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Invited Review Paper
Distraction Osteogenesis

Distraction osteogenesis versus bilateral sagittal split osteotomy for advancement of the retrognathic mandible: a review of the literature

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Abstract. Bilateral sagittal split osteotomy (BSSO) and distraction osteogenesis (DO) are the most common techniques currently applied to surgically correct mandibular retrognathia. It is the responsibility of the maxillofacial surgeon to determine the optimal treatment option in each individual case. The aim of this study was to review the literature on BSSO and mandibular DO with emphasis on the influence of age and post-surgical growth, damage to the inferior alveolar nerve, and post-surgical stability and relapse. Although randomized clinical trials are lacking, some support was found in the literature for DO having advantages over BSSO in the surgical treatment of low and normal mandibular plane angle patients needing greater advancement (>7 mm). In all other mandibular retrognathia patients the treatment outcomes of DO and BSSO seemed to be comparable. DO is accompanied by greater patient discomfort than BSSO during and shortly after treatment, but it is unclear whether this has any consequences in the long term. There is a need for randomized clinical trials comparing the two techniques in all types of mandibular retrognathia, in order to provide evidence-based guidelines for selecting which retrognathia cases are preferably treated by BSSO or DO, both from the surgeon's and the patient's perspective.

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For advancement of the retrognathic mandible, bilateral sagittal split osteotomy (BSSO) is the most frequently used surgical technique. Several modifications of this technique have been made since its introduction, resulting in fewer complications[4,16,26,34,90,101]. Although BSSO is considered a predictable and safe technique after cessation of growth, damage to the inferior alveolar nerve and post-surgical relapse remain a problem[17,64,101].

Nowadays, mandibular retrognathia can also be corrected by mandibular distraction osteogenesis (DO) using

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intraoral submerged distraction appliances[18,39,50,57,85,80,87]. Fifteen years of experience with DO in the facial skeleton and numerous studies regarding the technique and biology of DO have resulted in a variety of indications and a successful distraction protocol for the cranio-facial skeleton[42,43,50,74,87]. It has been suggested that DO may have the potential to overcome the hazards associated with BSSO, and offers the possibility for surgical intervention at an earlier age.

As either DO or BSSO may be used to surgically correct mandibular retrognathia, it is the responsibility of the maxillofacial surgeon to determine the optimal treatment option in each individual case. The aim of this study was to compare these two techniques in orthognathic correction of the non-syndromic deficient mandible by reviewing the relevant literature, with emphasis on the influence of age and post-surgical growth, damage to the inferior alveolar nerve, stability post-surgery, relapse and patient-centred outcome.

Material and methods

Reports on DO and BSSO for the advancement of the retrognathic mandible in non-syndromic patients published between January 1995 and August 2006 were critically reviewed. The literature was searched with Medline through Webspirs 5 using the following search strategy: [mandibular advancement] AND [(mandible surgery OR distraction osteogenesis)] AND [(angle class II OR child OR child, preschool OR inferior alveolar nerve OR mandibular condyle OR retrognathism OR stability OR temporomandibular joint OR patient satisfaction)] AND [limit to (review OR clinical trial OR randomized-controlled trial)]. Citation lists were examined and articles found on DO and BSSO for advancement of the mandible written in English or Dutch were included. The snowball method was applied to select additional potentially useful papers not included in the literature search data. Primarily, methodologically sound clinical trials were included. Unfortunately, randomized clinical trials are lacking and thus could not be used as an inclusion criterion for the literature search. As clinical trials were not even available on all topics, especially in the case of mandibular DO as this is a relatively new technique, part of the results had to be derived from sound, larger case and retrospective studies. The results were classified according to age and post-surgical growth, nerve damage, stability and relapse, and patient-centred outcome.

Age and post-surgical growth

Surgical correction of a mandibular deformity during growth may be indicated in some cases. Early correction may overcome psychosocial problems or problems related to pain, speech, airway, anatomy, occlusion and masticatory function. Early correction may also have practical advantages concerning orthodontic treatment[10,24,63,79,99]. When compared with BSSO, it is often assumed that DO may offer the advantage of safe application for mandibular advancement in actively growing children[13,29,36,41,49,63,73].

