Twenty adult patients (13 women and 7 men; mean age 41 years) were included. Mean mandibular advancement was 11.1 mm (range 6 mm to 15 mm); 19 of the 20 patients had a mandibular advancement >7 mm. The skeletal stability was analyzed with cephalometric analysis using lateral cephalograms at predistraction (T0), start of consolidation (T1), and postdistraction after device removal (T2). The basal sagittal relation of the mandible in relation to the cranial base (SNB), the relation between the maxilla and mandible (ANB), and the mandibular jaw angle (GN-tgAr) were analyzed.

Results: Cephalometric analysis indicated significant differences in ANB, SNB, and mandibular jaw angle between T0 and T1. There was also a significant difference in the mandibular jaw angle between T1 and T2. Sensory function in the mental nerve was subjected to evaluation. Forty percent of the operated sides had a partially affected sensory function at the 18-month postdistraction follow-up. Six patients (30%) had complications registered between the osteotomy and removal of the distraction device; two had device-related problems, two had operator-related problems, and two patients had minor problems with infection and local irritation.

Conclusion: Mandibular distraction osteogenesis is a sagittal skeletally stable method for adult patients in situations with larger advancements, with no risk for total loss of sensory function.

Keywords: Mandibular distraction; BSSO; NSD; IAN; Distraction osteogenesis

Introduction

Surgical advancement of the retrognathic mandible can be performed with either Bilateral Sagittal Split Osteotomy (BSSO) or Mandibular Distraction Osteogenesis (MDO) [1,2]. BSSO is the more frequently used technique but has downsides for the individual patient despite modifications. Large intermaxillary discrepancies create a need for extensive sagittal advancement of the mandible, which increases the risk for skeletal relapse. The surgical technique is also known for its risk for Neurosensory Disturbance (NSD) in the Inferior Alveolar Nerve (IAN), resulting in alteration of sensitivity in the patient’s lip and chin area corresponding to the sensory innervation in the mental nerve [3,4]. The risk of NSD after BSSO increases with the age of the patient, as well with the size of the advancement [5,6].

Distraction Osteogenesis (DO) is used for gradual advancement, and results in bone regeneration between two bone segments and simultaneous expansion of the soft tissues under a gradual tensile force [7,8]. The gradual advancement of bone segments usually starts 5 to 7 days postoperatively to allow callus formation between the bone segments and soft tissue healing in the incision (latency period). During the distraction period, advancement by 1 mm/day (0.5 mm twice daily) causes a tensile force, which pulls the bone segments apart and stimulates new callus formation. The newly formed bone will mineralize and consolidate during a period of 6 to 8 weeks after complete distraction (consolidation period), before the device is surgically removed [7,9]. It has been suggested that DO has fewer disadvantages than BSSO concerning skeletal relapse and the alteration of sensitivity, especially with respect to larger advancements [1,2,10]. Such risks are believed to depend on a gradual expansion of the soft tissues, less exposure of the periosteum, and placement of the osteotomy split anterior to the pterygomaseteric muscle, which could decrease the soft tissue tension and allow a better adaptation. Gradual advancement may facilitate physiological
adaptation over a longer time interval than BSSO [1,2,11].

Regarding postoperative stability and relapse, both BSSO and DO show similar results when the advancement is between 6 mm and 10 mm [2]. After BSSO, there is mainly a risk for relapse at two anatomical sites: In the osteotomy site due to instability in the fixation and due to condylar malpositioning. BSSO offers good skeletal stability and minimal relapse in patients with normal or low plane angle, but a higher risk of relapse in patients with high mandibular plane angle and when the mandible is advanced >7 mm [1,12].

Advancement >7 mm is considered to cause neurosensory disturbance with greater frequency [1,11-15]. For the BSSO, the literature is reporting irreversible neurosensory disturbance ranging from 0% to 85% [13,14,16]. Compared to a range of 0% to 56% after MDO [13,17,18]. Some studies have shown that MDO is a safer technique with no persistent damage to the nerve in advancements up to 10 mm, when the distraction rate does not exceed 1 mm/24 h [7,11,13]. A higher distraction rate disturbs the gradual adaptation of the nerve during distraction and carries a higher risk for nerve damage [2,8,19]. The age of the patient is another important factor. Studies have reported a correlation between permanent neurosensory disturbances and increasing age due to diminished regenerative capacity of the nerve [1,20-22]. However, in the existing literature the absolute majority of included adult patients have been in their late teens or early twenties.

