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Skeletal and dental stability of segmental distraction of the anterior mandibular alveolar process. A 5.5-year follow-up

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Abstract. 17 patients (14 female; 3 male) were analysed retrospectively for skeletal and dental relapse before distraction osteogenesis (DO) of the mandibular anterior alveolar process at T1 (17.0 days), after DO at T2 (mean 6.5 days), at T3 (mean 24.4 days), at T4 (mean 2.0 years), and at T5 (mean 5.5 years). Lateral cephalograms were traced by hand, digitized, superimposed, and evaluated. Skeletal correction (T5–T1) was mainly achieved through the distraction of the anterior alveolar segment in a rotational manner where the incisors were more proclined. The horizontal backward relapse (T5–T3) measured −0.3 mm or 8.3% at point B (non-significant) and −1.8 mm or 29.0% at incision inferior ($p < 0.01$). Age, gender, amount and type (rotational vs. translational) of advancement were not correlated with the amount of relapse. High angle patients (NL/ML′; $p < 0.01$) showed significant smaller relapse rates at point B. Overcorrection of the overjet achieved by the distraction could be a reason for dental relapse. Considering the amount of long-term skeletal relapse the DO could be an alternative to bilateral sagittal split osteotomy for mandibular advancement in selected cases.

Key words: distraction osteogenesis; skeletal stability; dental stability; relapse; cephalometrics.

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The principles of distraction osteogenesis (DO)[1] and its clinical application in maxillofacial surgery[2] have opened new horizons in the treatment of facial and skeletal disharmonies. Mandibular DO is still mainly used in patients with syndromes and congenital anomalies and less in non-syndromic adult patients.[3] Many surgeons still prefer to advance the mandible in one step by bilateral sagittal split osteotomy (BSSO) in normal patients than in several steps by DO. Mandibular DO seems to show similar risk factors for skeletal relapse when compared with BSSO for mandibular advancement.[4]

Today there are new surgical approaches to correct mandibular deficiency. DO of the anterior alveolar mandibular process[5] and mandibular wing osteotomy for the correction of the mandibular plane[6] are two of them. Triaca et al.[5] reported that DO of the mandibular alveolar process can be applied in several specific cases: in skeletal Class II patients with crowding to reduce the required sagittal distance to be achieved by an advancement BSSO; in skeletal Class III patients to create space for the decompensation of the lower incisor inclination; in skeletal Class I patients with a dental Class

II to create space of one premolar width and overjet normalization, and in skeletal and dental Class I patients with crowding to avoid extraction and the resulting unfavorable profile that often results.

Few studies have been published on the results of DO on the anterior alveolar mandibular process.[5] Recently, the soft tissue, skeletal and dental stability, neurosensory and function after DO of the anterior alveolar process were examined 2.0 years postoperatively.[7–9] Skeletal relapse at point B was found in 19%. No correlation between the amount of skeletal relapse and the amount of advancement, patient's age or gender could be demonstrated.[7] Studies on the long-term results of DO of the anterior alveolar process are still lacking. The aims of the present study were to evaluate the amount of skeletal changes and dental changes 5 years after treatment in patients treated with DO of the mandibular anterior alveolar process, and to identify factors related to skeletal and dental stability.

Materials and methods

This study reports the follow-up of an initial sample of 33 patients published previously.[7,8] Of the 33 patients, 17 patients were available for re-examination. The follow-up group (T1) consisted of 17 Caucasian patients (14 females and 3 males); aged 16.5–56.0 years (mean age 29.8 years, SD 11.9).

They were all treated orthodontically by one orthodontist (MA) and underwent DO of the mandibular anterior alveolar process to correct a skeletal Class II and large overjet with or without incisor crowding at the Pyramide Clinic in Zürich, Switzerland in the years 1998–2004. The female patients in the follow-up group had a mean age of 31.7 years (17.1–56.0 years, SD 12.0 years) and the male patients 21.5 years (16.5–31.4 years, SD 8.6 years) at T1. The surgical procedure was performed by one experienced maxillofacial surgeon (AT) and the technique has been published previously.[5,10] Patients receiving other surgical procedures simultaneously on the mandible and maxilla such as genioplasty, BSSO, and Le Fort were excluded. Syndromic or medically compromised patients were excluded.

Five cephalograms were taken: the first on average 17.0 days before surgery (T1); and the second (T2) between 0 and 12 days (mean 6.5 days) after the osteotomy and before any distraction was carried out. The third (T3) cephalogram was taken between 13 and 92 days (mean 24.4 days) when the distraction was completed; the fourth (T4) between 0.9 and 3.7 years (mean 2.0 years) at the end of orthodontic treatment; and the fifth (T5) between 2.7 and 8.3 years (mean 5.5 years) after distraction of the mandibular anterior alveolar process. Lower incisors were retained with a bonded canine to canine retainer. The DO procedure has been described previously.[5,10]

Ethical approval was given by the Ethic Committee of the Kanton Zürich, Switzerland, number 593. All subjects signed written, informed consent.

Cephalometric analysis

Skeletal changes were evaluated on profile cephalograms taken with the teeth in the intercuspal position, including a linear enlargement of 1.2%. The cephalograms were taken with the subject standing upright in the natural head position and with relaxed lips. The same X-ray machine and the same settings were used for all cephalograms.

