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Neurosensory and functional evaluation in distraction osteogenesis of the anterior mandibular alveolar process

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Abstract. Neurosensory status and craniomandibular function of 19 patients (mean age 35.2 years, range 17.8–58.8 years) treated by combined surgical orthodontic treatment with distraction osteogenesis of the mandibular anterior alveolar process (DO group) was compared with that in 41 orthodontically treated patients (mean age 22.9 years, range 15.1–49.0 years; control group). Clinical examination took place on average 5.9 years (DO group) and 5.4 years (control group) after treatment ended. Neurosensory status was determined by two-point discrimination (2-pd) and the pointed and blunt test. Lateral cephalograms evaluated advancement of the mandibular alveolar process and possible relapse. There was no significant difference in craniomandibular function and neurosensory status between the groups. Age was significantly correlated with 2-pd at the lips (DO: $p = 0.01$, $R = 0.575$; control group: $p = 0.039$, $R = 0.324$) and chin (DO: $p = 0.029$, $R = 0.501$; control group: $p = 0.008$, $R = 0.410$). Younger patients had smaller 2-pd values. Gender, age, the amount of advancement, and relapse at point B or incision inferior show no correlation with craniomandibular function and neurosensory impairment. DO of the mandibular anterior alveolar process is a valuable and safe method with minor side effects regarding neurosensory impairment.

Keywords: distraction osteogenesis; neurosensory status; craniomandibular function; impairment.

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The principles of distraction osteogenesis (DO) were first described by Codivilla[1] and widely applied and refined by Ilizarov.[2] In 1972 Snyder et al.[3] applied the technique of DO to lengthen a canine mandible and in 1989 the first human mandibular distraction was performed by McCarthy et al.[4]

Segmental intra-alveolar DO of the anterior mandibular alveolar process was first introduced by Triaca et al.[5] The goal was the creation of space and to reduce anterior crowding of the mandibular arch as a result of distraction of the anterior mandibular alveolar process. Segmental alveolar DO is an alternative to extraction orthodontic therapy which can often cause a compromised facial profile, dental stripping, or mandibular arch expansion to resolve dental crowding and its high risk of periodontal problems, such as root exposure. It allows the correction of Class II skeletal problems instead of a bilateral sagittal split osteotomy (BSSO). In skeletal

Class III patients the anterior mandibular dentition could be decompensated and the sagittal step for further orthognathic surgery (Le Fort I surgery) increased.[5,6] Recently, changes in skeletal stability, and soft tissue profile were analysed after DO of the anterior alveolar process.[7,8]

Besides the clinical benefits of DO, complications such as neurosensory disturbances of the inferior alveolar nerve are possible. Neurosensory changes in the alveolar nerve were evaluated mainly in animal studies after DO of the whole mandible.[9–12] The nerve tissue seems to have the ability to adapt to the gradual stretching due to DO within physiological limits. A distraction rate of 1 mm/day appears to be relatively safe for the inferior alveolar nerve[9,10] whereas rapid distraction may cause serious damage such as demyelination, axonal swelling, decrease of the number of axons, and axoplasmic darking.[10] Others[12] related the high incidence of nerve injuries tested by using sensory nerve action potentials to the device construction and osteotomy technique. Apart from these results, based on osteotomies in a BSSO surgical approach for mandibular distraction, no clinical data have been published on craniomandibular function and neurosensory impairment in patients who have osteotomy anterior of the foramen mandibulae to distract the anterior mandibular alveolar process only.

The aim of the present research was to analyse the neurosensory status and craniomandibular function of patients treated by DO of the anterior mandibular alveolar process and to compare the data with a control group of non-surgically treated orthodontic patients.

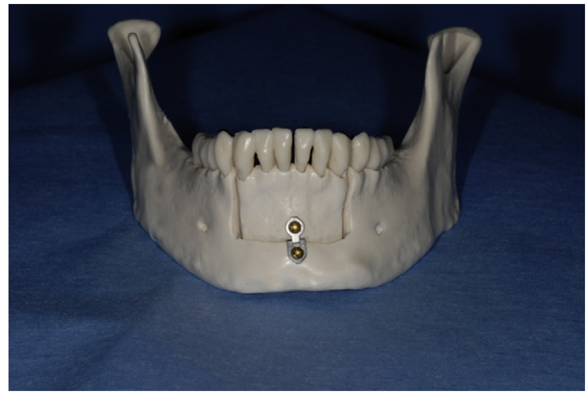

Fig. 1. The horizontal osteotomy is made about 5 mm inferior to the apices of the teeth. A joint plate is loosely fixed with screws before completion of the vertical osteotomies.

