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Neurosensory and functional impairment in sagittal split osteotomies: a longitudinal and long-term follow-up study

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SUMMARY The aim was to conduct a long-term follow-up study on the function and sensitivity of the mandible in advancement and setback patients after bilateral sagittal split osteotomy (BSSO) with rigid internal fixation.

The advancement and setback groups consisted of 16 (12 females and 4 males, mean age: 21.4 and 21.3 years, respectively) and 17 (11 females and 6 males, mean age: 27.1 and 27.7 years, respectively). The final follow-up was a mean of 12.7 years (T4) post-operatively. The other follow-up examinations were before surgery (T1) and 7.3/6.6 (T2) and 13.9/14.4 (T3) months after surgery. To evaluate craniomandibular function, mouth-opening capacity, laterotrusion, protrusion, deviations during opening, pain and clicking of the temporomandibular joint (TMJ), muscular pain, and the retruded contact position–intercuspal position (RC–IP) distance were examined. A questionnaire was used to record subjective reports. The neurosensory status was determined with two-point discrimination (2-pd), the pointed, blunt, and light-touch tests. Statistical analysis included the following tests: Wilcoxon signed ranked matched pairs, Mann–Whitney *U*, paired *t*, and Fisher's exact test. Bonferroni's adjustments were made for evaluation of the questionnaire and Spearman's rank correlation coefficients to determine the interdependence of selected variables.

Craniomandibular function showed restitution at T4 after 12.7 years. The 2-pd at the lip and chin had largely normalized in the two groups at T3. At T4, there was a significant increase of 2-pd at the lip and chin in both groups. The discrimination between sharp and blunt was limited in both groups in 25 per cent of patients at T4. Dysfunctions such as TMJ clicking, bruxism, and pain in the TMJ and muscles were neither increased nor decreased after BSSO. The initial post-surgical neurosensory impairment was barely detectable 1 year post-surgery. The new neurosensory impairment manifested at T4 was probably due to the normal human process of ageing. Neither age, gender, surgical advancement, nor setback showed any significant correlations.

Introduction

The bilateral sagittal split osteotomy (BSSO) was first described by Trauner and Obwegeser (1955). Since then, several modifications have been made by different surgeons (Dal Pont, 1961; Hunsuck, 1968; Spiessl, 1976).

Orthognathic surgery may evoke functional and structural changes within the stomatognathic system. Both the orthodontist and the surgeon are concerned with maintaining normal function of the stomatognathic system and eliminating functional and sensory impairment after BSSO.

Today, there is general agreement that the signs and symptoms of craniomandibular dysfunction are mostly reduced after BSSO (Pepersack and Chausse, 1978; Ingervall *et al.*, 1979; Wisth, 1984; Kerstens *et al.*, 1989; Harper, 1990). However, others have reported negative influences (O'Ryan and Epker, 1983; Storum and Bell, 1984; Aragon *et al.*, 1985; Harper, 1990) after BSSO.

Numerous studies have been published on sensory impairment after BSSO. Unfortunately, the data of these studies are still very heterogeneous. Other authors have therefore claimed to have standardized examination methods (Jones *et al.*, 1990; Chen *et al.*, 1999).

The aim of the present research was to analyse subjective and objective functional and sensory impairment after mandibular advancement and set-back surgery with the BSSO technique and rigid internal fixation, and to compare recovery after the two procedures in a long-term follow-up study. It should be considered as a continuation of a previous investigation (Thüer *et al.*, 1997). The two procedures were undertaken using the same surgical technique and by the same surgeons.

Subjects and methods

As a continuation of the study by Thüer *et al.* (1997), 16 patients with mandibular advancement and 17 with mandibular setback could be re-examined. As a consequence of marriage and change of name, residence, etc., the initial number of 25 in the mandibular advancement and 24 in the mandibular setback group could not be maintained (lost to follow-up).

There were 12 females (mean age: 21.4 years, range: 17.0–30.1 years) and four males (mean age: 21.3 years, range: 20.0–22.8 years) in the advancement group and in the set back group six females (mean age: 27.1 years, range: 18.9–40.5 years) and 11 males (mean age: 27.7 years, range: 18.5–54.8 years).