The lateral cephalograms were scanned and evaluated with the program Viewbox 3.1® (dHal software, Kifissia, Greece). The cephalometric analysis for T1, T2, T3, T4 and T5 was carried out by one author (CUJ) and included the reference points and lines shown in Fig. 1. Horizontal (*X*-values) and vertical (*Y*-values) linear measurements were obtained by superimposing the tracings of the different stages (T2, T3, T4 and T5) on the first radiograph (T1), and the reference lines were transferred to each consecutive tracing. During superimposition, particular attention was given to fitting the tracings of the cribriform plate and the anterior wall of the sella turcica which undergo minimal remodelling.[11] A template of the outline of the mandible of the preoperative cephalogram (T1) was made to minimize errors for superimposing on subsequent radiographs.

Conventional cephalometric variables as well as the coordinates of the reference points (Table 1) were calculated by the computer program. The coordinate system had its origin at point S (sella), and its *X*-axis formed an angle of 7° with the reference line NSL (Fig. 1). Overjet and overbite were calculated from the coordinates of the points Is (incision superior) and Ii (incision inferior).

The lateral cephalograms of T2 were only used to locate the cephalometric point alveolar surgical anterior base (Asab) before postoperative distraction

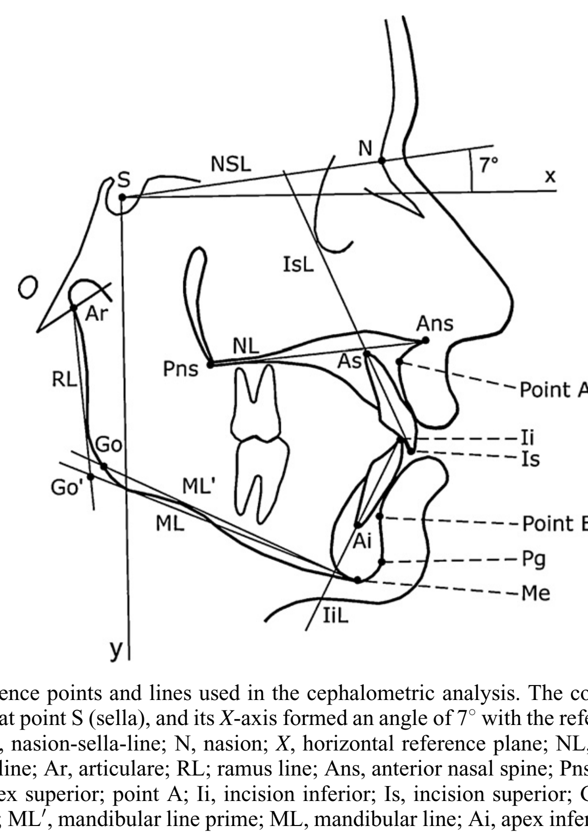

Fig. 1. Reference points and lines used in the cephalometric analysis. The coordinate system had its origin at point S (sella), and its *X*-axis formed an angle of 7° with the reference line NSL. S, sella; NSL, nasion-sella-line; N, nasion; *X*, horizontal reference plane; NL, nasal line; ILs, upper incisal line; Ar, articulare; RL; ramus line; Ans, anterior nasal spine; Pns, posterior nasal spine; As, apex superior; point A; Ii, incision inferior; Is, incision superior; Go, gonion; Go′, gonion prime; ML′, mandibular line prime; ML, mandibular line; Ai, apex inferior; point B; Pg, pogonion; Me, menton; and *y*, vertical reference plane. The Holdeway ratio is the distance between Ii vertical to N-B-line minus distance Pg vertical to N-B-line and the Jarabak ratio is the distance from S to Go′/distance N to Me.

Table 1. Random errors (Si) in mm or degrees of the cephalometric variables.

Variable	Si	Variable	Si	Reference point	Si (mm) X	Si (mm) Y
SNA (°)	1.14	IiL-N-point B (°)	1.14	Incision sup.	0.48	0.21
SNB (°)	0.82	IiL-N-point B (mm)	0.24	Incision inf.	0.58	0.55
ANB (°)	0.48	IiL-A-Pg (°)	1.29	Apex inf.	0.54	0.18
NSL/NL (°)	0.86	IiL-A-Pg (mm)	0.49	Point B	0.28	0.45
NSL/ML′ (°)	1.01	Holdaway ratio	0.47	Asab	0.35	0.25
NL/ML′ (°)	0.84	IsL/IiL (°)	1.63	Pogonion	0.37	1.19
Jarabak ratio	1.15	Overjet	0.36	Menton	0.89	0.45
IsL/NSL (°)	1.52	Overbite	0.53	Gonion′	2.48	1.14
IsL/NL (°)	1.31					
IiL/ML′ (°)	1.39					

See Fig. 1 for details of the variables.

of the alveolar process was carried out. Asab is the most anterior and inferior point of the lower anterior segment resulting from the surgical osteotomy (Figs 2 and 3). This cephalometric point was introduced to evaluate the movement (rotation vs. translation) of the lower anterior segment base in comparison to the lower incisors as the ratio (Ii [X-value; T3–T2]/Asab [X-value; T3–T2]).

