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Skeletal and dento-alveolar stability after surgical-orthodontic treatment of anterior open bite: a retrospective study

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SUMMARY The aim of this investigation was to assess skeletal and dento-alveolar stability after surgical-orthodontic correction of skeletal anterior open bite treated by maxillary intrusion (group A) versus extrusion (group B). The cephalometric records of 49 adult anterior open bite patients (group A: $n = 38$, group B: $n = 11$), treated by the same maxillofacial surgeon, were examined at different timepoints, i.e. at the start of the orthodontic treatment (T1), before surgery (T2), immediately after surgery (T3), early post-operatively (±20 weeks, T4) and one year post-operatively (T5). A bimaxillary operation was performed in 31 of the patients in group A and in six in group B. Rigid internal fixation was standard. If maxillary expansion was necessary, surgically assisted rapid palatal expansion (SRPE) was performed at least 9 months before the Le Fort I osteotomy. Forty-five patients received combined surgical and orthodontic treatment.

The surgical open bite reduction (A, mean 3.9 mm; B, mean 7.7 mm) and the increase of overbite (A, mean 2.4 mm; B, mean 2.7 mm), remained stable one year post-operatively. SNA (T2–T3), showed a high tendency for relapse. The clockwise rotation of the palatal plane (1.7 degrees; T2–T3), relapsed completely within the first post-operative year. Anterior facial height reduction (A, mean –5.5 mm; B, mean –0.8 mm) occurred at the time of surgery.

It can be concluded that open bite patients, treated by posterior Le Fort I impaction as well as with anterior extrusion, with or without an additional bilateral sagittal split osteotomy (BSSO), one year post-surgery, exhibit relatively good clinical dental and skeletal stability.

Introduction

The results of combined orthodontic and surgical treatment of skeletal open bites in adults are known to be rather unpredictable (Denison *et al.*, 1989). Variable rates and amounts of relapse have been reported after surgery (Forsell *et al.*, 1992). Relapse has a skeletal and a dento-alveolar component, and its aetiology is considered to be multifactorial. Among other factors, the type of osteotomy is claimed to play an important role in post-treatment stability (Brammer *et al.*, 1980; Hiranaka and Kelly, 1987). The surgical treatment of preference has changed over the years from mandibular osteotomies, including segmental osteotomies, to maxillary procedures (Epker and Fish, 1977). Surgical procedures involving a Le Fort I osteotomy render more stable and predictable results than those obtained with only mandibular ramus osteotomies (Schmidt and Sailer, 1991). Some studies have shown that bimaxillary osteotomies result in less mandibular, but more maxillary relapse than in each of the separate osteotomies (Hiranaka and Kelly, 1987). Others have, however, reported a comparable relapse tendency for both procedures

(Turvey *et al*., 1988). Another influencing factor of relapse, is the type of fixation used during surgery. Previously, maxillary osteotomies were stabilized with intra-osseous wires with or without infra-orbital, circumzygomatic or piriform rim suspension wires (Lello, 1987), while mandibular ramus osteotomies were stabilized by superior and inferior border wiring (Singer and Bays, 1985). In the 1980s, rigid fixation techniques using miniplates and/or screws were introduced to reduce post-surgical relapse (Rittersma *et al*., 1981). Internal plate fixation resulted in improved maxillary stability than intra-osseous wire fixation, however, results in the early post-operative period were masked by initial superior movement of the maxilla, when using wire fixation (Hoppenreijs *et al*., 1997). During the first 6 weeks, these maxillae demonstrated a tendency to move further superiorly, but these changes were reversed by inferior movement from the time of fixation release to one year follow-up (Bailey *et al*., 1994). Furthermore, post-treatment dento-alveolar changes (orthodontic relapse) may result in instability (McCance *et al*., 1992). It is, however, difficult to distinguish between orthodontically related post-surgical changes and those occurring from skeletal instability. Dental changes can accentuate or conceal skeletal changes.

The purpose of the present study was to evaluate the results of anterior open bite correction using an intrusive or extrusive Le Fort I maxillary osteotomy with small internal plate fixation immediately after surgery and one year post-operatively in order to identify relapse patterns and sites of relapse.

Subjects and methods

Patient selection

The records of 49 adult patients consecutively treated for anterior skeletal open bite were studied retrospectively. The inclusion criteria were:

1. the lack of vertical overlap of the central incisors on lateral cephalometric radiographs at the start of treatment;
2. open bite correction with a Le Fort I osteotomy, with or without a mandibular ramus osteotomy and/or genioplasty;
3. rigid internal plate fixation and operated on by the same maxillo-facial surgeon;
4. availability of pre-treatment, pre-operative, immediate and late post-operative cephalograms.