All had sagittal split osteotomies with rigid lag screw fixation. No genioplasties were performed. The surgical procedure, the amount of surgical displacement, and the effect on the hard and soft tissues have previously been described in detail (Raveh *et al.*, 1988; Thüer *et al.*, 1994; Ingervall *et al.*, 1995).

Records were obtained in the advancement group 1 day (range: 0–1 day) before (T1), 7.3 months (range: 6.0–9.9 months) after (T2), 13.9 months (range: 11.8–19.3 months) after (T3), and 12.7 years (range: 10.9–14.2 years) after (T4) surgery and in the setback group, 1 day (range: 0–5 days) before (T1), 6.6 months (range: 4.2–9.7 months) after (T2), 14.4 months (range: 11.5–18.7 months) after (T3), and 12.7 years (range: 11.1–14.0 years) after (T4) surgery.

Craniomandibular function

All subjective and objective tests were carried out as described previously (Thüer *et al.*, 1997).

Symptoms. Symptoms of craniomandibular dysfunction were evaluated by a questionnaire, which included questions on the ability to chew and bite, parafunctions, occurrence of headaches, complaints concerning mandibular function, and pain in the temporomandibular joint (TMJ) and muscles. The patients could fill in the questionnaire with the optional help of an examiner to explain the questions that were unclear, but without influencing the patient's opinion. The questions and the number of affirmative answers are presented in Table 1.

Signs. Clinical findings on function were recorded as follows.

1. The maximum opening capacity was measured with a steel ruler to the nearest half millimetre as the distance between the edges of the maxillary and mandibular central incisors, with the addition of overbite. The mean of the two measurements was recorded as the maximum opening capacity.
2. Maximum lateral movement was measured as follows: a vertical line was drawn at maximum intercuspation from one maxillary incisor to the corresponding mandibular incisor. The patient then moved the mandible to either side as far as possible, opening his or her mouth just as far as necessary to disclose the teeth. The maximum side-shift capacity was measured with a ruler, and the mean of two measurements each to the right and the left was used.
3. Overjet was measured with a steel ruler at maximum protrusion. The patient was then asked to advance the mandible as far as possible. The distance between the labial surfaces of the maxillary and mandibular incisors was measured at maximum intercuspation and maximum protrusion. The sum of the two measurements is the maximum protrusion. The mean of the two measurements was used.
4. Deviations to the left or right during maximum opening were recorded on a three-point scale: 0 = 0–1 mm; 1 = 2–5 mm, and 2 = >5 mm. The patients were also examined for audible or palpable TMJ sounds.
5. Tenderness of the TMJ was examined by palpation from a lateral and posterior position (via the ear canal). Grade 1 was recorded when the subject could feel a difference between the right and left sides, or if the palpation was painful, and grade 2 when the patient showed a palpebral reflex or guarding.
6. The antero-posterior and lateral distances between the retruded contact position (RCP) and the intercuspal position (ICP) of the mandible were measured with a ruler to the nearest half millimetre (Helkimo *et al.*, 1973).

Neurosensory test

The examiner first asked the patient to describe their perceptions in the lower lip and the chin. The function of the inferior alveolar nerve was then tested by examination of the innervation of the mental nerve by distinguishing two regions of the lip and chin: the lower lip and the region between the vermilion border of the lower lip and the

Table 1 Number of affirmative answers to questions regarding biting, chewing, and symptoms of craniomandibular dysfunction before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	Advancement and setback groups pooled (n = 33)			
	T1	T2†‡	T3	T4
Biting				
With no difficulty	14	25**	28**	28**
With some difficulty	19	6**	5**	5**
Chewing				
With no difficulty	27	26	29	31
With some difficulty	6	5	4	2
Clenching				
Sometimes or often	11	8	7	14
Rarely or never	22	23	26	19
Grinding				
Sometimes or often	1	4	2	5
Rarely or never	32	27	31	28
Headaches				
Daily to once a week	18	9	15	6*
Rarely to never	15	22	18	27*
TMJ clicking	12	10	11	11
Muscle fatigue	4	2	2	2
Mouth-opening difficulties	3	9	8	6
Deviation on opening	6	3	2	5
Pain during jaw movement	1	1	0	0
Pain in TMJ or muscles	10	2	5	10