In girls, usually at 15 years, and in boys, usually at the age of 17–18 years, approximately 98% of facial growth, especially mandibular growth, is complete[99]. Interindividual variation in growth is considerable[59,63]. These data do not indicate that surgical intervention has to wait until cessation of growth, as there is a discrepancy in time between basic dento-skeletal growth and completion of facial growth. Support for this assumption comes from Schendel et al.[76] and Wolford et al.[100] who concluded that above the age of 5 years the basic dento-skeletal morphology is established in almost all (>97%) individuals with mandibular deficiency syndrome and Class II malocclusion. Further facial growth is harmonious and does not result in significant alteration of the existing maxillo-mandibular relationship[76,100]. Besides determining the growth vector, it is also important to establish whether the mandible has a normal or deficient growth rate[99]. In patients with normal mandibular growth, the mandible is in a retruded position relative to the normally positioned maxilla, or may be smaller[99]. Surgical correction of this situation during growth results in stable and predictable results[99]. On the basis of the growth data it should be possible to perform BSSO or DO in non-syndromic patients at an early age.

Technically speaking, it is reported to be more difficult to perform a BSSO in young patients than in adults, due to the greater elasticity of the bone, the thickness of the cortical bone, the presence of unerupted molars, the lingula which is located more posteriorly and superiorly on the ramus, and the relatively short posterior vertical mandibular ramus height[63,72,99]. There are several reports supporting the application of BSSO with favourable treatment outcomes in growing children. Precious et al.[68] concluded after performing a BSSO in 34 children (age range 6–15 years) that corrective surgery for dentofacial deformities can be carried out in children and adolescents with little morbidity and few complications. Freihofer[24], Schendel et al.[76] and Wolford et al.[100] reported harmonious maxillo-mandibular post-surgical growth following BSSO in actively growing patients. Only Huang & Ross[33] (22 children, aged 8.7–16.9 years, mean advancement 10.9 mm) reported no clinically significant increase in mandibular length post-surgically, which may be attributed to their study design (Dal Pont modification, inclusion of syndromic patients). Although there is some evidence to conclude that BSSO is a safe technique in growing children with no restrictions on post-surgical, mainly vertically expressed, mandibular growth, BSSO is still applied with caution in youngsters[24,76,79,100].

From a surgical point of view DO is of smaller magnitude than BSSO and is easily accomplished in growing individuals[63]. As with DO there is simultaneous expansion of the functional soft-tissue matrix, a more normal functional matrix for succeeding growth is created[29,49]. The potential for bony regeneration is highest in younger individuals[28,49,50,85,87]. Difficulties of DO include the risk of damage to tooth buds and compliance required from the parents and infant during the distraction period[29,50,73]. Growth seems to continue following DO, even when performed in very young children. With regard to lengthening the mandible with intraoral distractors in teenagers, van Strijen et al.[84] (14 children, 12.8–15.9 years, mean advancement 7.6 mm) and Breuning et al.[10,11] (26 children, 12.8–15.9 years, mean advancement 7.6 mm) reported that mandibular DO is an effective treatment, but possible post-surgical growth awaits further evaluation[11,84]. In syndromic patients, Carls & Sailer[13] and Hollier et al.[29] reported growth to continue after DO in very young children, but such data are lacking in non-syndromic patients.

To conclude, there is a need for further studies focussing on post-surgical growth following both BSSO and DO. Currently, there is some evidence that BSSO can be applied in growing infants, but there are no data yet available on post-surgical growth following DO for advancement of the retrognathic mandible in non-syndromic patients.