The subjects were divided into two groups. Group A (n = 38) consisted of patients with posterior and anterior impaction of the maxilla whereas group B (n = 11) consisted of those with anterior extrusion of the maxilla. All patients were healthy adults with a mean age for the total group of 20.5 years at the time of surgery, without further dentofacial anomalies.

The groups consisted of 31 females and 18 males (group A: 28 females and 10 males; group B: three females and eight males). The mean age was 20.9 years (SD = 6.9; range: 14.8–39.6 years) for the women and 20.1 years (SD = 4.5; range: 16.5–30.8 years) for the men. Forty-five patients received pre- and post-operative orthodontic treatment. All maxillae were moved into their correct relationship with the cranial base by a Le Fort I down fracture procedure.

Of the 38 patients who had an impaction of the maxilla (group A), a Le Fort I osteotomy as the only procedure was performed in seven subjects. In 31 patients, a bilateral mandibular sagittal split osteotomy was additionally performed. From the 11 patients who had an extrusion of the maxilla (group B), five had a Le Fort I osteotomy only, and the other six underwent an additional bilateral mandibular sagittal split osteotomy (BSSO). An additional genioplasty was performed in 16 patients in order to improve facial harmony (Table 1). No correction of the transverse relationship was performed during the Le Fort osteotomy. When necessary, the transverse dimension was corrected by surgically assisted rapid palatal expansion (SRPE), 9–12 months before the Le Fort I osteotomy.

In the presentation of the results the mandibular changes will be excluded since the impaction and extrusion groups in this study were too small to differentiate between uni- or bimaxillary surgeries.

Table 1 Overview of treatment characteristics.

Type of osteotomy	No.	Genioplasty	Orthodontics	Type BSSO	
				Set-back	Advancement
Group A: maxillary impaction					
Le Fort I only	7	3	7	/	/
Bimaxillary surgery	31	12	29	8	23
Group B: maxillary extrusion					
Le Fort I only	5	1	3	/	/
Bimaxillary surgery	6	0	6	6	0

BSSO: Bilateral sagittal split osteotomy.

Method of analysis

Lateral cephalometric radiographs were available from start of orthodontic treatment (T1), pre-operatively (±51 days, T2), immediately post-operatively (±4 days, T3), approximately 140 days post-operatively (T4), and one year post-operatively (T5). The mean follow-up time was 374 days (SD = 20.9 days; range 332–416 days). The radiographs were taken with the patient orientated with the Frankfort plane horizontal, the teeth in centric occlusion and the lips at rest. The lateral headplates were traced and one and the same person manually identified the cephalometric landmarks. Linear and angular variables were measured for skeletal and dento-alveolar analysis. The cephalometric analysis described by Hoppenreijs *et al.* (1997) was used for this purpose (Figure 1).

A horizontal reference line (S'N) that approximates the Frankfort horizontal was constructed: a line through nasion rotated 7 degrees from the sella-nasion line (Burstone *et al.*, 1978). This line is a correction for canting of the anatomic SN-line. The selected maxillary landmarks were: point A, anterior nasal spine (ANS), posterior nasal spine (PNS), the incisal edge of the maxillary central incisor (+1i), the apex of the maxillary central incisor (+1a), the mesio-buccal cusp tip of the left maxillary first molar (+6). The selected mandibular landmarks were: point B, menton (Me), gonion (Go), the incisal edge of the mandibular central incisor