TMJ, temporomandibular joint.
Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 3$): *$P \leq 0.01667$, **$P \leq 0.00333$, and ***$P \leq 0.000333$.
†After 7.3 months $n = 15$. ‡After 6.6 months $n = 16$.

lower border of the chin. The following tests were carried out:

Light-touch test. The light-touch test was performed with a cotton roll, with the subject's eyes closed. The patients were asked to compare the left and the right sides and inform the examiner whether they found the light touch normal or abnormal.

Pointed-and-blunt test. A ball burnisher and a pointed dental probe were pressed lightly and randomly on the skin to check the ability to differentiate between pointed and blunt objects.

Two-point touch test (2-pd). The patient's ability to discriminate between two points was measured with a sliding calliper. The two pointed, but not sharp, tips of the calliper touched the skin simultaneously with light pressure while the patient's eyes were closed. The separation of the two points was gradually reduced from 20 mm at the chin and 10 mm at the lips to the moment where the patient could feel one point only. The minimum separation at which two points could be reported was recorded.

Buccal nerve test. Both cheeks were gripped with two fingers to check the sensitivity of the buccal nerve.

Statistical methods

The following tests were used: Wilcoxon's signed rank test for matched pairs, the Mann–Whitney *U*-test for comparisons between mandibular advancement and setback and the paired *t*-test for comparisons between the right and left sides of the face. Fisher's exact test was applied in the analysis of the questionnaire and the data on craniomandibular function and neurosensory status (Tables 1–3). Spearman's ranked correlation coefficients were calculated for evaluation of the interdependence of selected variables.

Results

Craniomandibular function

For evaluation of the questionnaire, the two groups were combined (Table 1). The questionnaire showed a very significant ($P < 0.00333$) increase in the number of patients who had no difficulties in biting, from 14 to 28. Headaches which occurred daily to once a week decreased significantly ($P < 0.01667$), from 18 to 6 patients.

The objective examination (Table 2) did not reveal any symptoms of deviation on opening in the two groups, i.e. TMJ clicking and pain on palpation of TMJ from the lateral or posterior position that differed significantly with time. On the whole, the prevalence of most of the symptoms of craniomandibular function were either numerically smaller after surgery or remained numerically the same as before surgery. Exceptions were seen in the number of TMJ clickings unilaterally and deviation on opening in the advancement group at T4.

The maximum opening capacity (Tables 4 and 5, Figure 1) was less in the two groups at T2 than that before surgery.

Table 2 Number of patients with signs of craniomandibular dysfunction before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	Advancement group ($n = 16$)				Setback group ($n = 17$)			
	T1	T2†	T3	T4	T1	T2‡	T3	T4
Deviation on opening	2	5	2	3	5	4	2	3
TMJ clicking (total)	4	4	3	5	4	1	2	4
Unilateral	3	4	3	4	2	1	2	3
Bilateral	1	0	0	1	2	0	0	1
Pain on palpation of TMJ from lateral position (total)	0	0	1	0	2	0	0	1
Unilateral	0	0	1	0	1	0	0	1
Bilateral	0	0	0	0	1	0	0	0
Pain on palpation of TMJ from posterior position (total)	1	0	1	1	1	0	1	0
Unilateral	1	0	0	1	0	0	1	0
Bilateral	0	0	1	0	1	0	0	0
RCP–ICP distance lateral >0.5 mm	1	3	1	0	2	0	1	1
RCP–ICP distance lateral <0.5 mm	2	4	4	0	3	2	0	1

Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 3$): $*P \leq 0.01667$, $**P \leq 0.00333$, and $***P \leq 0.000333$. †After 7.3 months $n = 15$. ‡After 6.6 months $n = 16$.