Nerve damage

Permanent neurosensory disturbance is a common complication of BSSO[38,40,47,64]. The incidence of neurosensory deficit ranges from 34% to 97% in the first week to 0–75% at 1 year after surgery[8,38,47,60–62,64,67,71,75,92,94,95,102–105]. It is difficult to

compare the various studies because of wide variations in follow up and assessment of nerve function. Nerve damage does not occur at a fixed time point, but may occur during many stages of the surgical procedure[17,38,40,47,60,61,67,71,86,88]. A close correlation between increasing age and frequency of permanent neurosensory deficit following BSSO is reported in many studies[7,61,62,64,77,95,104]. The higher incidence of neurosensory deficit in older patients may be due to poor regeneration of damaged nerves[92]. The magnitude of mandibular advancement also influences the percentage of neurosensory disturbance. This is thought to be due to mechanical tearing of axons within the nerve or to ischemia caused by compression of the vasa nervosum[5,31]. The magnitude of mandibular advancement (>7 mm) during surgery showed significant positive correlation with neurosensory disturbance in some studies[77,104], while others did not observe such a correlation[61,83,95]. Neurosensory disturbance was reported not to be dependent on gender[61,95,104], indication for the osteotomy[104], type of osteosynthesis[2,62,77,95,104], simultaneous removal of third molars[2], and intraoperative or postoperative complications[7,104].

After DO of an extremity, Ilizarov's studies showed proliferating nerve fibres around the distraction gap with features of developing fetal nerve trunks[36,37]. This finding, and the fact that surgery was of a lesser extent, raised the question as to whether mandibular DO will lead to less neurosensory deficit when advancing the mandible. Conflicting results on nerve preservation in some early studies on mandibular DO might be amendable to the differences in the amount of elongation and construction of the distraction device[43,55]. A recently published study showed that DO is assumed not to be harmful to the inferior alveolar nerve[96]. These authors studied the function of the inferior alveolar nerve after mandibular DO with mandibular hypoplasia. They concluded that the surgical technique and method of fixation had no lasting negative effect on inferior alveolar nerve function, but stressed that more studies are needed[96]. After DO of 10 mm (rate 1 mm/24 h), all nerves recovered to preoperative (40% of the nerves) or near preoperative (60% of the nerves) values within 1 year[96]. Whether nerve injury will occur may depend on physiologic limits. From animal experiments it can be learned that only a stretch injury resulting from DO beyond the adaptive capacity of the nerve may result in serious damage[5,31,32,93]. Thus, there is some evidence that distraction rates not exceeding 1 mm/24 h will result in either no change in sensibility or in a short period of decreased function followed by gradual recovery[5,31,32,93,96]. Even if some neurosensory deficit occurred, the patients probably have adapted to a mild neurosensory deficit and will report sensory function as normal and not uncomfortable despite a slightly altered sensation, just as for BSSO[7,47,62,67,104].

In conclusion, both BSSO and DO may result in permanent sensory nerve damage. Up to now, no comparative clinical trials have been performed assessing which technique has the least impact on post-surgical nerve function. After large mandibular advancements and in older patients the risk of permanent sensory nerve damage is high when performing a BSSO; whether this risk is lower after DO requires further study.

Stability and relapse

In the hierarchy of stability of orthognathic procedures, BSSO for mandibular advancement in patients with normal or decreased facial height is considered as one of the most stable procedures[70]. Relapse may occur after BSSO at two anatomic locations: at the osteotomy site (due to slippage of the fragments or perimandibular soft-tissue tension) or at the temporomandibular joint (due to condylar malpositioning or condylar resorption)[20,21,25,44,56,65,78]. Skeletal relapse after BSSO for mandibular advancement is a complex multifactorial phenomenon[15,17,20,37,50,57,66]. High mandibular plane angle is seen as a major aetiological factor contributing to postoperative skeletal relapse[27,56,70]. The most likely reasons for this relapse are related to myoskeletal balance in high mandibular plane angle patients and the counter-clockwise rotation that can occur during advancement in high angle cases[20,21,25,56,65,70,83]. The other major a etiologic factor is the amount of advancement, as with larger advancements there is a directly proportional increase of relapse potential related to perimandibular soft-tissue tension[6,21,25,65,97]. The duration of relapse also tended to be longer with larger advancements[97].

With regard to BSSO, many techniques, including different fixation methods and methods to decrease soft-tissue tension, have been advocated to improve stability[19,20,21,25,65,70,78,97]. Post-surgical results of patients with normal mandibular plane angles, advancements less than 7 mm and proper seating of the condyles were essentially stable when rigid fixation was used[19,20,25,44,56,65,70,75,78]. In high-risk cases, namely large advancements and patients with high mandibular plane angles, relapse was also seen despite the use of rigid fixation[25,27,56,70,78].