The aim of this study is to evaluate mandibular distraction osteogenesis regarding skeletal stability and the neurosensory function of the IAN for a cohort of elderly patients in combination with mandibular advancement >7 mm.

Materials and Methods

Patients, indications, and complications

This retrospective study included 20 patients (13 women and 7 men) who were referred for surgical correction of sagittal and vertical discrepancies between the mandible and maxilla at the department of oral and maxillofacial surgery, Umeå University Hospital, Sweden between 2003 and 2014. The inclusion criteria were age >30 years or planned mandibular sagittal advancement >7 mm. All patients were planned for mandibular advancement with distraction osteogenesis using an intraoral device. Prior to the surgery, all patients went through orthodontic treatment with fixed appliances. The amount of mandibular advancement and the vector of distraction were planned before the surgery by analyzing each patient’s occlusion, dental casts, lateral cephalograms, and clinical photos. Six patients went through additional maxillary surgery owing to extensive vertical discrepancy. For seven patients, a genioplasty was performed as a final separate surgical procedure after the follow-up at 18 months post-MDO. The median age at the time of MDO was 41 years (range 19 to 65 years). Complications between the osteotomy and removal of the distractor were registered from the patients’ medical records. Patient characteristics and descriptive data are summarized in (Table 1).

Radiographic examination and cephalometric analysis

All patients were examined with pre- and postoperative radiographic examinations including a panoramic overview, lateral

<table>
<thead>
<tr>
<th>Patient Number</th>
<th>Sex</th>
<th>Age, Years</th>
<th>Distraction, mm</th>
<th>Prosthetic indication</th>
<th>Bimax. Surgery</th>
<th>Genioplasty</th>
<th>Affected Sensory function 18 months</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>39</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td>Left</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>53</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Right</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>62</td>
<td>9</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>47</td>
<td>8</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>Incomplete osteotomy on the right side</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>27</td>
<td>11</td>
<td>X X</td>
<td></td>
<td></td>
<td>X</td>
<td>Local irritation</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>19</td>
<td>8</td>
<td>X X</td>
<td></td>
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<td>-</td>
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</tr>
<tr>
<td>7</td>
<td>M</td>
<td>65</td>
<td>12</td>
<td>X</td>
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<td></td>
<td>X</td>
<td>Infection</td>
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<td></td>
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<td>9</td>
<td>F</td>
<td>33</td>
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<td></td>
<td></td>
<td></td>
<td>Device fracture</td>
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<td>48</td>
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<td>X X</td>
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<td>X</td>
<td>Fixation screw adjusted</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>22</td>
<td>15</td>
<td></td>
<td>X X</td>
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<td>X</td>
<td>-</td>
</tr>
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<td>17</td>
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<td>22</td>
<td>13,5</td>
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<td>X X X</td>
<td></td>
<td>X</td>
<td>Device fracture</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>48</td>
<td>10</td>
<td></td>
<td>X X X</td>
<td></td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>F</td>
<td>42</td>
<td>15</td>
<td>X</td>
<td></td>
<td>X X X</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>F</td>
<td>41</td>
<td>13</td>
<td></td>
<td></td>
<td>X X X</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

F: Female; M: Male

Notes: Age: age at surgery. Affected sensory function was classified as 1 in a scale of 0-2 (0 = loss of sensory function, 1 = affected sensory function, 2 = normal sensory function). Complication: complication registered in a medical chart.
cephalograms, and en face projections. To evaluate the advancement of the mandible, three lateral cephalograms were performed for all patients (Figure 1a-1c).

Predistraction (T0, Figure 1a); start of consolidation period/completed active distraction (T1, Figure 1b); and postdistraction/final control after removal of distraction device/orthodontic appliance, 18 months after start of consolidation period (T2, Figure 1c). The analyses were performed manually on lateral cephalograms (T0 to T2) using the following reference points: Sella (S), Nasion (N), Point A (A), Point B (B), Articulare (A), Gonion (Gn), and tgo.

