (SNMnP) by $3.8$ degrees.

**Discussion**

In the present study, the decision to confine surgical intervention to the mandible was primarily made on the severity of mandibular prognathism. This was confirmed by the cephalometric data as there were seven patients who initially presented with the maxillary base within normal limits and the mandible beyond the normal range—this is comparable to the largest group as categorized by Jacobson et al. (1974) and also by Sanborn (1955). None of the patients exhibited a severe enough discrepancy between the bases to warrant a bimaxillary surgical procedure, the largest difference being $-5$ degrees (angle ANB). However, dental compensation in the maxillary arch, as represented by inclination of the incisors (Table 1) was not eliminated in all cases, thus masking the true basal discrepancy and also providing a smaller reverse overjet prior to surgery. The proclined position of the maxillary incisors may have influenced the final clinical decision to confine surgery to the mandible.

A small number of stage 3 radiographs were not taken immediately post-operatively. It is possible that some changes in incisor inclination or bodily position in the first few weeks after surgery, would compensate for early skeletal relapse. Therefore, the mean figures for the stage 3 records may reflect less change than was actually achieved by the surgery.

In this investigation, the mean mandibular sagittal changes are represented by angle SNB (Table 1). The individual changes are illustrated in Fig. 3. With surgery, the mean reduction of $4.3$ degrees was comparable to $4.8$ degrees quoted by Pepersack and Chausse (1978), $5$ degrees by Moss and Willmott (1984), and $4.8$ degrees for the female sample in Reitzik’s study (1980). A more accurate depiction of the change is the combined horizontal and vertical movements of point B for the 15 cases (Fig. 2). This illustrates the range of variation, both in direction and amount which is often masked by mean figures. Orthodontic mechanics prior to surgery may affect mandibular position especially in the vertical plane.

In the present study, the mean horizontal movement at point B as a result of surgery was $6.6$ mm (Table 2) and this compares with $7.2$ mm quoted by Nakajima et al. (1979), $8.4$ mm by Kobayashi et al. (1986), but was less than the average of $10$ mm achieved in the sample studied by Vijayaraghavan et al. (1974). The changes varied widely in magnitude (range $-1.2$ mm to $-12.9$ mm). When examining individual cases, method errors of even $1$ mm make it difficult to ascertain whether small changes observed are effects rather than methodological errors (Houston, 1983).

The amount and type of surgical change that can be obtained in each patient is determined by the severity of the presenting skeletal discrepancy and the occlusion achievable at the time of the
Figure 2  (a)–(c) Horizontal and vertical changes at point B during the three stages of treatment (individual cases marked with number in circle).
operation—in this respect the cant of the occlusal plane, incisor relationship, and also posterior intercuspation allowing 'best fit' may be determining factors. Furthermore, sagittal split osteotomy for a mandibular setback requires a lateral ostectomy in addition to the ramal split. The difficulty in performing the ostectomy to the exact dimensions and specific geometry required may reduce the accuracy of the desired surgical change.

The horizontal changes at point B following surgery ranged between +3.3 and —4.6 mm, i.e. there were a few patients in whom the mandible moved further posteriorly (Cases 2, 9, and 10; Fig. 2). Hence, the mean horizontal relapse of 0.7 mm (SD±2.2) which is very small, does not reflect the variation. Kobayashi et al. (1986) demonstrated a similar amount of relapse (0.9 mm) and variation (SD±2.0). The variation in direction of change postsurgically may partly be due to instability of the ostotomy site which is unable to resist forces including those generated by Class III elastics worn to the removable retainers.

In the present study, inclination of the lower incisors was measured to both the mandibular (LIMnP) and cranial reference plane (LISN) in order to assess the effect following surgery on the mandibular plane due to changes in position of the distal segment. During this period, the lower incisors retroclined by 1 degree when measured relative to the mandibular plane, but proclined in relation to the cranial reference plane by 1.7 degrees, i.e. the angle LISN reduced. The mandibular plane forms a triangle with the lower incisor axis (LIMnP) and the base of the skull (SNMnP). Therefore, any reduction in the angle LISN not resulting from movement of teeth must be reflected in an increase in the angle SNMnP, indicating a backward rotation of the distal segment after surgery. Due to the use of rigid intermaxillary fixation, the vertical change was primarily in the gonial region rather than more anteriorly at menton (Table 2).