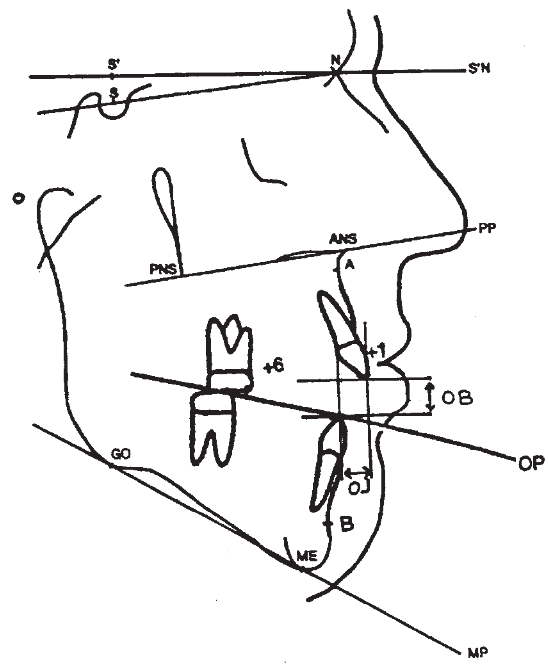

Figure 1 Cephalometric landmarks and linear measurements as described by Hoppenreijs *et al.* (1997) used to evaluate stability of surgically corrected open bites. The horizontal reference line S'N is a line through nasion (N) clockwise rotated 7 degrees from the sella–nasion line. Overbite (OB) is the distance between two lines, crossing the incisal edge of upper and lower central incisor, parallel to S'N. Overjet (OJ) the distance between two lines, crossing the incisal edge of upper and lower central incisor, perpendicular to S'N. Occlusal plane (OP) a line through the incisal edge of the mandibular central incisor and the mesio-buccal cusp tip of the first mandibular molar. Mandibular plane (MP) a line through menton (Me) and gonion (Go). Palatal plane (PP) a line through the anterior nasal spine (ANS) and the posterior nasal spine (PNS).

(–1i), the apex of the mandibular central incisor (–1a), the mesiobuccal cusp tip of the left mandibular first molar (–6). The lines and planes used were: horizontal reference line (S'N), sella-nasion line (SN), palatal plane (PP, i.e. ANS–PNS), occlusal plane (OP; i.e. –1i–6), mandibular plane (MP, i.e. Me–Go).

Using these landmarks and lines the linear and angular post-operative changes of the maxilla were determined. The horizontal maxillary movements were assessed in degrees by SNA and SN–PP, the vertical movements in millimetres by +1i/S'N and +6/S'N, and by +1i/PP and +6/PP.

The interincisal angle (–1–+1) and the inclination of the upper and lower incisors were both measured (–1–MP, +1–PP). Overbite was recorded as the distance between two lines drawn through +1i and –1i, parallel to S'N; and overjet as the distance between two lines drawn through +1i and –1i, perpendicular to S'N. Open bite was measured as the distance from –1i, in the direction of its long axis, to the maxillary central incisor or the palate in a subject with a positive overjet. In a subject with a reverse overjet, the open bite distance was measured from +1i, in the direction of its long axis, to the mandibular central incisor or the lingual surface of the mandible.

Linear and angular changes in the horizontal and vertical directions were measured for the consecutive time intervals: T1–T2 (pre-operative period), T2–T3 (intra-operative period), T3–T4 (early post-operative period), T4–T5 (late post-operative period), T3–T5 (overall post-operative period) and T2–T5 (operation + one year follow-up).

Statistical analysis

Statistical analysis was performed with SAS-procedure PROC MIXED (SAS/STAT software, SAS institute Inc., Cary, NC, USA) since some data were missing. The accuracy of landmark identification, superimposition, and measurements were evaluated by retracing three cephalometric radiographs at intervals T2, T3, and T4 of 15 randomly selected patients. The error of the method was determined by comparing all variables on the 45 corresponding radiographs, at different periods and corresponding time intervals.

Results

The reliability of the measurements showed correlation coefficients between 0.965 and 0.997, indicating high measurement reliability. Table 2 shows mean values of variables before orthodontic treatment (T1), pre-operatively (T2), immediately post-operatively (T3), approximately 140 days post-operatively (T4), and one year post-operatively (T5).

Mandibular and maxillary dento-alveolar changes (Tables 3–4)

During the pre-operative period (T1–T2) a vertical displacement of the maxillary incisors (+1i/S'N) occurred: a mean orthodontic extrusion of 0.6 mm was seen. This change was not significantly different for groups A or B. The vertical displacement of the upper left molar (+6/S'N) was significantly different between the groups: no change was seen in group A, a significant extrusion of 1.5 mm was seen in group B. Pre-operatively the mean open bite was 7.3 mm (5.8 mm for group A, 8.7 mm for group B).

During surgery (T2–T3) the interincisor angle increased significantly (7.0 degrees). The open bite decreased 5.0 mm and the overbite increased 2.0 mm. As part of the surgical procedure, the posterior occlusion was opened in both groups: a posterior open bite was created intra-operatively.

Early post-operatively (T3–T4) the interincisor angle relapsed: a reduction of 2.4 degrees occurred within the first 140 days after surgery. The inclination of the maxillary and mandibular incisors however remained unchanged.

Late post-operatively (T4–T5) the open bite re-opened in group A (0.3 mm), whereas a supplementary closure of 1.2 mm was seen in group B.