Error of the method

To determine the error of the method, 21 randomly selected cephalograms were retraced and re-analysed after a 2-week interval. Horizontal (X-values) and vertical (Y-values) linear measurements were re-obtained by superimposing the tracings of the different stages (T2, T3, T4, and T5) on the first radiograph (T1). The error of the method (Si) was calculated with the formula

$$\mathrm{Si} = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between the repeated measurements and n is the number of duplicate determinations.[12]

The random errors are presented in Table 1. No systematic errors were found when the values were evaluated with a paired t-test. The drop-out analysis included the unpaired t-test to compare drop-outs with the remaining patients for age and cephalometric features at T1, T2, T3 and T4, and the χ^2 test for sex. Drop-out analysis showed that there were no significant differences between the drop-out and the remaining patients for age and cephalometric features at T1, T2, T3 and T4.

Statistical analysis

Statistical analyses were conducted using SPSS software (version 19.0, SPSS Inc., Chicago, IL, USA). Normal distribution was confirmed with the Kolmogorov–Smirnov test. The effect of treatment, i.e. the differences between the variables and co-ordinates at T3 and T1 (T3 and T2 for Asab), T5 and T1 (T5 and T2 for Asab), T5 and T4 were tested with a paired t test. The relationships between skeletal variables, age, and gender were analysed with the Pearson's product moment correlation coefficient.

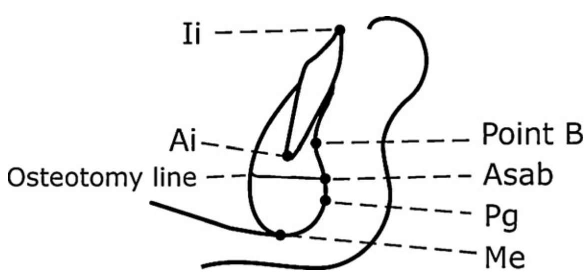

Fig. 2. Reference points used in the cephalometric analysis of the lower apical base in DO patients. Ii, incision inferior; point B; Ai, apex inferior; Asab, apical surgical anterior base; Pg, pogonion; and Me, menton. Asab is the most anterior and inferior point of the lower anterior segment formed by the surgical osteotomy. This cephalometric point was introduced to evaluate the movement (rotation vs. translation) of the lower anterior segment base in comparison to the lower incisors (Ii) as the ratio Ii (X-value)/Asab (X-value).

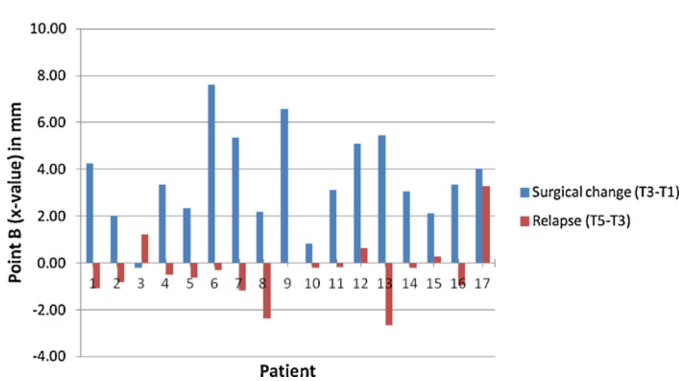

Fig. 3. Surgical change (T3–T1) and amount of relapse (T5–T3) of point B (X-value in mm) in individual patients (n = 17).

Results

Table 2 shows the selected variables before surgery (T1) and at 5.5-year follow-up (T5). The mean changes, standard deviations, and ranges for the selected cephalometric parameters before surgery and during the subsequent observation periods are given in Tables 3 and 4.

Negative values imply a backward and positive values a forward movement of the point in the horizontal plane. In the vertical plane, negative values imply an upward and positive values a downward movement of the point.

Horizontal changes

The mean advancement of the anterior alveolar process immediately following DO (T3–T1) was 3.6 mm at point B, 2.2 mm at Asab (T3–T2), and 6.2 mm at incision inferior (all $p = .000$). Mean relapse (T5–T3) was −0.3 mm or 8.3% at point B, −1.0 mm or 45.5% at Asab (T5–T2), and −1.8 mm or 29.0% at incision inferior of the initial surgical advancement. Figures 3 and 4 show the surgical changes (T3–T1) and the amount of relapse (T5–T3) of point B and overjet. Figure 5 shows the changes of point B and incision inferior over time from T1 to T5.

Regarding the ratio Ii [X-value; T3-T2]/ Asab [X-value; T3–T2], the alveolar

Table 2. Values of selected cephalometric variables at T1 (before surgery) and T5 (5.5 years after surgery).