The evaluation included measurement of the basal sagittal relation of the mandible in relation to the cranial base (SNB), the relation between the maxilla and mandible (ANB), and the mandibular jaw angle (GN-tgo-Ar). The measured angles were classified according to Clinical Cephalometry for the Bergen-technique [23].

Interclass correlation
All lateral cephalograms were evaluated twice by two independent observers. Interclass correlation between the observers was calculated in order to control the reliability of tracing.

Surgical procedure and distraction protocol
The surgical procedure was performed under general anesthesia. All patients received local anesthesia with xylocaine-adrenalin 20 mg/ml to achieve vasoconstriction and benzyl-penicillin 3 g × 3 or clindamycin 600 mg × 3 for patients with penicillin allergy.

A soft tissue incision was made bilaterally from the trigonum retromolare following the external oblique ridge to the first premolar. A mucoperiosteal flap was reflected, exposing the lateral part of the mandibular body and mandibular base. The distractor device was attached to the lateral part of the mandible with two fixation screws on either side of the planned osteotomy line. The device was then removed prior to the osteotomy. Using a surgical saw, cortical bone was cut from the lingual to the buccal cortex on the trigonum retromolare, at which point a vertical cut in the buccal cortex was made down to the mandible base. The osteotomy was completed with an osteotome and the distraction device was reattached to the earlier drilled holes by fixation screws and activated to verify stability and direction of movement. The soft tissue incision was closed with resorbable sutures. Patients were hospitalized 1 or 2 days postoperatively and given phenoxymethyl-penicillin 1.6 g × 3 or clindamycin 300 mg × 3 for 10 to 14 days. All patients were prescribed paracetamol or non-steroid anti-inflammatory drugs postoperatively. After a latency period of 5 to 7 days, the distraction of the mandible started at a rate of 1 mm/day until the desired relation between mandible and maxilla was achieved. During the active distraction period and the consolidation period, all patients had rubber elastics to stabilize the mandible vertically. The distraction device was removed surgically after a consolidation period with a mean time of 3 months.

Sensory function in the IAN
To evaluate postoperative neurosensory function in the IAN, the sensory function on the lower lip (mental nerve) was evaluated by light touching with the tip of the right index finger on the vermillion border. This evaluation was performed at 6 and 18 months postoperatively. Seven patients were treated with additional genioplasty as a final and separate surgical procedure. The genioplasty was performed a minimum of 18 months after the postoperative neurosensory evaluation.

The vermillion border of the upper lip (or, in the case of bimaxillary surgery, the skin latero-inferior to the eye on the same side) served as a reference. Sensory function was graded subjectively in three categories by the patient: not affected (grade 2), partially affected (grade 1), or total loss of sensory function (grade 0).

Statistics
Mean values and standard deviation for T0-T2 were calculated and presented in box plots. For evaluation of the changes in ANB, SNB, and jaw angle during treatment, paired t-test between T0, T1, and T2 was used for analysis. P-values ≤ 0.05 were considered significant.

Results
Mandibular advancement
The mean advancement was 11.1 mm (range 6 mm to 15 mm) with 19 patients exceeding 7 mm advancement.

Cephalometric analysis of stability after MDO
The changes in ANB during treatment are shown in (Figure 2a). There were statistically significant differences between predistraction (T0: 6.8 ± 3.3) and start of consolidation (T1: 4.5 ± 3.7), and between

Figure 1: Lateral Cephalograms for Analysis.
- a. Predistraction (T0).
- b. Start of consolidation (T1).
- c. Postdistraction (T2).
predistraction (T0: 6.8 ± 3.3) and postdistraction (T2: 4.4 ± 3.7) (p<0.05 for both). No significant difference (p=0.7316) was observed between start of consolidation (T1) and postdistraction (T2).

The changes in SNB during treatment are depicted in (Figure 2b). The result shows statistically significant differences between predistraction (T0: 76.5 ± 5.7) and start of consolidation period (T1: 80.4 ± 6.0), and between predistraction (T0: 76.5 ± 5.7) and postdistraction (T2: 79.5 ± 6.4) (p<0.05 for both). No significant difference (p=0.1173) was observed between the start of consolidation (T1) and postdistraction (T2).