Increased stability is thought to be one of the main advantages of DO[53,91]. The better stability and thus presumably less risk of relapse in the case of DO when compared to BSSO lies at the root of the fact that the main factor assumed to contribute to relapse after BSSO is the acute stretching of soft-tissue components and the time necessary for the muscles to adapt[21,25,56,65,70,91,97]. Such stretching and need for adaptation of muscles especially occurs in patients with high mandibular plane angles and after large advancements[21,25,56,65,70,91,97]. DO is accompanied by distraction histiogenesis, giving simultaneous expansion of the entire soft-tissue envelope[14,18,35,36,80,87,91]. Gradual adaptation over the distraction and consolidation period will occur, and probably will result in fewer post-surgical changes[53,91] because of the relatively slow expansion of the soft-tissue complex (usually 0.5–1 mm/day). Mandibular DO is also considered beneficial for stability because of less periosteal stripping and placement of the osteotomy site distal to the pterygo-masseteric sling[53,83].

Although there have been many reports of the assumed beneficial effect of DO on stability and lower risk of relapse when compared to BSSO[29,46,48,49,84], few studies have properly assessed the actual relapse following mandibular DO[83]. Some promising results with minimal to no relapse were reported in the studies that did assess relapse after mandibular DO. In the few cases in which relapse did occur, this was mainly due to other factors than regenerate bone relapse, such as non-compliance or persisting growth[29,46,48,49,83,84]. In a retrospective study, VAN STRIJEN et al.[83] reported that after mandibular DO patients (50 patients, mean lengthening 8.7 mm, rate 0.5 mm/12 h) with a low to normal mandibular plane angle showed no significant relapse, even with advancements of 10 mm or more. Conversely, patients with a high mandibular plane angle showed significant and frequent relapse, as is also often observed after BSSO. The reported high risk of condylar resorption in the latter group of patients was not thought to be the cause of this relapse[83].

Progressive condylar resorption (PCR) may occur after mandibular advancement surgery and may give rise to a specific and

usually late form of relapse[9,30,54,58,75,78]. The mandible will progressively retrude as the condyle head decreases and changes in shape[1,30,75,78]. PCR may occur when certain stresses, in this case due to advancement surgery, are exerted on the articular structures that exceed normal or decreased adaptive capacity[1]. Forces needed to distract the two mandibular fragments during DO might act as a compressive force on distant sites such as the temporomandibular joint[45,52,89]. The loading of the condyles caused by these forces during distraction of 1 mm/day is thought to be gradual, instead of acute, which might prevent or decrease the risk of development of PCR[51,52,83,89,106], as occasionally observed after BSSO[1,9,30,54,58,75]. This hypothesis requires proof in long-term follow-up human studies.

To conclude, BSSO is considered a stable procedure with minimal relapse in patients with normal or decreased facial height, whereas it shows a tendency for relapse in high mandibular plane angle cases and when used for larger advancements (>7 mm). Based on the few human studies yet performed, DO seems to be a technique with less risk of relapse after large advancements (10 mm or more), but seems as relapse prone as BSSO in the high angle cases.

Patient-centred outcome

The rate of success in modern medicine and dentistry is not only measured by means of a clinically centred outcome as judged by peer review, but also by the quality of delivered care according to the patients' perspective[15,22,66,98]. With regard to orthognathic surgery, dissatisfaction is reported to be related to insufficient or inaccurate information (especially regarding general anaesthesia, postoperative diet and weight loss, absence from work, loss of sensation and damage to the dentition) and to the fact that swelling, pain and numbness were much worse than anticipated[15,22,98]. This illustrates that the level of dissatisfaction is related to communication with patients and to postoperative symptoms and discomforts as experienced by the patients, rather than surgical aspects and clinical outcome. Short-term dissatisfaction is not a predictor for long-term satisfaction. Fortunately, the long-term satisfaction of the patients following orthognathic surgery is generally high (87–100% of treated patients)[15,22,23,98].