	T1			T5		
	Mean	SD	Range	Mean	SD	Range
SNA (°)	80.9	3.7	73.1 to 85.7	80.0	2.8	74.0 to 84.4
SNB (°)	76.7	4.2	69.8 to 83.8	77.3	3.8	70.7 to 85.5
ANB (°)	4.2	2.2	0.3 to 7.1	2.7	3.0	−2.9 to 6.3
NSL/NL (°)	7.4	4.1	−1.9 to 15.0	7.6	3.7	0.1 to 13.0
NSL/ML′ (°)	33.6	7.9	21.4 to 53.7	34.7	7.1	23.9 to 53.7
NL/ML′ (°)	26.2	6.4	16.2 to 44.8	27.1	5.8	19.8 to 45.2
Gonion angle (°)	125.9	8.1	115.6 to 145.8	124.3	8.0	111.0 to 143.0
Jarabak ratio	64.5	6.5	49.2 to 75.7	63.6	5.4	49.9 to 72.5
IsL/NSL (°)	109.3	9.8	81.7 to 120.5	105.0	7.1	91.3 to 117.0
IsL/NL (°)	116.7	9.4	91.0 to 126.7	112.6	6.2	99.0 to 121.8
IiL/ML′ (°)	91.0	6.8	77.2 to 104.6	96.5	6.6	81.5 to 108.3
IiL-N-point B (°)	21.2	8.3	6.2 to 36.3	28.5	6.7	18.1 to 42.3
IiL-N-point B (mm)	4.4	3.8	−1.0 to 12.9	7.3	3.7	2.5 to 15.6
IiL-A-Pg (°)	20.1	6.5	7.6 to 30.3	26.4	5.7	18.4 to 39.9
IiL-A-Pg (mm)	0.1	3.7	−5.3 to 9.0	4.8	2.7	1.3 to 11.9
Holdaway ratio	1.0	5.8	−6.1 to 13.6	6.3	4.9	−3.4 to 17.2
IsL/IiL (°)	126.2	14.0	106.9 to 157.3	123.8	6.6	81.5 to 108.3
Overjet (mm)	7.7	2.1	4.5 to 11.9	2.8	0.9	1.3 to 4.5
Overbite (mm)	4.4	1.7	1.0 to 7.3	3.0	1.5	0.2 to 5.5

See Fig. 1 for details of the variables.

segment moved as a result of the DO in a rotational way in all but one patient if the ratio between 0.8 and 1.2 was taken as translational movement. That means that in 13 patients the incisal edges of the lower incisors (Ii) were more advanced than their Asab. In three patients the ratio was negative; that means that point Asab was even set back while point Ii was advanced by the DO.

Correlations

No significant correlations were found between the amount of relapse (T5–T3 and T5–T4, *X*-value) at point B, Ii, Asab or pogonion with gender and age of the patients. No correlations were found for the amount of advancement (T3–T1) and long-term relapse (T5–T3) at Ii, point B and Asab. The type of advancement (rotational vs. translational; Ii [*X*-value; T3–T2]/Asab [*X*-value; T3–T2]) had no influence on relapse (T5–T3) at point B (*X*-value) and Asab (*X*-value).

A larger gonial angle (T1) was significantly correlated with a smaller relapse (T5–T3) at the *X*-values of pogonion ($p = 0.024$; $R = 0.544$). A larger NL/ML′ angle (T1) showed significant correlations with a smaller relapse at the *X*-values of point B (T5–T3: $p = 0.006$; $R = 0.633$; T5-T4: $p = 0.015$; $R = 0.576$) and pogonion (T5–T3: $p = 0.000$; $R = 0.773$; T5–T4: $p = 0.013$; $R = 0.588$). The same was seen for a larger NSL/ML′ angle (T1) and a smaller relapse (T5–T3) at the *X*-value of point B ($p = 0.047$; $R = 0.487$) and pogonion ($p = 0.012$; $R = 0.596$). A larger Jarabak ratio (T1) was significantly correlated with a larger relapse (T5–T3) at the *X*-values of point B ($p = 0.026$; $R = -0.538$) and pogonion ($p = 0.014$; $R = -0.586$).

No correlation was seen between the advancement of point B (T3–T1) and the vertical relations at T1 of NSL/ML′, NL/ML′, and Jarabak ratio. Relapse as a pure geometric correlation between vertical and sagittal relationship was thus excluded.

Discussion

The present study was undertaken to investigate long-term dental and skeletal changes in patients undergoing DO of the mandibular anterior alveolar process. In a previous paper on skeletal and dental stability 2 years after DO of the anterior alveolar process the authors reported a 19% amount of relapse at point B.[7] To the authors' knowledge, no other study on DO of the mandibular anterior alveolar process has been published, which makes a direct comparison of the present data impossible for the moment. For the present study a uniform group of 17 patients was obtained due to the exclusion of additional surgical procedures on the mandible (genioplasty, BSSO) and maxilla. An examination of alveolar segmental DO without the influence of other confounding surgical procedures on the hard tissue was thus possible. An inherent problem of long-term studies is the loss of patients for follow-up examinations. Only 17 of 31 patients initially evaluated[7] could be re-examined. The drop-out analysis showed that there was no significant difference between the drop-out and the remaining patients for cephalometric parameters, age and sex. Even though the percentage of skeletal relapse in this sample is 8.3% which is smaller than the 19% reported 2 years after DO of the anterior alveolar process. Figures 6 and 7 illustrate long-term skeletal and dental changes from T1 to T5 in two different patients. The number of re-examined patients is comparable to the 18 patients receiving DO in the long-term study by Baas et al.[13]

Although there are no studies on DO of the mandibular anterior alveolar process there are some comparing mandibular advancement with DO or by a BSSO. Vos et al.[14] could not show retrospectively any significant skeletal differences in non-syndromic adult patients treated for mandibular advancement either with DO (BSSO type) or BSSO 10–49 months after surgery. Recently, in a follow-up study Baas et al.[13] could still not show any difference 46–95 months after surgery on the same but reduced patient samples while the mean distance of advancement was comparable in both groups. No difference in relapse between patients with high or normal to low mandibular plane was found. In contrast to the study of Baas et al.,[13] high angle patients (NL/ML′) examined in the present study showed significantly smaller relapse rates at point B ($p < 0.01$) and pogonion ($p < 0.001$). This was a surprising finding when compared to relapse patterns after a BSSO for mandibular advancement where a large

Table 3. Changes (mm or degree) in the variables and coordinates of the mandible and lower incisors as the immediate (T3–T1) and final (T5–T1) result of DO surgery.