Table 3 Number of patients with abnormal reactions to touch tests before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	Advancement group ($n = 16$)				Setback group ($n = 17$)			
	T1	T2†	T3	T4	T1	T2‡	T3	T4
Abnormal reaction to light touch	1	3	3	7	0	4	4	7*
Reduced ability to differentiate between pointed and blunt touch	1	4	4	5	0	4	5	4
Disturbed sensitivity of the cheek	0	0	1	1	0	2	1	0

Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 3$): $*P \leq 0.01667$, $**P \leq 0.00333$, and $***P \leq 0.000333$. †After 7.3 months $n = 15$. ‡After 6.6 months $n = 16$.

A very significant decrease of −6.75 mm was observed in the advancement group and a non-significant decrease of −5.55 mm in the setback group. At T3, there was an improvement but still a significant decrease of −4.43 mm in the advancement group and a non-significant decrease of −2.93 mm in the setback group. A complete restitution of maximum opening capacity was seen at T4.

Table 4 Maximum movement capacity of the mandible (mm) before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	T1			T2†‡			T3†‡			T4			Changes from T1 to T3		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Advancement group ($n = 16$)															
Mouth-opening	51.2	6.4	38.0 to 63.0	44.3	6.3	34.0 to 55.0	−10.1**	12.8	−53.5 to 2.0	46.8	7.6	35.0 to 65.0	−4.4*	5.1	−12.0 to 9.0
Lateral movement	11.1	2.5	7.0 to 16.0	9.5	2.2	6.0 to 14.0	−2.1*	3.0	−10.0 to 1.0	9.7	3.2	2.0 to 16.0	−1.4 (ns)	2.9	−8.0 to 4.0
Protrusion	10.9	2.6	5.5 to 15.0	8.1	1.4	6.0 to 11.0	−3.2*	3.9	−15.0 to 1.5	9.1	1.6	7.0 to 12.0	−1.8 (ns)	2.5	−6.0 to 4.5
Setback group ($n = 17$)															
Mouth-opening	50.6	9.0	35.0 to 67.0	47.8	6.4	37.0 to 62.0	−5.6 (ns)	12.0	−42.0 to 15.0	47.6	6.5	37.0 to 57.0	−2.9 (ns)	5.2	−16.0 to 5.0
Lateral movement	9.7	2.3	5.0 to 16.0	8.8	2.0	5.0 to 12.0	−1.3 (ns)	3.4	−12.0 to 6.0	8.9	2.4	3.0 to 14.0	−0.8 (ns)	2.7	−7.0 to 4.0
Protrusion	7.7	2.5	2.0 to 11.0	7.0	2.3	3.0 to 10.0	−1.1 (ns)	3.2	−6.0 to 8.0	7.9	2.6	4.0 to 14.0	0.2 (ns)	1.7	−2.0 to 4.0

Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 4$): $^*P \leq 0.0125$, $^{**}P \leq 0.0025$, and ns, not significant.
†After 7.3 months $n = 15$. ‡After 6.6 months $n = 16$.

Lateral movement capacity and maximum protrusion (Tables 4 and 5) showed a significant increase only in the advancement group, whereas a significant and a non-significant decrease were observed at T4 in the setback group. At T4, lateral movement capacity was restored in both groups, but maximum protrusion was restored only in the setback group. The advancement group still had a decrease of −1.63 mm at T4 (non-significant).

However, an increase of opening capacity was noted at T4 in 14 patients (seven in each group).

There were no significant changes in the distance between RCP and ICP in either group. A value greater than 1.5 mm in the antero-posterior RCP–ICP distance at T4 was noted in one patient in the advancement group but in no patient in the setback group. Nevertheless, there were three patients in the setback group with a value of 1.5 mm at T4. On the other hand, pre-surgical high RCP–ICP distances of 5 or 4 mm were reduced to 0 mm in two patients. All patients, except one in the advancement group, had an RCP–ICP distance which was greater than 1 mm. No correlations with age and gender in either group were found. The advancement at point Pg correlated positively and significantly with the magnitude of the RCP–ICP distance at T4.