The changes in mandibular jaw angle during treatment are shown in (Figure 2c). The result shows statistically significant differences between predistraction (T0: 127.2 ± 9.2) and start of consolidation period (T1: 132.4 ± 8.8), and between predistraction (T0: 127.2 ± 9.2) and postdistraction (T2: 134.7 ± 7.5) (p<0.05 for both). There was a significant difference (p<0.05) between start of consolidation (T1) and postdistraction (T2).

**Sensory function after MDO**

None of the examined patients experienced a total loss of sensitivity in the examined area (0) during the postoperative follow-ups. Therefore, all results are based on patients with partially affected (grade 1), or unaffected (grade 2) sensory function. The results are based on the total number of examined sides (left and right sides) at 6 and 18 months postoperative follow-up. Sensory function was partially affected (grade 1) in 53% of the operated sides (20 of 38 sides) at the 6-month postoperative follow-up. At the final control, minimum 18 months postoperatively, 40% of the operated sides (16 of 40 sides) had partially affected sensory function (grade 1). Analysis of the neurosensory function in the mental nerve is presented in (Figure 3a,3b).

**Table 2: Interclass correlation between two observers.**

<table>
<thead>
<tr>
<th>Angle</th>
<th>Predistraction</th>
<th>Start of consolidation</th>
<th>Postdistraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANB</td>
<td>0.960 (0.894-0.985)</td>
<td>0.948 (0.867-0.980)</td>
<td>0.988 (0.971-0.995)</td>
</tr>
<tr>
<td>SNB</td>
<td>0.982 (0.955-0.993)</td>
<td>0.988 (0.970-0.995)</td>
<td>0.983 (0.957-0.993)</td>
</tr>
<tr>
<td>Jaw angle</td>
<td>0.992 (0.981-0.997)</td>
<td>0.990 (0.975-0.996)</td>
<td>0.983 (0.957-0.993)</td>
</tr>
</tbody>
</table>

Note: All data are presented as value (range).

**Figure 2: Evaluation of Skeletal Stability.**

a. Changes in ANB during treatment. Boxplots showing differences in mean (Standard Deviation: SD) of ANB during treatment. There were statistically significant differences between ANB predistraction (T0) and ANB start of consolidation period (T1), and between predistraction (T0) and ANB postdistraction (T2) (p<0.05 for both).

b. Changes in SNB during treatment. Boxplots showing differences in mean (SD) of SNB during treatment. There were statistically significant differences between SNB predistraction (T0) and SNB start of consolidation period (T1), and between predistraction (T0) and SNB postdistraction (T2) (p<0.05 for both).

c. Changes in mandibular jaw angle during treatment. Boxplots showing differences in mean ± SD jaw angle during treatment. There were statistically significant differences between predistraction (T0: 127.2 ± 9.2) and start of consolidation period (T1: 132.4 ± 8.8), between predistraction (T0: 127.2 ± 9.2) and postdistraction (T2: 134.7 ± 7.5), and between start of consolidation period (T1) and postdistraction (T2) (p<0.05 for all).

**Figure 3: Sensory Function in the Mental Nerve.**

a. Sensory function at 6 postoperative months, based on 38 examined sides.

b. Sensory function at 18 postoperative months, based on 40 examined sides.
Complications

Incomplete osteotomy occurred in patient no. 4 but was completed with mobilization of the osteotomy. Two patients had fractures of the distraction device. For patient no. 9, the fracture occurred during the distraction period, and the device was exchanged surgically under general anesthesia. The other device fracture (patient no. 17) happened during the consolidation period; the fractured distractor was exchanged with a fixed subcortical titanium plate. Patient no. 5 had a local irritation in the soft tissue from the flexible activation arm. The activation arm was fixed to the orthodontic appliance. Patient no. 7 had an infection in the area where the activator arm penetrated the soft tissue. The infection was successfully treated with antibiotics. One patient (no. 15) experienced intense pain on the left side during activation. Radiographic examination indicated a fixation screw penetrating into the mandibular canal. Removal of the screw and changing the screw position reduced the pain.

Interclass correlation

The interclass correlation between the two observers is presented in (Table 2).