Subjects and methods

The DO group consisted of 19 patients (mean age 35.2 years, range 17.8–58.8 years) who had orthodontic treatment in combination with DO of the anterior mandibular alveolar process as described by Triaca et al.[5] No additional mandibular surgery (genioplasty, BSSO) was performed. In 16 patients, the osteotomy for the DO was between the lower canine and first premolar, and in the remaining 3 patients it was between lower lateral and canine. Additional maxillary surgery was accepted and performed in 5 patients. Two patients had an additional one piece Le Fort I osteotomy, two others a surgically assisted rapid maxillary expansion (SARME), and one a distraction of the maxillary anterior alveolar segment in the DO group. No syndromes, clefts, traumas, or other abnormalities were accepted. The DO group was examined on average 5.9 years (range 2.7–8.4 years) after DO of the anterior alveolar mandibular process and completion of orthodontic treatment. 15 patients were female (mean age 37.7 years, range 17.8–58.8 years) and 4 male (mean age 25.9 years, range 19.6–37.8 years) and the mean age at surgery was 29.3 years (range 12.3–56.1 years).

The control group comprised 41 orthodontically treated patients (mean age 22.9 years, range 15.1–49.0 years) without any concomitant maxillofacial surgery. Orthodontic treatment had finished a mean of 5.4 years previously (range 0.2–12.9 years). 21 patients were female (mean age 22.9 years, range 15.3–49.0 years) and 20 were male (mean age 22.9 years, range 15.1–41.8 years).

All patients were treated by the same orthodontist (MA) with a straight wire appliance and for mandibular anterior alveolar DO by the same maxillofacial surgeon (AT) at the Pyramide Clinic in Zürich, Switzerland. The patients were clinically examined in the private practice by one of the authors (CJ) in Zürich, Switzerland. All clinical examinations and analysis of the radiographic data were carried out by the same clinician (CJ).

Ethical approval was accomplished and admitted by the ethic committee of the Kanton Zürich, Switzerland, number 593. All patients provided written, informed consent.

Surgical procedure

The DO procedure was performed as described by Triaca et al.[5] and illustrated in Figs. 1 and 2. Prior to surgery, the inter-root space of the teeth next to the vertical osteotomies is increased by tipping them orthodontically. The desired new anterior position of the anterior alveolar segment has to be defined by the orthodontist and surgeon, from which the required position of the hinge axis is derived. The surgery

Fig. 2. After the horizontal osteotomy is completed, incomplete vertical osteotomies are made mostly between the canine and first premolars. The vertical osteotomies are then completed, the mandibular anterior alveolar segment is then mobilized with a chisel, and the screws holding the plate are tightened.

can be performed under local or general anaesthesia. A horizontal incision is made from canine to canine 1 cm from the attached gingiva. The osteotomy is made about 5 mm inferior to the apices of the teeth with the help of a thin burr-type bone cutter (Cutter E0540, Maillefer, Ballaigues, Switzerland). After the horizontal osteotomy is completed, incomplete vertical osteotomies are made mostly between the canine and first premolars (less often between the lateral incisors and canines). When creating the osteotomies, care must be taken to maintain the lingual periosteum and mucosa largely intact. A joint plate is loosely fixed with screws before completion of the vertical osteotomies. The vertical osteotomies are completed, the segment is mobilized with a chisel, and the screws holding the plate are tightened. The free rotation of the anterior bone segment is confirmed, and the wound is closed, and sutured. After 5 days of healing, the orthodontic appliance to distract the anterior alveolar segment is activated for 0.5 mm/day. After the desired position is reached, the segment is held in position for 6 weeks with the help of the activation appliance, which is locked in the final position.[5]

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

First, the 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.

Second, the two point touch test (two point discrimination, 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. The mean of two measurements was used.

Craniomandibular function

Signs of craniomandibular dysfunction concerning mandibular function, clickings, crepitus, and pain in the temporomandibular joint (TMJ) and muscles (temporalis and masseter) were evaluated by palpation.