Neurosensory status

At T1, all patients in the setback group could be considered to have normal sensory sensations, while in the advancement

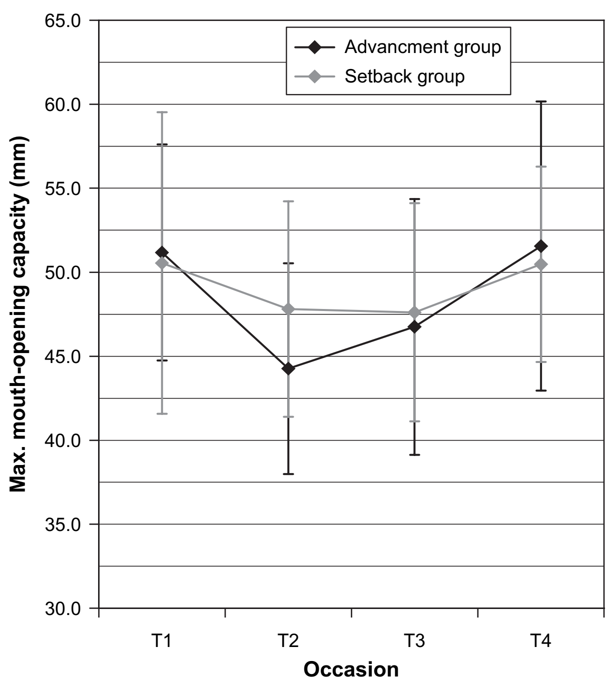

Figure 1 Means and standard deviations of mouth-opening capacity before surgery (T1), and 7.3/6.6 months (T2), 13.9/14.4 months (T3), and 12.7 years (T4) after surgery for the advancement/setback groups.

Table 5 Maximum movement capacity of the mandible (mm) before and after surgery and loss of original movement capacity (%) before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	T4			Changes from T1 to T4			Loss of original capacity at T4	Changes between T3 and T4			Loss of original movement capacity between T3 and T4
	Mean	SD	Range	Mean	SD	Range	Mean	Mean	SD	Range	Mean
Advancement group (n = 16)											
Mouth-opening	51.6	8.6	36.0 to 72.0	0.4 (ns)	5.6	−10.0 to 11.0	0.8	4.8*	4.7	−4.0 to 14.0	71.3
Lateral movement	10.6	3.2	5.0 to 17.0	−0.5 (ns)	3.4	−10.0 to 5.0	−4.7	0.9 (ns)	3.0	−5.0 to 7.0	52.6
Protrusion	9.3	2.0	5.0 to 13.0	−1.6 (ns)	2.5	−6.0 to 2.5	−15.0	0.1 (ns)	1.8	−3.0 to 4.0	5.3
Setback group (n = 17)											
Mouth-opening	50.5	5.8	37.0 to 59.0	−0.1 (ns)	9.3	−12.0 to 19.0	−0.2	2.9 (ns)	7.1	−7.0 to 17.5	51.4
Lateral movement	9.3	2.3	3.0 to 15.0	−0.3 (ns)	3.0	−7.0 to 6.0	−3.5	0.5 (ns)	2.1	−4.0 to 5.0	35.1
Protrusion	7.9	2.7	4.0 to 13.0	0.2 (ns)	3.3	−4.0 to 11.0	3.1	0.0 (ns)	3.0	−5.0 to 7.0	0.0

Significant differences were calculated together with a Bonferroni adjustment (P/n; n = 4): *$P \leq 0.0125$. ns, not significant.

group one subject had an abnormal reaction to light touch and one a reduced ability to differentiate between pointed and blunt touch.

There was a significant increase (P = 0.007) in seven patients showing reaction to light touch at T4 in the setback group (Table 3), while in the advancement group six patients showed a non-significant increase (P = 0.037). There was an increase in the ability to differentiate between pointed and blunt touch in the two groups (n = 4).

Total anaesthesia or neuralgia was not reported at any time point. At T4, paresthesia was found in five and six patients in the advancement and setback groups, respectively. The most frequent complaint was the presence of paresthesia or slight hyposensitivity on one side of the lower lip or chin. A significant difference between the right and left side could not be determined with any of the tests. Both sides were therefore pooled and the findings are presented in Tables 6 and 7 and in Figures 2 and 3.