During the total follow-up period (T3–T5) the decrease of interincisor angle was 2.9 degrees. The vertical position of the upper first molar (+6/PP) showed a significant reduction: 0.7 mm intrusion (Figure 2). This change was not

Table 2 Mean values of variables before orthodontic treatment (T1), pre-operatively (T2), immediately post-operatively (T3), approximately 140 days post-operatively (T4), and one year post-operatively (T5).

Time intervals		T1	T2	T3	T4	T5
+1–PP (°)	group A	33.1	33.8	33.8	33.6	33.7
	group B	29.8	29.7	30.1	29.9	31.2
–1–MP (°)	group A	85	85.7	87.3	87.7	87.4
	group B	79.3	83.8	82.6	84.3	82.8
–1–+1 (°)	group A	130	130.7	138	135.5	135.1
	group B	142.2	139.3	145	143.2	142.7
Overbite (mm)	group A	–0.7	–0.6	1.3	1.4	1.8
	group B	–2.1	–1.9	0.2	0.4	0.8
Overjet (mm)	group A	5.1	3.9	2.6	2.9	3.2
	group B	–4.3	–2.4	2.8	1.8	3.9
Open bite (mm)	group A	6.4	5.8	1.1	1.6	1.9
	group B	6.6	8.7	2.3	2.3	1.1
SN–PP (°)	group A	7.9	7.8	9.2	8.7	8
	group B	8.9	9.4	11.8	12.1	9.3
S–N–A (°)	group A	80	79.8	83.7	83.4	83
	group B	77.4	77.9	83.2	83.2	82.5
+1/S'N (mm)	group A	80.4	81.1	79.6	79.8	79.6
	group B	88.2	89	90.3	91.1	90
+1/PP (mm)	group A	33.1	33.8	33.8	33.6	33.7
	group B	29.8	29.7	30.1	29.9	31.2
+6/S'N (mm)	group A	84.8	84.9	81	80.6	80.5
	group B	83.6	85.1	85.1	85.5	84.6
+6/PP (mm)	group A	27.9	28.1	27.9	27.4	27.1
	group B	27.1	27	27.2	27.2	26.9
S–Go (mm)	group A	81.9	83	82.6	79.7	80
	group B	87.7	89	89.5	89.8	90.6
N–Me (mm)	group A	139.1	139.7	134.2	133.3	133.6
	group B	135.9	137.1	136.3	136.5	134.2
ANS–Me (mm)	group A	84.1	85	81.3	81.1	81.7
	group B	77.8	78.3	76.3	76.4	75.4
N–ANS (mm)	group A	57.8	57.8	54.5	54.4	54.3
	group B	60.2	60.6	58.3	58.7	57.3

Table 3 Mean changes of dento-alveolar measurements for all examined patients pre-operatively (T1–T2), intra-operatively (T2–T3), early post-operatively (T3–T4), late post-operatively (T4–T5), one-year follow-up (T3–T5) and one-year follow-up with surgery included (T2–T5).

Time intervals	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
+1–PP (°)	–1.5	1.2	NS	–0.4	0.8	NS	0	0.8	NS	–0.7	0.7	NS	–0.7	0.1	NS	–1.1	0.9	NS
–1–MP (°)	1.5	1.1	NS	1	0.7	NS	0.6	0.6	NS	–0.5	0.7	NS	0.1	0.8	NS	1.1	0.9	NS
–1–+1 (°)	0	1.7	NS	7	1.1	***	–2.4	0.7	**	–0.5	0.7	NS	–2.9	1	**	4.1	1.3	**
Overbite (mm)	0.1	0.4	NS	2	0.6	**	0.1	0.3	NS	0.4	0.3	NS	0.5	0.3	NS	2.5	0.6	NS
Overjet (mm)	–0.5	1.1	NS	–0.1	0.9	NS	0.1	0.2	NS	0.3	0.2	NS	–0.4	0.3	NS	0.3	0.9	NS
Open bite (mm)	0	0.5	NS	–5	0.6	***	0.4	0.3	NS	0	0.2	NS	0.4	0.3	NS	–4.6	0.6	***

NS: not significant; $^{**}P < 0.01$; $^{***}P < 0.0001$.

Table 4 Mean changes of dento-alveolar measurements after Le Fort I impaction osteotomy versus Le Fort I extrusion osteotomy.