Clinical findings on function were recorded as follows. The maximum opening capacity was measured with a steel ruler to the nearest 0.5 mm 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. Maximum lateral movement was measured as follows: a vertical line was drawn on the incisors 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 the 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. Overjet was measured with a steel ruler for maximum protrusion. The patient was 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 two measurements was used. Deviations to the left or right during maximum opening were recorded on a three-point scale: 0 = 0–2 mm; 1 = 3–4 mm, and 2 = >5 mm. The patients were examined for audible or palpable TMJ sounds (clicking and crepitus). 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 0.5 mm.[13]

The first cephalogram was taken at a mean of 34.5 days before surgery (T1), the second (T2) at a mean of 11.2 days, T3 at a mean of 34.3 days, and clinical follow-up (T4) at a mean of 5.9 years. The skeletal tissue changes were evaluated on profile cephalograms taken with the teeth in the intercuspal position, and 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 to obtain all cephalograms.

The lateral cephalograms of each patient were scanned and evaluated with the program Viewbox 3.1® (dHal software, Kifissia, Greece). The cephalometric analysis was carried out by one author (CJ) and included the reference points and lines shown in Fig. 3. Horizontal (x-values) and vertical (y-values) linear measurements were obtained by superimposing the tracings of the different stages (T2, T3, and T4) 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.[14] 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 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. 3).

The lateral cephalograms of T2 were only used to locate the cephalometric point alveolar surgical anterior base (Asab) before postoperative distraction 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 (Fig. 4). 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-T1)/Asab(x-value; T3-T2). The cephalometric values of the same groups were recently published.[7,8]

Statistical methods

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 paired t-test was used for comparisons between the right and left sides of the face. The unpaired t-test was used for inter-group comparisons in analysis of neurosensory status and craniomandibular function. The relationships between cephalometric variables, age, and gender were analysed with the Pearson's product moment correlation coefficient.

To determine the error of the method, 21 initial lateral cephalograms were selected randomly after 2 weeks and reanalysed (Table 1). 21 subjects were selected randomly after 2 weeks to measure the 2-pd of the lips ($si = 0.6$ mm) and chin ($si = 0.7$ mm). The error of the

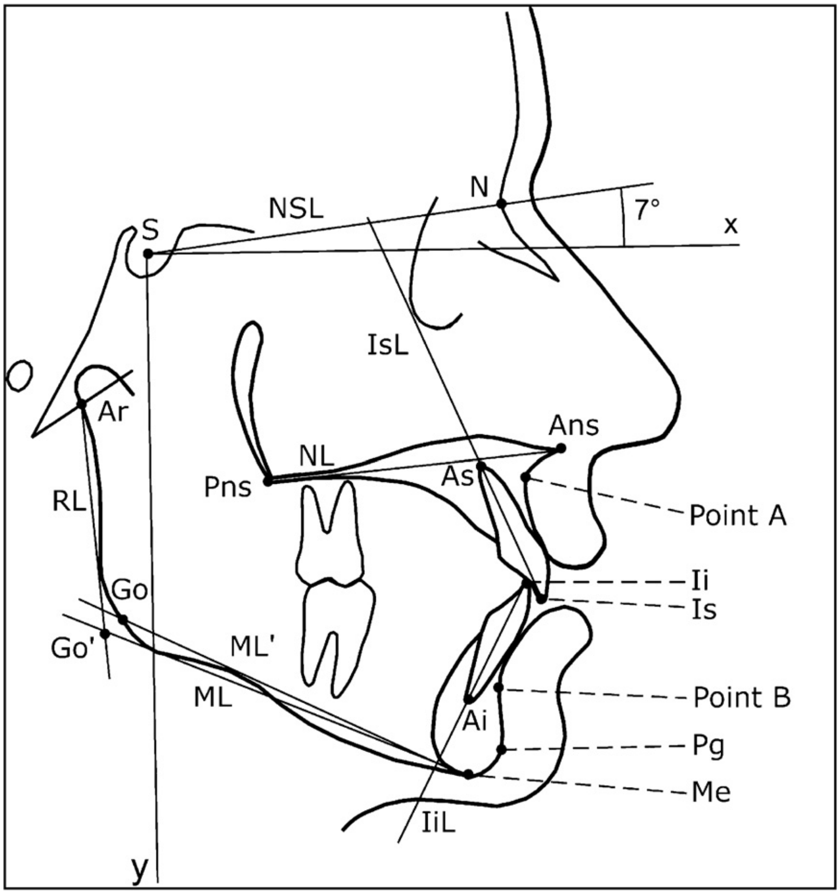

Fig. 3. Reference points and lines used in the cephalometric analysis. The coordinate system had its origin at point S (sella), and its *x*-axis formed an angle of 7 degrees with the reference line NSL. S, sella; NSL, nasion-sella-line; N, nasion; *x*, horizontal reference plane; NL, nasal line; ILs, 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.

method (*si*) was calculated with the formula:

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

where *d* is the difference between the repeated measurements and *n* is the number of duplicate determinations.[15] No systematic errors were found when the values were evaluated with a paired *t*-test.