The two-point discrimination (2-pd) showed a significant increase (P = 0.006) of 2.33 mm of the lip in the advancement group at T2. There was a non-significant increase (P = 0.013) of 2.35 mm in the setback group. The 2-pd of the chin was increased non-significantly (P = 0.109) by 1.83 mm in the advancement group and (P = 0.018) by 2.44 mm in the setback group.

A normalization of 2-pd was seen at the lower lip and the chin in both groups at T3. Only the 2-pd of the lower lip was still significantly increased in the setback group.

Although restoration was observed at T3, the lower lip and the chin in both groups were significantly increased at T4. The 2-pd of the lower lip increased (P = 0.000) by 2.33 mm in the advancement group and by 3.03 mm (P = 0.001) in the setback group. The chin increased by 3.41 mm (P = 0.005) in the advancement and by 3.88 mm (P = 0.003) in the setback group (both significant). There was

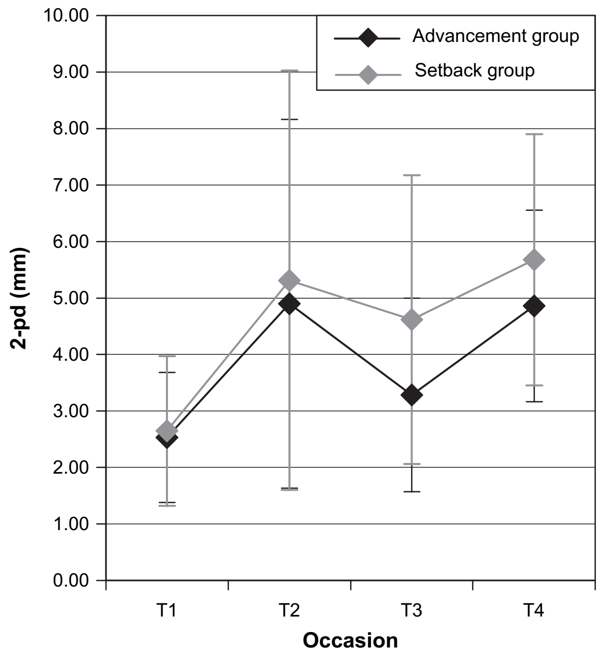

Figure 2 Means and standard deviations of two-point discrimination of the lips before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

no difference in 2-pd between the two groups at any time point.

Age, gender, and advancement did not correlate with other variables in either group.

Discussion

There are numerous studies on the range of mandibular motion and neurosensory status after BSSO. However, a

Table 6 Minimum distance (mm) for two-point discrimination before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	T1			T2†‡			Changes from T1 to T2			T3			Changes from T1 to T3		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Advancement group (n = 16)															
Lip	2.5	1.2	1.0 to 7.0	4.9	3.3	1.0 to 15.0	2.0*	3.5	−2.0 to 12.0	3.28	1.7	0.5 to 8.0	0.8 (ns)	1.7	−2.0 to 5.0
Chin	6.8	2.9	4.0 to 13.0	8.8	4.2	2.0 to 20.0	1.8 (ns)	4.8	−6.0 to 16.0	8.75	5.1	2.0 to 24.0	2.0 (ns)	5.4	−6.0 to 13.0
Setback group (n = 17)															
Lip	2.7	1.3	1.0 to 6.0	5.3	3.7	1.0 to 14.0	2.4 (ns)	4.0	−3.0 to 11.0	4.62	2.6	1.0 to 11.0	2.0*	2.9	−3.0 to 8.0
Chin	6.5	2.5	3.0 to 12.0	9.5	3.6	4.0 to 15.0	2.4 (ns)	5.2	−8.0 to 12.0	10.12	6.3	2.0 to 30.0	3.6 (ns)	7.0	−8.0 to 22.0

Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 4$): $*P \le 0.0125$, $**P \le 0.0025$, and $***P \le 0.00025$; ns, not significant.
†After 7.3 months n = 15. ‡After 6.6 months n = 16.