Time intervals	A versus B	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
+1–PP (°)	NS	1.7	/	/	–1.7	/	/	0.7	/	/	–0.3	/	/	0.4	/	/	–1.3	/	/
–1–MP (°)	NS	3.8	/	/	–2.9	/	/	1.3	/	/	–1.2	/	/	0.2	/	/	–2.7	/	/
–1–+1 (°)	NS	–3.6	/	/	–1.6	/	/	0.7	/	/	0	/	/	0.7	/	/	–0.9	/	/
Overbite (mm)	NS	0.1	/	/	0.1	/	/	0.1	/	/	0	/	/	0.1	/	/	0.3	/	
Overjet (mm)	***	3.2	3.8	NS	6.5	2.4	**	–1.3	0.6	*	1.8	0.7	**	0.5	0.8	NS	7	2.8	*
Open bite (mm)	**	2.8	1.5	NS	–1.8	2	NS	–0.5	0.6	NS	–1.5	0.4	**	–2	0.1	**	–3.8	1.7	*

NS: not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.0001$.

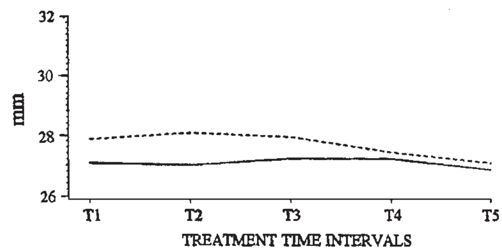

Figure 2 Changes of +6/PP (impaction versus extrusion) during the pre-operative (T1–T2), intra-operative (T2–T3), and follow-up periods (T3–T5).

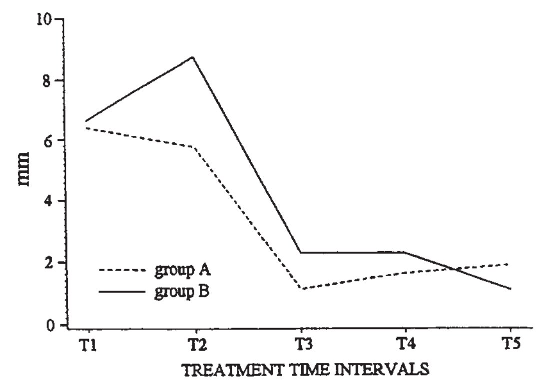

Figure 3 Change in open bite (impaction versus extrusion) during the pre-operative (T1–T2), intra-operative (T2–T3), and follow-up periods (T3–T5).

significantly different between the groups. One year post-surgery the open bite was increased 0.8 mm in group A and a supplementary decrease of 1.2 mm occurred for group B. The mean open bite at T5 was 1.5 mm.

Total change of variables from T2 (pre-operatively) to T5 (one-year follow-up) showed a mean open bite reduction of 4.6 mm, which was stable one year post-operatively. The reduction of the open bite was however significantly different for both groups. In group A, the open bite was reduced by 3.9 mm. In group B, this reduction was nearly double: 7.6 mm (Figure 3). The mean overbite at one-year follow-up was 1.3 mm, whereas it was –1.3 mm pre-operatively. A lack of vertical overlap between opposing central incisors was present in 11 per cent of patients. No statistically significant difference between the groups was found for overbite (Figure 4). The interincisor angle decreased by 4.1 degrees and

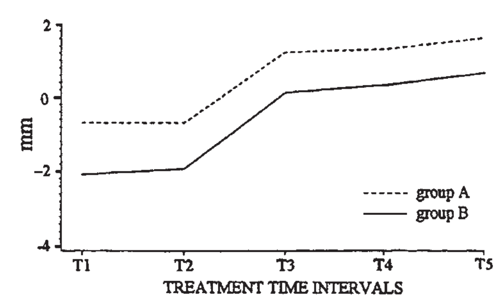

Figure 4 Change in overbite (impaction versus extrusion) during the pre-operative (T1–T2), intra-operative (T2–T3), and follow-up periods (T3–T5).

the upper first molar was intruded by 0.8 mm (T2–T5).

Maxillary movements (Tables 5–6)

No changes occurred in maxillary measurements during the pre-operative period (T1–T2).

During surgery (T2–T3) the distance of +1/S'N and +6/S'N decreased for group A 1.5 mm and 3.9 mm, respectively. For group B, these increased 1.3 and 0.1 mm, respectively. Both maxillary movements resulted in a clockwise tilting of the palatal plane (1.7 degrees). Due to this clockwise tilting and advancement of the maxilla, the SNA-angle increased by 4.2 degrees.

No significant changes in maxillary measurements occurred early post-operatively (T3–T4).

Late post-operatively (T4–T5) the canting of the palatal plane (SN–PP) decreased significantly by 1.0 degrees.