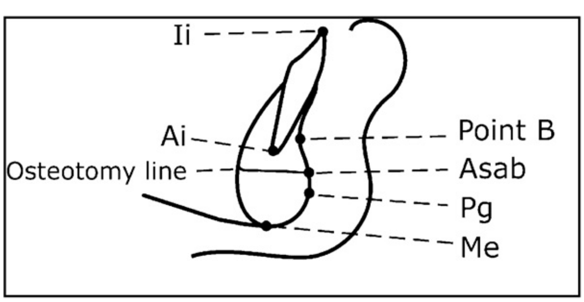

Fig. 4. Reference points used in the cephalometric analysis of the lower apical base in DO patients. Ii, incision inferior; point B; Ai, apex inferior; Asab, apical surgical anterior base; Pg, pogonion; and Me, menton. Asab is the most anterior and inferior point of the lower anterior segment resulted 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; T3-T1)/Asab(*x*-value; T3-T2).

Results

Neurosensory status

Comparisons between the right and left side of the face regarding the 2-pd and pointed and blunt test showed no significant difference for the control and DO groups. For this reason, the right and left side each for the chin and for the lips were pooled together. No significant differences were found between the DO and control groups for the 2-pd at the lips and chin (Table 2). Only one patient in the DO group was unable to differentiate between sharp and blunt at the chin.

In the DO group, gender was significant correlated with the 2-pd at the lips ($p = 0.021$; $R = 0.524$) and chin ($p = 0.026$; $R = 0.509$). Women showed larger values for 2-pd than men, but there were significantly older female than male patients in the sample ($p = 0.045$; $R = 0.464$). Age was significantly correlated with 2-pd at the lips ($p = 0.01$; $R = 0.575$) and chin ($p = 0.029$; $R = 0.501$). Younger patients had smaller 2-pd values than older patients. The amount of advancement (T3-T1) and relapse (T4-T3) at point B, incision inferior, anterior surgical apical base, and Ii(*x*-value; T3-T1)/Asab(*x*-value; T3-T2) were not correlated with the 2-pd at the lips or chin. Gender, age, the amount of advancement (T3-T1), and relapse (T4-T3) at point B, incision inferior, anterior surgical apical base, and Ii(*x*-value; T3-T1)/Asab(*x*-value; T3-T2) were not correlated with the maximum mouth opening, laterotrusion, and protrusion. One exception was that patients with more horizontal relapse (T4-T3) at incision inferior showed significantly less maximum protrusion ($p = 0.018$; $R = -0.536$).

In the control group, gender did not show any significant correlations but a higher age was significantly correlated with an increase in 2-pd at the lips ($p = 0.039$; $R = 0.324$) and chin ($p = 0.008$; $R = 0.410$).

Multiple regression analysis was used to test the significance of age, gender and surgery on 2-pd of the lips and chin in both groups pooled together (Tables 3 and 4).

Craniomandibular function

The objective examination on signs of craniomandibular dysfunction did not demonstrate any statistical difference between the DO and control groups (Table 5). Two patients (11%) in the DO group and three (7%) in the control group showed TMJ clicking. One patient in the DO group showed pain on palpation of the temporalis muscles whereas none did in

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

Variable	*si*	Variable	*si*	Reference point	*si* (mm)	
					x	*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					

Asab, alveolar surgical anterior base.

Table 2. Minimum distance (mm) for two-point discrimination.

	DO group ($n = 19$)			Control group ($n = 41$)			Unpaired *t*-test
	Mean	*SD*	Range	Mean	*SD*	Range	*p*
Lip	3.7	1.4	1–6	3.7	1.2	1–6	0.938
Chin	8.7	2.5	4–15	8.3	2.1	4–15	0.507

the control group. The RCP-ICP sagittal distance tended to be larger than 0.5 mm in the control group with 6 patients (14%) compared to 1 patient (5%) in the DO group.