Compared to other malocclusions, Class III cases commonly present with a greater degree of dentoalveolar compensation, especially in the incisor region. Correction of the incisor inclinations facilitates a greater surgical movement. The literature contains little reference to dental changes achieved by orthodontic treatment prior
to surgery (Nakajima et al., 1979). The only comparable investigation that stated presurgical changes in incisor inclination is by Soya et al. (1983). In their study, 16 patients received similar orthodontic treatment and mandibular surgery. However, their sample consisted of more severe cases as the surgical movement in the horizontal plane ranged from 7 to 25 mm (mean value 15.6 mm). Both upper and lower incisors were measured to the Frankfort plane. The presurgical proclination of lower incisors achieved was 6.1 degrees while the upper incisors were retroclined by 4.5 degrees, compared to 8.1 degrees of proclination of the lower incisors in the present study with very little mean change in the upper incisor inclination. The changes in incisor inclinations in the post-surgical period were small and insignificant in both studies.

In an analysis of records of 24 Class III patients treated without orthodontics, Barton (1977) found that in 18 of the patients there was no forward movement of the lower incisors one year after operation. Reitzik (1980) examined records of 50 patients with Class III malocclusions corrected surgically, but without any orthodontic intervention. 11 cases received a sagittal split osteotomy—in eight the incisors proclined in the post-operative period whilst three retroclined. The mean net gain in proclination was 1.2 degrees. In the present study, the net gain in lower incisor proclination of 6.2 degrees is similar to that of Soya et al. (1983). However, both studies exhibit a large variation in incisal inclinations at all stages of treatment.

Changes in incisor inclination are often deceptive in orthognathic surgery. Those decompensations which are achieved by unstable orthodontic mechanics before surgery often begin to relapse when fixation is released and compound the situation which is inherently a post-surgical problem. Dental changes which occur during intermaxillary fixation without skeletal stabilization manifest themselves in a similar manner when fixation is released. The minimal changes in incisor inclinations following surgery in this study were paralleled by similar small changes in postoperative mandibular position, Hence, no significant correlations were found between the post-surgical skeletal and dental changes. The combined orthodontic/surgical approach is more common in the young adult compared to the older patient (Tornes and Lyberg, 1987). However, this may partly be a reflection of its availability and the increasing level of co-operation between the specialities in treating more severe malocclusions.

Presurgical orthodontic treatment, while being a practical necessity in many cases, may predispose to relapse following surgery. Epker and Wessberg (1982) feel that a significant aetiological factor in early skeletal relapse is the increased mobility of the teeth. This mobility, often significant following rapid presurgical orthodontic treatment facilitates the movement of the teeth through the alveolar bone during dental stabilization and permits an accelerated skeletal relapse with even greater dental compensations. Bell and Creekmore (1973) suggest that more stable results may be achieved by correcting the mandible surgically before or with a minimum of orthodontic treatment, and that the alignment be completed when the mandible has stabilized. However, orthodontic decompensation allows a larger surgical correction, and this may be a more important factor in the relapse. Both Nakajima et al. (1979), and Peppersack and Chausse (1978) failed to find any correlation between the anterior movement and anterior relapse of the mandible in patients with Class III malocclusion treated with surgery, while Kobayashi et al. (1986) found a significant correlation ($r=0.58, P<0.01$) for the above parameters at point B. In the present study, the magnitude of relapse, measured along the horizontal axis at point B, was associated with surgical change at the same point ($r=0.57, P<0.05$).

The association between the post-surgical and surgical change was greater for angle SNB ($r= -0.68, P<0.01$). However, this type of correlation must be regarded with caution since the values are computed from a common data point (T3, the post-surgical radiograph) and false negative correlations are likely (Houston, 1983).

Conclusions

Despite limiting the present investigation to Class III malocclusions treated by sagittal split osteotomy, no significant patterns in either the dental or skeletal changes emerged. However, the study does confirm that most of the dental decompensation in Class III surgical correction is stable.

The skeletal relapse following surgery was
limited, but variable. This was not related to the
dental changes. The study illustrates the range of
variation which indicates that relapse is a multi-
factorial problem.

Address for correspondence
Mr N. S. Vasir
Orthodontic Department
University College and Middlesex School of Dentistry
Mortimer Market
London WCIE 6JD

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