	T3–T1[1]				T5–T1[2]			
Variable or coordinate	Mean	p	SD	Range	Mean	p	SD	Range
Horizontal (X-value [mm])								
Point B	3.6	***	2.0	−0.21 to 7.6	3.2	***	2.3	−0.2 to 7.3
Asab	2.2	***	2.1	−1.1 to 5.4	1.2	*	2.1	−2.2 to 4.7
Pogonion	0.1	ns	1.0	−1.7 to 1.8	0.5	*	1.0	−0.8 to 2.4
Go′	−0.6	ns	2.4	−3.5 to 2.5	−0.4	ns	2.7	−5.7 to 2.8
Incision sup.	1.1	**	1.4	−1.3 to 3.2	−0.4	ns	1.9	−4.1 to 3.0
Incision inf.	6.2	***	2.5	−0.5 to 10.9	4.6	***	3.2	−1.6 to 11.5
Apex inf.	4.2	***	1.9	1.7 to 8.8	3.1	***	2.2	−0.6 to 6.7
Vertical (Y-value [mm])								
Point B	1.4	**	1.7	−1.6 to 4.8	0.0	ns	1.9	−6.0 to 2.3
Asab	−0.4	ns	1.4	−4.6 to 1.0	0.1	ns	1.3	−2.5 to 2.1
Pogonion	0.2	ns	2.4	−5.1 to 4.8	0.3	ns	1.8	−2.8 to 4.8
Menton	0.1	ns	0.5	−0.6 to 1.2	0.0	ns	1.0	−1.5 to 1.5
Go′	−0.3	ns	2.4	−3.5 to 2.5	−0.6	ns	1.9	−3.5 to 3.2
Incision sup.	−1.8	***	1.7	−6.7 to 0.4	−0.3	ns	1.4	−3.3 to 2.4
Incision inf.	1.3	**	1.9	−1.8 to 4.9	1.3	*	1.9	−1.7 to 4.9
Apex inf.	0.2	ns	1.2	−2.8 to 2.0	0.1	ns	1.8	−2.8 to 3.4
Angular (°), linear measurements (mm), and ratios								
SNA (°)	−0.4	ns	1.6	−3.0 to 1.7	−0.9	*	1.6	−3.2 to 2.2
SNB (°)	0.9	*	1.2	−0.6 to 3.9	0.6	ns	1.6	−1.7 to 3.3
ANB (°)	−1.3	***	1.0	−3.9 to 0.9	−1.5	***	1.2	−3.7 to 0.2
Wits (mm)	−3.1	***	1.5	−5.3 to 0.4	−2.9	***	2.2	−7.7 to 1.3
NSL/NL (°)	0.2	ns	1.3	−2.0 to 2.8	0.2	ns	1.3	−2.1 to 2.1
NSL/ML′ (°)	1.3	***	1.3	−0.5 to 3.5	1.1	*	1.6	−2.8 to 3.8
NL/ML′ (°)	1.1	**	1.5	−0.4 to 3.7	1.0	*	1.4	−1.6 to 3.6
Gonion angle (°)	−2.1	**	2.7	−7.0 to 1.9	−1.6	ns	3.7	−10.2 to 4.5
Jarabak ratio	−0.3	ns	1.6	−2.7 to 2.2	−0.9	ns	2.0	−4.0 to 3.4
IsL/NSL (°)	1.3	ns	5.9	−5.1 to 22.0	−4.3	**	6.0	−16.7 to 9.6
IsL/NL (°)	1.5	ns	5.3	−4.6 to 20.1	−4.1	**	5.7	−14.7 to 8.0
IiL/ML′ (°)	7.2	***	4.9	−6.5 to 15.7	5.5	**	5.9	−5.7 to 16.1
IiL-N-point B (°)	9.4	***	4.6	−4.2 to 16.1	7.2	***	6.1	−4.3 to 16.5
IiL-N-point B (mm)	3.4	***	1.5	−1.7 to 5.2	2.9	ns	2.5	−1.4 to 7.8
IiL-A-Pg (°)	6.2	***	4.0	−4.9 to 13.4	6.3	***	5.7	−3.1 to 14.7
IiL-A-Pg (mm)	6.0	***	1.9	0.5 to 8.9	4.6	***	2.7	−0.5 to 11.4
Holdaway ratio	7.9	***	2.7	1.4 to 12.7	5.4	***	3.3	−1.2 to 13.3
IsL/IiL (°)	−9.7	***	7.9	−31.4 to 4.9	−2.4	ns	9.6	−21.9 to 14.5
Overjet (mm)	−5.1	***	1.7	−7.8 to −1.1	−4.9	***	1.9	−9.2 to −3.0
Overbite (mm)	−3.1	***	1.7	−6.4 to 0.1	1.5	**	1.7	−5.3 to 1.1
Ii/Asab	1.8		7.5	−22.4 to 9.7				