No statistical differences were found for the maximum opening capacity, laterotrusion, and protrusion between the two groups (Table 6). The mean values were similar. Patients with maximum mouth opening capacities of less than 40 mm were found in both groups: 1 patient with 38 mm (5%) in the DO group and 2 patients (5%) in the control group.

Discussion

The present study could not find any differences between patients with DO of the anterior mandibular alveolar segment and control patients regarding neurosensory status and craniomandibular function.

A limitation of this study could be that the clinical data were collected on a long-term single occasion and approximately 5 years after DO or orthodontic treatment. The comparison of the surgically treated patients with a control group of orthodontically treated patients was chosen to overcome the disadvantage of missing presurgical and immediate post-surgical follow-ups. Nevertheless, this clinical evaluation and set-up allows the authors to draw some conclusions about the postsurgical situation in craniomandibular function and neurosensitivity regarding DO.

The present study is based on non-growing and healthy adult patients with no history of trauma or other types of mandibular surgery. There is a lack of human studies evaluating neurosensory status and cranimandibular function after DO in the literature. To the authors’ knowledge this data on DO of the anterior alveolar segment is missing. In general, DO is mainly carried out in young patients with different syndromes[16] (hemifacial microsomia, Nager, and Treacher Collins) whereby presurgical neurosensory function and regenerative potential of the inferior alveolar nerve is questionable.

Whitesides and Meyer[17] followed 5 patients prospectively who underwent vertical posterior body osteotomy or BSSO with the application of a distraction device for advancement of the mandible of 10–14 mm. They concluded that all 10 nerves showed improvement of function as measured by 2-point discrimination, response to painful stimulus, and moving brush stroke identification 1 year after surgery.

Several publications on animals addressed the morphological and clinical changes of the inferior alveolar nerve after DO. Block et al.[9] performed nerve testing and histology on operated and non-operated sides in four dogs. They found only mild pathological changes on microscopic examination when the mandible was lengthened on average 5.5 mm, apart from one case that showed significant nerve degeneration resulting from acute laceration by an extraoral device. Makarov et al.[12] evaluated the inferior alveolar nerve in 12 dogs with mandibular distraction of 10 mm using sensory nerve action potentials. 12 of 24 nerves showed complete loss of evoked potentials after surgery without recovery. The high incidence was thought to be related to device construction and osteotomy technique.

In the present study, age was significantly correlated with 2-pd at the lips and chin in both the DO and control group with no significant difference between the groups. Younger patients had smaller 2-pd values than older patients. These findings are in accordance with the research of Brill et al.[18] which demonstrated a significant increase of 2-pd in older subjects. Joss and Thüer related the newly manifested increase 12.7 years postoperatively in 2-pd distance in patients with BSSO and mandibular advancement or setback to the normal human process of ageing.[19] It has been reported that the incidence or severity of neurosensory impairment after BSSO increases with age.[20–22]

The present study shows that neither the amount of advancement (T3-T1), nor the relapse (T4-T3) at point B, incision inferior, and anterior surgical apical base

Table 3. Multiple regression analysis to test the significance of age, gender and surgery on 2-pd of the lips.

Independent variables	Coefficient *b*	Standard error	Significance
Age	0.060	0.018	0.001
Gender	0.314	0.297	0.296
Surgery	0.806	0.370	0.034

Significance of the model: $R = 0.453$, $R^2 = 20.5\%$, $p = 0.005$.
Dependent variable (y): 2-pd of the lips.
Multiple regression analysis: $y = 0.506 + b_1\text{age} + b_2\text{gender} + b_3\text{surgery}$.

Table 4. Multiple regression analysis to test the significance of age, gender and surgery on 2-pd of the chin.

Independent variables	Coefficient *b*	Standard error	Significance
Age	0.130	0.032	0.000
Gender	−0.395	0.543	0.470
Surgery	1.084	0.677	0.115

Significance of the model: $R = 0.481$, $R^2 = 23.1\%$, $p = 0.002$.
Dependent variable (y): 2-pd of the chin.
Multiple regression analysis: $y = 3.374 + b_1\text{age} + b_2\text{gender} + b_3\text{surgery}$.

Table 5. Number of patients with signs of craniomandibular dysfunction.