After the total follow-up period (T3–T5) the change of SN-PP was no longer significant (Figure 5). Also the sagittal maxillary position (SNA) relapsed significantly (–0.74 mm).

Total change of variables from T2 (pre-operatively) to T5 (one-year follow-up) showed a significant reduction of +1/S'N and +6/S'N (1.0 and 3.6 mm, respectively). The change of +6/S'N was significantly different for both groups: group A showed a reduction of 4.3 mm and group B 0.5 mm. Despite the significant relapse of SNA from T3 to T5, the intra-operative increase of SNA was still significant after one year (+3.5 degrees).

Table 5 Mean changes of maxillary measurements for all examined patients pre-operatively (T1–T2), intra-operatively (T2–T3), early post-operatively (T3–T4), late post-operatively (T4–T5), one-year follow-up (T3–T5) and one-year follow-up with surgery included (T2–T5).

Time intervals	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
SN–PP (°)	0	0.3	NS	1.7	0.6	**	–0.4	0.3	NS	–1.1	0.4	*	–1.5	0.4	***	0.2	0.5	NS
S–N–A	0.2	0.4	NS	4.2	0.5	***	–0.3	0.3	NS	–0.4	0.3	NS	–0.7	0.3	*	3.5	0.5	***
+1/S'N (mm)	0.6	0.2	**	–0.9	0.5	NS	0.3	0.2	NS	–0.4	0.3	NS	–0.1	0.2	NS	–1	0.4	*
+1/PP (mm)	0.5	0.2	NS	0.1	0.2	NS	–0.2	0.2	NS	0.3	0.3	NS	0.1	0.3	NS	0.2	0.3	NS
+6/S'N (mm)	0.4	0.3	NS	–3.1	0.5	***	–0.3	0.3	NS	–0.2	0.3	NS	–0.5	0.3	NS	–3.6	0.5	***
+6/PP (mm)	0.1	0.3	NS	–0.1	0.2	NS	–0.4	0.3	NS	–0.3	0.3	NS	–0.7	0.3	*	–0.8	0.3	*

NS: not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.0001$.

Table 6 Mean changes of maxillary movements after Le Fort I impaction osteotomy versus Le Fort I extrusion osteotomy.

Time intervals	A versus B	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
SN–PP (°)	NS	0.7	/	/	0.9	/	/	0.8	/	/	–2	/	/	–1.3	/	/	–0.4	/	/
S–N–A (°)	NS	0.4	/	/	1.4	/	/	0.3	/	/	–0.3	/	/	0	/	/	1.4	/	/
+1/S'N (mm)	***	0	0.7	NS	2.8	1.2	*	0.5	0.5	NS	–0.9	1.1	NS	–0.4	0.8	NS	2.5	1.3	NS
+1/PP (mm)	NS	–0.8	/	/	0.4	/	/	0	/	/	1.2	/	/	1.2	/	/	1.6	/	/
+6/S'N (mm)	***	1.4	0.5	*	3.9	1	**	0.8	0.6	NS	–0.9	0.8	NS	–0.1	0.7	NS	3.8	0.9	***
+6/PP (mm)	NS	–0.3	/	/	0.3	/	/	0.5	/	/	0	/	/	0.5	/	/	0.8	/	/

NS: not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.0001$.

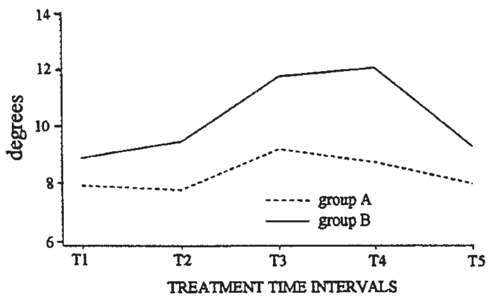

Figure 5 Change in SN–PP (impaction versus extrusion) during the pre-operative (T1–T2), intra-operative (T2–T3), and follow-up periods (T3–T5).

Facial height (Tables 7–8)

In the pre-operative period (T1–T2) no significant change of total anterior face height occurred. The lower anterior facial height (ANS–Me) on the contrary increased significantly (0.8 mm).

During surgery (T2–T3) total anterior face height (N–Me) decreased in both groups. This mean decrease was more pronounced in group A (–5.5 mm) than in group B (–0.8 mm). The mean decrease in lower anterior face height (ANS–Me) was 3.3 mm and in upper anterior face height (N–ANS) 3.0 mm (T2–T3). No statistically significant difference for posterior face height (S–Go) was seen during surgery

Early post-operatively (T3–T4) group A had a significant reduction of 2.4 mm for S–Go and group B showed a minor, yet significant, increase of 0.3 mm.