See Fig. 1 for details of the variables. T1, before surgery; T3, 24.4 days after surgery; T5, 5.5 years after surgery.
[1] T3–T2 for Asab, Ii (X-value, T3–T2)/Asab (X-value, T3–T2) instead mean value the median was taken for this ratio and no paired t-test was possible because measured on a single occasion
[2] T5–T2 for Asab. Negative values imply a backward and positive values a forward movement of the point in the horizontal plane. In the vertical plane, negative values imply an upward and positive values a downward movement of the point.
* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

mandibular plane angle (NL/ML′) is often correlated with increased horizontal relapse.[15] It is possible that patients with a hyperdivergent facial pattern have a lower perioral muscular tonus and thus fewer relapse.[7]

It could also be argued that DO of the mandibular anterior alveolar segment might be beneficial to prevent biomechanical side effects on the mandibular condyle that can occur after BSSO or mandibular DO.[16] This could prevent progressive condylar resorption which is related to long-term relapse and impaired mandibular function. The target groups for condylar resorption are young women with a high mandibular plane angle.[17,18] It was shown that 7% of all BSSO advancement patients appear to undergo progressive condylar resorption.[19] Further research is needed to elucidate whether condylar resorption is less in cases treated with DO of the mandibular alveolar process. Recently, Joss et al.[9] showed that DO of the mandibular anterior alveolar process is a valuable and safe method with minor side effect regarding neurosensory impairment and craniomandibular function. No significant difference in craniomandibular function and neurosensory status between a DO group and an orthodontically treated control group could be found.

In the present study the amount of advancement (T3–T1) had no influence on the amount of relapse (T5–T3) at point B, at Ii, and Asab. Smaller advancements with DO did not show less relapse than larger advancements even though the mean advancement at

Table 4. Changes (mm, degree or ratio) in the variables and coordinates of the mandible and lower incisors as the relapse (T5–T3) and the long-term change (T5–T4) of DO surgery.

Variable or coordinate	T5–T3 Mean	T5–T3 *p*	T5–T3 SD	T5–T3 Range	T5–T4 Mean	T5–T4 *P*	T5–T4 SD	T5–T4 Range
Horizontal (*X*-value [mm])								
Point B	−0.3	ns	1.3	−2.7 to 3.3	0.3	ns	0.7	−1.0 to 2.0
Asab	−1.0	***	0.9	−2.4 to 1.1	0.1	ns	0.6	−1.1 to 1.5
Pogonion	0.4	ns	1.0	−1.6 to 2.9	−0.1	ns	0.7	−1.0 to 2.0
Go′	0.2	ns	2.7	−6.4 to 4.7	−0.4	ns	2.5	−7.6 to 4.1
Incision sup.	−1.5	**	1.7	−5.4 to 1.2	0.1	ns	0.6	−1.6 to 0.9
Incision inf.	−1.8	***	1.9	−5.4 to 0.6	−0.2	ns	0.6	−1.6 to 1.4
Apex inf.	−1.1	*	1.7	−3.8 to 1.6	0.1	ns	1.4	−3.5 to 2.9
Vertical (*Y*-value [mm])								
Point B	−1.4	*	2.7	−7.9 to 2.7	−0.1	ns	1.7	−3.2 to 3.2
Asab	0.5	ns	1.0	−1.1 to 2.7	−0.1	ns	0.6	−1.9 to 0.9
Pogonion	0.1	ns	2.3	−3.7 to 3.3	0.4	ns	1.7	−4.6 to 3.0
Menton	−0.2	ns	0.6	−1.3 to 0.9	0.0	ns	0.6	−1.0 to 1.0
Go′	−0.3	ns	1.4	−2.9 to 2.4	−0.4	ns	1.5	−2.9 to 2.1
Incision sup.	1.4	***	1.5	−1.2 to 3.9	0.5	**	0.8	−0.6 to 1.8
Incision inf.	−0.1	ns	1.6	−4.3 to 2.8	−0.1	ns	0.7	−1.1 to 1.4
Apex inf.	0.3	ns	1.7	−2.5 to 3.0	−0.6	ns	1.5	−4.2 to 2.9
Angular (°), linear measurements (mm), and ratios								
SNA (°)	−0.5	ns	1.3	−2.9 to 2.4	0.2	ns	1.4	−2.6 to 2.4
SNB (°)	−0.3	ns	1.1	−1.9 to 1.9	0.4	ns	0.8	−1.0 to 1.8
ANB (°)	−0.2	ns	1.0	−2.2 to 1.8	−0.2	ns	1.0	−2.5 to 1.4
Wits (mm)	0.2	ns	1.8	−3.2 to 2.8	−0.2	ns	1.4	−2.1 to 2.2
NSL/NL (°)	0.0	ns	0.8	−1.3 to 1.4	−0.3	ns	0.9	−1.7 to 1.6
NSL/ML′ (°)	−0.1	ns	1.4	−3.5 to 1.9	−0.6	ns	1.3	−3.5 to 1.6
NL/ML′ (°)	−0.1	ns	1.2	−2.2 to 2.1	−0.3	ns	1.1	−1.9 to 1.8
Gonion angle (°)	0.6	ns	3.4	−7.3 to 6.7	−1 to 1	ns	3.6	−7.1 to 4.6
Jarabak ratio	−0.6	ns	1.7	−3.9 to 2.1	0.6	ns	1.6	−2.9 to 3.5
IsL/NSL (°)	−5.5	***	4.5	−12.4 to 0.1	−0.6	ns	2.7	−5.7 to 3.0
IsL/NL (°)	−5.5	***	4.6	−12.3 to 0.3	−1.0	ns	2.9	−5.4 to 3.2
IiL/ML′ (°)	−1.7	ns	5.4	−11.5 to 9.0	0.0	ns	3.1	−5.1 to 7.8
IiL-N-point B (°)	−2.1	ns	5.3	−12.2 to 10.1	−0.3	ns	3.4	−5.8 to 9.0
IiL-N-point B (mm)	−0.5	ns	2.3	−4.8 to 4.0	−0.5	*	0.7	−2.1 to 0.7
IiL-A-Pg (°)	0.1	ns	5.9	−12.1 to 11.7	−0.2	ns	3.3	−5.6 to 8.1
IiL-A-Pg (mm)	−1.4	**	1.9	−5.5 to 2.5	−0.3	ns	1.0	−1.8 to 1.3
Holdaway ratio	−2.6	***	2.2	−6.0 to 1.2	−0.3	ns	0.9	−2.2 to 1.0
IsL/IiL (°)	7.3	***	6.3	−7.0 to 18.3	1.3	ns	4.0	−5.3 to 9.3
Overjet (mm)	0.1	ns	1.4	−2.6 to 2.4	0.3	*	0.5	−0.4 to 1.7
Overbite (mm)	1.7	***	1.7	−1.5 to 3.9	1.0	**	1.1	−0.5 to 4.0