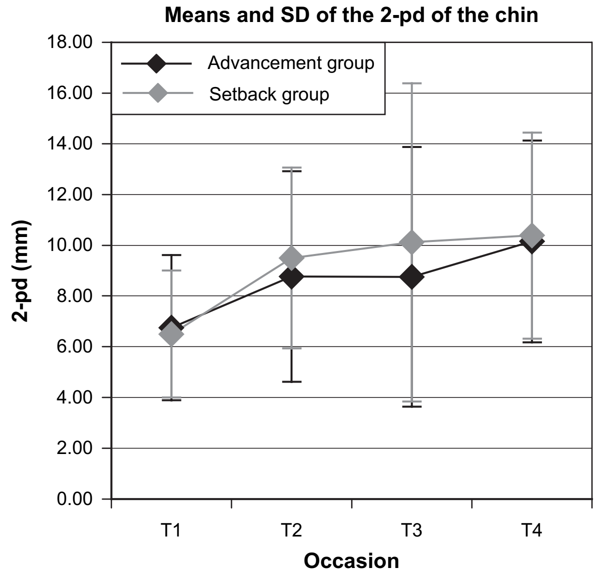

Figure 3 Means and standard deviations of the two-point discrimination of the chin at T1, T2, T3 and T4.

lack of long-term follow-up studies over more than 3 years is evident.

The findings of the present investigation show that, in general, there are only minor negative effects on the function of the stomatognathic system after BSSO for advancement or setback surgery, which is in contrast to several studies which found an improvement (Timmis *et al.*, 1986; Harper, 1990) or deterioration (Feinerman and Piecuch, 1995) after BSSO. Subjectively, there was a highly significant increase from 14 to 28 in the number of patients who had no difficulties in biting. This was mostly due to an increase in the setback group. These findings are in agreement with Wisth (1984) who showed that patients with mandibular prognathism had a reduced mouth-opening and reduced protrusion capacity. He concluded this to be part of the normal anatomical and functional pattern.

Almost no change was seen in the prevalence of TMJ clicking. This was consistent with the results of Magnusson *et al.* (1990) and Smith *et al.* (1992).

A reduction in TMJ clicking does not necessarily mean functional improvement (Zimmer, 1993). He conducted a clinical–axiographic study to evaluate the TMJ after BSSO and rigid internal fixation in 10 patients. In subjects where TMJ sounds disappeared after surgery, post-operative mandibular mobility was reduced to such a degree that the point at which the acoustic symptom originated pre-operatively could no longer be attained.

In those patients, where a disc dislocation as the origin for the TMJ sound is probable, the important question would be if the disc is correctly interposed between the candyle and fossa in the post-operative situation. The present data

Table 7 Minimum distance (mm) for two-point discrimination before surgery (T1), 7.3/6.6 months after surgery (T2), 13.9/14.4 months after surgery (T3), and 12.7 years after surgery in the advancement/setback groups.

	T4			Changes from T1 to T4			Changes from T3 to T4		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Advancement group (*n* = 16)									
Lip	4.9	1.7	3.0 to 10.0	2.3***	1.7	0.0 to 8.0	1.6*	2.0	−2.0 to 7.0
Chin	10.2	4.0	5.0 to 20.0	3.4*	4.5	−3.0 to 16.0	1.4 (ns)	5.0	−7.0 to 12.0
Setback group (*n* = 17)									
Lip	5.7	2.2	2.5 to 10.0	3.0**	2.7	−2.5 to 8.0	1.1 (ns)	2.5	−4.0 to 6.0
Chin	10.4	4.1	5.0 to 22.0	3.9*	5.4	−3.0 to 19.0	0.3 (ns)	5.7	−20.0 to 10.0

SD, standard deviation; ns, not significant.
Significant differences were calculated together with a Bonferroni adjustment (P/n; $n = 4$): $*P \leq 0.0125$.

provides no evidence to confirm that TMJ clicking occurred either because of disc repositioning or disc dislocation.

There was a significant decrease in the prevalence of headaches at T4. However, it is not considered that this can only be the result of the BSSO. Headaches are indeed a more complex phenomenon and are also caused by vasomotor and psychogenic diseases or by parafunctions, living conditions, etc. Recently, Egermark *et al.* (2000) showed a significant correlation between the subjective symptoms of TMJ dysfunction, clinical dysfunction according to Helkimo (1974), bruxism, and headache.