Late post-operatively (T4–T5) the change of total anterior face height (N–Me) was significantly different for both groups. Group A had an increase of 0.3 mm; group B had a decrease of 2.3 mm.

The early post-operative change of S–Go was still significant at one-year follow-up (T3–T5;

Table 7 Mean changes of face height for all examined patients pre-operatively (T1–T2), intra-operatively (T2–T3), early post-operatively (T3–T4), late post-operatively (T4–T5), one-year follow-up (T3–T5) and one-year follow-up with surgery included (T2–T5).

Time intervals	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
S–Go (mm)	1.1	0.6	NS	0	1.1	NS	–2.4	0.9	**	0	0.8	NS	–2.4	0.7	**	–2.4	1.1	*
N–Me (mm)	0.7	0.5	NS	–4.5	0.7	***	–0.7	0.6	NS	–0.2	0.5	NS	–0.8	0.4	NS	–5.4	0.6	***
ANP–Me (mm)	0.8	0.4	*	–3.3	0.6	***	–0.2	0.4	NS	0.4	0.4	NS	0.2	0.6	NS	–3.1	0.6	***
N–ANS (mm)	0.1	0.3	NS	–3	0.8	**	0	0.2	NS	–0.3	0.3	NS	–0.4	0.3	NS	–3.4	0.6	***

NS: not significant; *P < 0.05; **P < 0.01; ***P < 0.0001.

Table 8 Mean changes of face height maxillary movements after Le Fort I impaction osteotomy versus Le Fort I extrusion osteotomy.

Time intervals	A versus B	T1–T2			T2–T3			T3–T4			T4–T5			T3–T5			T2–T5		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
S–Go (mm)	**	0.2	1.7	NS	0.9	1.9	NS	3.3	1	**	0.6	1.4	NS	3.8	1.2	**	4.8	1.3	**
N–Me (mm)	***	0.7	1.1	NS	4.6	1.6	**	1.1	1.1	NS	–2.6	0.8	**	–1.5	1.1	NS	3.1	1	**
ANP–Me (mm)	NS	–0.4	/	/	1.7	/	/	0.3	/	/	–1.6	/	/	–1.3	/	/	0.4	/	/
N–ANS (mm)	NS	0.5	/	/	1	/	/	0.6	/	/	–1.3	/	/	–0.7	/	/	0.2	/	/

NS: not significant; **P < 0.01; ***P < 0.0001.

Figure 6). The changes in anterior face height were all stable at one-year follow-up.

Discussion

The aim of this investigation was to assess skeletal and dento-alveolar stability after surgical-orthodontic correction of skeletal anterior open bite treated by maxillary intrusion (group A) versus extrusion (group B). Cephalometric records of 49 adult anterior open bite patients (group A: *n* = 38, group B: *n* = 11), treated by the same maxillofacial surgeon, were examined at different timepoints. Cephalometric analysis of patients undergoing surgical-orthodontic treatment is however fraught with problems related to landmark identification. Landmarks can be altered by orthodontic treatment, surgery, and bone remodelling. In addition, it is difficult to distinguish between orthodontically related post-surgical changes and those occurring from skeletal instability (Hoppenreijs *et al*., 1997).

The same maxillofacial surgeon treated all the patients in this one-centre study yet a number of different orthodontists performed the orthodontic treatment, with four patients receiving no orthodontic treatment. There was also variation in the surgical procedures: 16 received a genioplasty to improve facial harmony. It has, however, been proven that stability of the surgical procedure is not influenced by orthodontic treatment (Bailey

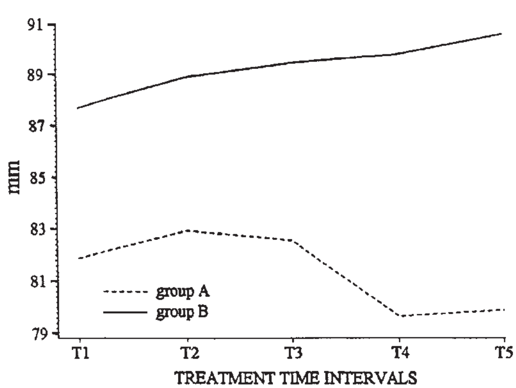

Figure 6 Change in S–Go (impaction versus extrusion) during the pre-operative (T1–T2), intra-operative (T2–T3), and follow-up periods (T3–T5).

et al., 1994) or additionally performed genioplasty (Turvey *et al*., 1988).