See Fig. 1 for details of the variables. T3, 24.4 days after surgery; T4, 2.0 years after surgery; T5, 5.5 years after surgery. Negative values imply a backward and positive values a forward movement of the point in the horizontal plane. In the vertical plane, negative values imply an upward and positive values a downward movement of the point.

$^{*}p \leq 0.05$.

$^{**}p \leq 0.01$.

$^{***}p \leq 0.001$.

point B (*X*-value) was rather low with 3.6 mm. This is in accordance with the findings of the authors' previous study 2.0 years after DO of the anterior alveolar segment.[7] In contrast, in BSSO a positive correlation between the amount of relapse and the amount of mandibular advancement is often seen.

Advancements in the range 6–7 mm or more predispose to horizontal relapse.[15] Only two of 17 of the patients had advancements larger than 6 mm at point B. The amount of relapse at point B was 8.3% 5.5 years after DO of the anterior alveolar segment. Nevertheless, the amount of relapse at point B was 19.0% after 2.0 years.[7] Reasons for this improvement regarding the relapse rate at point B could be the missing data from the 16 patients which could not be re-examined for this 5.5 year follow-up. The systematic review on BSSO for mandibular advancement of Joss and Vassalli[15] showed a large variability from 2 to 50.3% in long-term relapse (>1.5 years) at point B.

A reason for the amount of dental relapse of 29.0% at incision inferior to the initial surgical advancement could be the overcorrection achieved by the distraction where an edge-to-edge incisal position or negative overjet at T3 had to be corrected with Class III elastics postsurgically. Furthermore, the DO creates space distal of the canines while crowding is still present in the incisor region. Incisor alignment is carried out in this newly generated space to prevent further proclination or round tripping. For this reason, it is possible that incision inferior moves further posteriorly by orthodontic forces.[7]

The distraction vector (translation vs. rotational) was defined by the type of distraction appliance chosen, whereas pseudarthrosis at the osteotomy sites occurred in none of the 17 patients examined. The hinge plate allows a more rotational and the base-distractor a more translational movement of the anterior

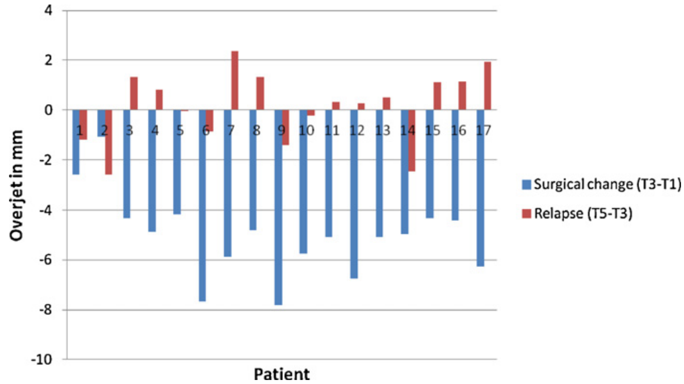

Fig. 4. Surgical change (T3–T1) and amount of relapse (T5–T3) of overjet (in mm) in individual patients ($n = 17$).