One of the most obvious findings of the present investigation was the impairment in movement capacity at T2, especially for the mandibular advancement group. While there was still a smaller decrease in movement capacity at T3, there was no decrease at all at T4. Nevertheless, high standard deviations and wide ranges in mandibular mobility were detected from T1 to T4. Such findings show that while some patients benefited significantly from treatment others did not.

If 40 mm is considered as an acceptable value for mouth-opening capacity (Helkimo, 1974; Ingervall *et al.*, 1980; Storum and Bell, 1984; Zimmer *et al.*, 1991), two patients in the advancement group were below this level at T4. On the other hand, there was only one patient in the setback group.

Before surgery, patients undergoing advancement or setback surgery should be informed that mandibular movement capacity may be reduced as a result of surgery. In general, there will be a complete restitution within a few years. An increase of opening capacity occurred in 14 patients without special diet or physiotherapy (Bell *et al.*, 1983; Storum and Bell, 1986; Aragon and Van Sickels, 1987; Boyd *et al.*, 1991).

RCP–ICP distance was considered important, because a small distance after surgery is preferable. It means that the mandibular condyles are well centred in the fossae when the teeth are in intercuspation (Thüer *et al.*, 1997). A large RCP–ICP distance indicates that the condyles are displaced forward in the ICP, i.e. that a dual bite exists (Egermark-Eriksson *et al.*, 1979).

All patients in the setback group had a normal RCP–ICP distance (not exceeding 1.5 mm) at T4. In the advancement group, there was only one patient with an RCP–ICP distance greater than 1.5 mm. Two patients in the setback group who originally had large RCP–ICP distances (2 mm or more) at T1 showed a normal distance at T2 which was still present at T4. These patients probably had a functional component of their Class III malocclusion.

Of all the tests used to evaluate neurosensory status, the 2-pd was the most meaningful. With the exception of the lip in the setback group, there was almost complete restoration in the two groups in 2-pd at T3. There were also significant to highly significant increases in 2-pd in both groups at T4. Why did an increase occur again at this time? The effect of age may have contributed to this finding. While the mean age at T1 was 21.4 years in the advancement and 27.5 years in the setback group, at T4 it was 34.1 and 40.2 years, respectively (range: 29.8–68.8 years).

The influence of age on 2-pd of the skin has been examined and confirmed in several other studies (Brill *et al.*, 1974a,b; Kayahan *et al.*, 1976; Shimokata and Kuzuya, 1995; Sato *et al.*, 1999).

Brill *et al.* (1974a) examined 2-pd of the trigeminal nerve in 50 subjects between 21 and 28 years and 40 and 85 years of age. They found a highly significant increase in 2-pd in the older group. There were no differences in gender within each group. The mean 2-pd of the chin was 5.83 mm in the younger and 10.12 mm in the older group. Compared with 2-pd data of the present study, the data of Brill *et al.* (1974a,b) were 10.16 mm in the advancement and 10.38 mm in the setback groups at T4. The chin showed no difference.

The values can therefore be regarded as normal. Schultze-Mosgau *et al.* (2001) reported 2-pd values of 13.9/14.4 months after surgery, a little higher than 4 mm at the chin and 5 mm at the lip after 12 months. However, the values at T1 in the present study were also somewhat higher. Unfortunately, 2-pd values have not been published in numerous studies.

If present, the neurological changes were mild. The influence of a BSSO on function of the inferior alveolar nerve is not problematic. Nevertheless, there were several patients who still complained of paresthesia in the chin region at T4. Total anaesthesia or neuralgia was not present at any time point.

Conclusions

This study evaluated the long-term effects on the craniomandibular function and neurosensory status of patients with BSSO with rigid internal fixation for mandibular advancement or setback. The results suggest that craniomandibular function shows mostly restitution 12.7 years after surgery.

The initial post-surgical neurosensory impairment was barely detectable 1 year after surgery. The neurosensory deficit 12.7 years after surgery was probably due to the normal human process of ageing, and the 2-pd was comparable with control subjects of the same age.

Dysfunctions such as TMJ clicking, bruxism, and pain in the TMJ and muscles are neither increased nor decreased after BSSO. On the contrary, they are the same as in a normal population.

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