The advantages of plate fixation both on clinical grounds and for patients' comfort are factors in favour of using miniplates for maxillary and mandibular surgical procedures. Rigid internal fixation has proved its advantages in skeletal stability compared with wire fixation (Rubens *et al*., 1988; Kahnberg *et al*., 1994).

Lo and Shapiro (1998) registered that there was no relationship between pre-surgical extrusion of the maxillary incisors and the stability of the open bite correction: a moderate amount of pre-surgical incisor extrusion is stable long-term and has little influence on post-treatment stability of an open bite. However, Ellis and McNamara (1984, 1985) stated: 'A basic treatment principle is to correct rather than camouflage the existing deformity'. Orthodontic extrusion of anterior teeth in an open bite patient is not desirable as it merely camouflages the existing deformity and the result is often unnatural in appearance. Therefore, pre-surgical orthodontic extrusion of the anterior teeth has to be reduced to a minimum.

Drawing conclusions about the reduction of overjet is difficult as no differentiation was made between uni- or bimaxillary surgery, and as there were more Class II-subjects in the impaction group and more Class III-patients in the extrusion group.

Due to a clockwise rotation of the maxilla (increase of SN–PP angle) and counter-clockwise rotation of the mandible (decrease of SN–MP angle) at the time of surgery, the posterior occlusion was opened in both groups. A posterior open bite is created intra-operatively. This bite opening is normally supported by a thick acrylic wafer and should be closed post-operatively by gradual grinding of the acrylic from posterior to anterior, combined with vertical traction using elastics to enforce the extrusion of the maxillary molars (Haymond *et al*., 1991). In this study, however, no post-operative extrusion of the maxillary molars occurred. On the contrary, a statistically significant intrusion was found (Figure 2). An explanation might be that the molars were unable to extrude due to the use of a rigid wire in this final stage of orthodontic treatment. It may be that elastic traction on this rigid dental complex caused skeletal relapse in this patient group: a total relapse of the SN–PP angle one year post-operatively was seen (Figure 5).

Lower anterior face height increased in the pre-operative period. This was probably caused by uprighting of the molars, especially of the lower molars in a Class III situation. The uprighting of these lingually positioned lower molars opens the bite. On the other hand, a contributing factor in the decrease of anterior face height during surgery may be the genioplasty performed in 16 patients.

The fact that no change in posterior face height was seen during surgery indicates that the mandibular ramus remained in its original position. This is important for the well being of the temporomandibular joint (TMJ). In this sample there were no subjective signs of TMJ-disorders after surgery.

The decrease of posterior face height early post-operatively in the impaction group can be explained by remodelling of the gonial angle after bimaxillary surgery. The impaction group comprised far more Class II patients who received a BSSO advancement. Remodelling of the gonial angle is probably more pronounced after a BSSO advancement than after BSSO set-back. In the case of a setback, the gonial angle after surgery is composed of bicortical bone, whereas in the case of advancement there is no overlap of cortical bone. Since mono-cortical bone is probably more prone to resorption and remodelling, the gonial angle will be less pronounced and S–Go will decrease.

Surgical-orthodontic treatment usually results in three-dimensional correction of skeletal and dento-alveolar components in patients with severe anterior open bite. Reasonable stability in a vertical and antero-posterior direction, following surgical correction, was found in this study. The stability of transverse corrections is just as important when trying to achieve a stable and functional occlusion (Nemeth *et al.*, 1995). Transverse widening of the maxilla, however, is prone to relapse (Philips *et al.*, 1992; Hoppenreijs *et al.*, 1998). Post-treatment relapse of transverse expansion carries the risk of extrusion of molars and premolars, deterioration of interdigitation, subsequent clockwise rotation of the mandible and tongue interposition, and thus, relapse of the vertical open bite (Hoppenreijs *et al.*, 1997).

The impaction and extrusion groups in this study were too small to differentiate between uni- or bimaxillary surgery. This difference in treatment is, however, important, since horizontal maxillary movements are found to be more stable after bimaxillary than one jaw surgery (Turvey *et al.*, 1988). Well-controlled, prospective research is needed to document the exact movement of the dento-alveolar segments during the orthodontic and surgical phases of treatment, and to study their relationship to stability of treatment.

Conclusions

Open bite patients, treated with Le Fort I impaction or extrusion, with or without an additional BSSO, exhibit good skeletal maxillary stability one year post-surgery. However, canting of the palatal plane relapsed completely within the first year after surgery.

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