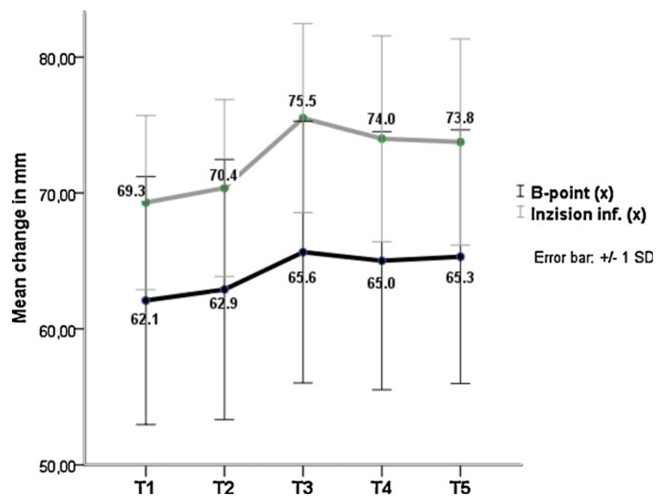

Fig. 5. Changes of point B and overjet from T1 to T5.

Fig. 6. Superposition of serial tracings (T1, T3, T4, and T5) in a male patient (number 12) with little skeletal and dental changes in long-term. Legend: T1 (24.06.2002), T3 (13.08.2002), T4 (28.09.2005), and T5 (27.06.2007).

mandibular alveolar segment. The introduction of the newly defined skeletal points (Asab) permits the evaluation of the movement of the surgical base independently and the bone remodeling at the surgical site.[7] A comparison between the movements of Ii, point B, and lower incisor apex can determine whether DO created predominantly a rotation or translation of the alveolar process, especially when considering the ratio Ii (*X*-value, T3–T2)/Asab (*X*-value, T3–T2). A ratio of 1 signifies that a pure translation of the segment had taken place. The higher the ratio over 1 the more the centre of rotation is located at the lower incisor apex or at Asab, respectively, and the opposite for values below 1.

Three of the 17 patients had a negative ratio indicating a setback of point Asab while point Ii was advanced. Only one patient had a ratio between 0.8 and 1.2 which could be described as translation movement, that means that 13 patients had a more or less accentuated rotational movement of the distracted segment. Some proclination of the lower incisors was related to the orthodontic treatment which could have biased the assessment of that ratio.

In this study, the relapse rate at Asab (45.5%) was quite large. This could be due to remodeling of the border of the segment to smooth the contour and aspect of the anterior symphysis. The interface of the surgical section of the anterior aspect of the symphysis is highly susceptible to resorption and bony remodeling. This has also been shown at the surgical borders of advancement genioplasties where osseous remodeling was highest.[20]

In summary, this long-term follow-up found that no change in further relapse was seen between 2.0 years and 5.5 years postoperatively regarding point B and the incision of the lower incisors. DO of the mandibular anterior alveolar process resulted in a mainly rotational rather than translational advancement of the tooth bearing alveolar segment. 5 years after treatment 8.3% of the original skeletal advancement and 29% of the dental advancement has vanished. Considering the amount of long-term skeletal relapse the procedure could be an alternative to BSSO for mandibular advancement in selected cases.

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None.

Competing interests

None declared.

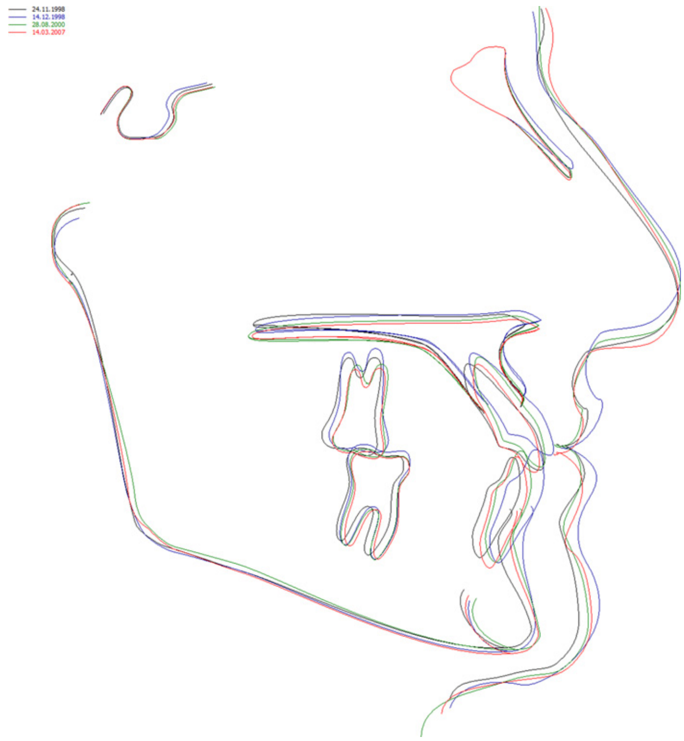

Fig. 7. Superposition of serial tracings (T1, T3, T4, and T5) in a female patient (number 13) with important skeletal and dental changes in long-term. Legend: T1 (24.11.1998), T3 (14.12.1998), T4 (28.08.2000), and T5 (14.03.2007).

Ethical approval

Yes. Ethical approval was admitted by the Ethic Committee of the Kanton Zürich, Switzerland, number 593.

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