	DO group ($n = 19$)	Control group ($n = 41$)
Deviation on opening		
0–2 mm (normal)	14 (74%)	37 (90%)
3–4 mm	4 (21%)	3 (7.5%)
≥5 mm	1 (5%)	1 (2.5%)
TMJ clicking total	3 (16%)	3 (7.5%)
Unilateral	2 (10.5%)	3 (7.5%)
Bilateral	1 (5.5%)	0
TMJ crepitus total	2 (10.5%)	2 (5%)
Unilateral	1 (5.5%)	2 (5%)
Bilateral	1 (5.5%)	0
Pain on palpation of TMJ from lateral total	0	0
Unilateral	0	0
Bilateral	0	0
Pain on palpation of TMJ from posterior position total	0	0
Unilateral	0	0
Bilateral	0	0
Pain on palpation of the temporalis muscles total	1 (5.5%)	0
From extraoral	0	0
From intraoral	1 (5.5%)	0
Pain on palpation of the masseter muscles total	0	0
From extraoral	0	0
From intraoral	0	0
RCP-ICP distance sagittal ≤ 0.5mm	18 (94.5%)	35 (85%)
RCP-ICP distance sagittal > 0.5mm	1 (5.5%)	6 (15%)
RCP-ICP distance lateral ≤ 0.5mm	18 (94.5%)	41 (100%)
RCP-ICP distance lateral > 0.5mm	1 (5.5%)	0

ICP, intercuspal position; RCP, retruded contact position.

Table 6. Maximum movement capacity of the mandible (mm).

	DO group ($n = 19$)			Control group ($n = 41$)			Unpaired t-test
	Mean	SD	Range	Mean	SD	Range	p
Max. mouth-opening capacity	51.6	6.6	38–61	52.8	6.6	33–65	0.520
Max. lateral movement capacity	9.2	2.9	5–15	9.5	2.3	2–15	0.656
Max. protrusion	8.6	2.1	6–14	8.5	1.8	4–12	0.860

inferior or the type of movement of the distracted segment were correlated to the 2-pd at the lips or chin.

It has been demonstrated that stretching of the inferior alveolar nerve in BSSO with large mandibular advancement could result in increased loss of neurosensensory function.[22] The osteotomy design in the present patient population avoids stretching and direct contact with the inferior alveolar nerve, which seems to be the major reason for the absence of neurosensory problems after DO of the mandibular anterior alveolar segment. Vertical osteotomies are made mostly between the canine and first premolars (less often between the lateral incisors and canines) and therefore anteriorly to the exit of the inferior alveolar nerve. A horizontal osteotomy is made about 5 mm inferior to the apices of the teeth.[5]

Generally, 40 mm is considered an acceptable value for maximum mouth opening capacity.[23] One patient in the DO group and two patients in the control group were below this level.

BSSO for mandibular advancement aims, as does DO of the mandibular anterior process, for a sagittal correction of the mandible. Therefore these studies could be helpful for indirect comparisons with the present data. Joss and Thüer found a significant impairment in movement capacity 7.3 months after surgery which was still reduced but improved at 13.9 months. 12.7 years post-surgically, full restitution to pre-surgical values was shown.[19] Only minor changes were found in TMJ signs such as clicking or pain before and after surgery[19,24,25] whereas others found an improvement[26] or impairment.[27] 5 years after treatment, craniomandibular function, as measured in this study, was comparable to non-surgical controls. The range of mandibular motion, TMJ dysfunction such as clicking, crepitus, muscular pain, and deviation on opening were normal and similarly distributed in both groups.

It could also be argued that DO of the mandibular anterior alveolar process might be beneficial to prevent biomechanical side effects on the mandibular condyle that can occur after BSSO or mandibular DO. 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.[28] It was showed that 7% of all BSSO advancement patients appear to undergo progressive condylar resorption.[29]

Mandibular widening by symphyseal distraction osteogenesis is another approach to resolve lower incisor crowding to gain space and prevent premolar extractions.[30] Histological findings in 9 monkeys showed morphological differences within the fibrous layer, cartilage layer or bone/cartilage interface. Specific areas of condylar compression due to rotation of the condyle around a vertical axis resulted from the symphyseal distraction. More degenerative changes would occur in an increased rate of midline distraction beyond the adaptive capacity of the condyles.[30] It was also speculated that adaptive potential is being lost with age and thereby rendering the mandibular condyles more susceptible to adverse changes.

In conclusion, no differences between orthodonically treated control subjects and patients with DO could be found. DO of the mandibular anterior alveolar segment is a valuable and safe method with minor side effect regarding craniomandibular function and neurosensory impairment.

Competing interests

None declared.

Funding

None.

Ethical approval

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

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