Discussion

This study reports the results regarding skeletal stability, neurosensory alteration, and complications after extensive mandibular advancements with distraction osteogenesis in adult patients.

The mean mandibular advancement for this patient cohort was 11.1 mm. The literature reports that advancement exceeding 7 mm with BSSO is associated with increased risk of relapse [1,24,25]. MDO has previously shown promising results in advancements >10 mm [1,9,11,17]. Our results confirm the findings from the literature that distraction osteogenesis yields reliable sagittal skeletal stability [1,2,7,11,9]. The cephalometric analyses indicate sagittal skeletal stability with no significant relapse in SNB and ANB during the follow-up period. The cephalometric measurement analysis of the mandibular jaw angle showed a significant difference before and after treatment, indicating an increased jaw angle. All patients in this follow-up had elastics during active distraction and the consolidation period in order to counteract vertical opening in the front. Previous studies have reported that MDO may cause an open bite, especially when intraoral devices are used [12,25]. The higher risk for developing an open bite when using intraoral devices is associated with several factors, such as incorrect distraction vector or placement at the time of surgery, occlusional disturbances, or suprahyoid muscle pull during the distraction and consolidation period. Because intraoral distraction devices usually result in an increased jaw angle, they may be more suitable for patients with low plane angles [12,25]. One can conclude that the jaw angle increase in our study cohort indicates a risk for postoperative open bite.

NSD is one of the main factors that influences each patient’s definition of postoperative good result and quality of life. The large variation in the incidence of reported NSD depends on several factors, such as different methods for evaluation of the nerve function and different follow-up periods [15]. Evaluation methods are based on objective or subjective assessments. The objective evaluation is based on different parameters, and the subjective evaluation is based on the patient’s self-report [13,15]. A previous study by Westermark et al. [26] demonstrated a correlation between subjective evaluation and the objective assessment of neurosensitivity. The most common complication correlated to BSSO is the risk for NSD. The literature reports an NSD ranging between 0% and 85% during the first 2 years after BSSO [13,14,16]. The patient’s age (>30 years), advancement >7 mm, and manipulation of the nerve during the surgery are factors that can have a negative effect of NSD [1,2,13].

The main symptoms of NSD are loss of sensory function in the lower lip, the mental nerve area, and the gingiva of the affected side. Severe cases of NSD can also include neuropathic pain, which could strongly affect quality of life and patient satisfaction [15]. It has been indicated that NSD is more common among elderly patients [27 due to poorer regeneration ability in the damaged nerves [1,20-22]. Few studies have investigated the occurrence of NSD after MDO, but the reported prevalence ranges between 0% and 56% [13,18]. Our study included 20 patients with a median age of 41 years at the time of surgery who were evaluated by the subjective assessment of neurosensory function. The patients were examined preoperatively, and at 6 and 18 months postoperatively. Our results show 43% had partially affected sensory function at 6 months postoperatively and 40% had partially affected sensory function at a minimum of 18 months postoperatively. None of our patients experienced a total loss of sensitivity after treatment. Our results suggest less NSD as patients in this present study are older than 30 years of age and the degree of mandibular advancement is considered large. Previous studies have mainly focused on younger patients with less advancement.

Six patients (30%) in our cohort had complications during treatment; two patients (10%) had device-related problems, two patients (10%) had operator-related problems (incomplete osteotomy, malplaced fixation screw), and two patients (10%) had minor problems with infection and local irritation. Verlinden et al. [28] made a systematic review of mandibular distraction osteogenesis that included 1,258 patients with congenital deformities. The authors observed an overall complication incidence of 34.4%. A direct comparison with our cohort is difficult due to differences in the respective patient cohorts, but the incidence of complications in our cohort does not exceed the result described by Verlinden et al. [28].

In conclusion, our study confirms previous results. Distraction osteogenesis with a large advancement of the mandible in adult patients yields a reliable sagittal skeletal stability. The results also indicate that MDO is a safe method of treatment for large advancements with less risk for total loss of sensitivity even among patients older than 30 years of age.

Ethical Approval

This study was performed according to the ethical standards of the Helsinki Declaration. Ethical application was approved by the Regional Ethical Review board in Umeå (Dnr 2016-205-31M).

References