The physiological features of surgery, such as swelling and pain, occur with both BSSO and DO, although they tend to be slightly less following DO due to the less invasive technique. Any surgical intervention also bears a risk of early and late complications. BSSO and DO for mandibular advancement are accompanied by numerous and mostly similar complications that may occur either during or after the intraoperative and postoperative phase. Examples are vascular problems such as haemorrhage, unfavourable osteotomy, nerve injury and post-surgical infection[17,64,82,101]. These complications do not occur in all treated patients, and the risk of developing a complication may be related to the type of intervention, the surgical technique applied and the skills of the surgeon.

Taking the patients' level of satisfaction into account when assessing the benefits and disadvantages of DO and BSSO, some factors specifically inherent to the technique of DO that affect the discomfort experienced by patients have to be considered. Some disadvantages have been overcome with the development of intraoral distraction devices, i.e. sleeping problems due to difficulty in attaining a proper resting position, problems with washing and dressing, extraoral skin scarring due to pin movement and less disruption of recreational activities[3,69]. Other disadvantages such as problems with eating and maintaining oral hygiene, due to the physical presence of the activation rods in the oral cavity, are not solved with the introduction of intraoral distraction devices[69]. Some disadvantages are inherent to the period of active distraction which is part of the DO technique. DO requires a high degree of co-operation and compliance of patients during the activation period of the device for a proper end result[3,69,82]. This activation period distresses some patients and/or parents in such a way that they neglect school or work. Besides intraoral discomfort and often the pain experienced, this distress is also related to the regular check-ups with the surgeon or orthodontist during the period of active distraction[3,69,91].

Time, in particular related to the duration of treatment, is a significant factor contributing to the magnitude of discomfort experienced by the patient. VAN STRIJEN et al.[81] and BREUNING et al.[12] reported a slightly shorter average hospitalization time for DO than BSSO, but DO still has the disadvantage of requiring a second surgical intervention to remove the distraction device[12,81,91]. It is very hard to compare the differences in (overall) treatment times, as many different protocols exist between clinics, e.g. treatment performed in daycare or in a hospitalized setting. Only BREUNING et al.[12] retrospectively compared the duration of orthodontic treatment for BSSO and DO in a group of patients with similar skeletal relationships in need of advancement of the mandible. Treatment time in the mandibular DO group was significantly shorter than in the BSSO group[12]. Unfortunately, the authors did not provide an explanation for this difference in overall treatment time[12].

In conclusion, the patient-centred outcome should be considered as a main factor when choosing a treatment method. From the few comparative studies, it can only be concluded that DO is accompanied by some extra distress to the patient. DO and BSSO have to be compared in further studies with regard to patient-centred outcome, e.g. patients' experience of surgery, post-surgical discomfort and duration of treatment. Short-term distress is a poor predictive factor for long-term satisfaction, as many patients indicated openness to re-treatment if needed, not withstanding the encountered problems[3,15,22,23,69,98].

Discussion

Patients with mandibular retrognathia can present at any age, and DO advocates suggest that there are earlier intervention possibilities with DO[13,29,36,41,49,63,73,84]. Early intervention offers the advantage of uninterrupted orthodontic treatment. According to the literature, both DO and BSSO are technically feasible in growing children and adolescent patients, although BSSO is slightly more complicated[11,13,24,29,41,48–50,63,68,73,76,79,84,99,100]. As discussed before, basic dento-skeletal morphology is established at the age of 5 years in a Class II malocclusion; thereafter, surgical intervention with BSSO does not seem to influence the existing, harmonious, normal growth potential[24,76,79,100]. Several authors have stated that mandibular advancement with BSSO can safely be performed after the age of 12 years without influencing the growth rate[68,76,79,99,100]. Studies on DO in children also show a trend towards further growth post-surgery. As most DO studies are preliminary, deal with very young patients and/or lack a proper follow up, conclusions about non-syndromic patients cannot be drawn as yet[13,29,41,84].

Neurosensory disturbance is a serious risk associated with BSSO. Both age at time of surgery (>30 years) and magnitude of mandibular advancement (>7 mm) have been shown to significantly increase the risk of post-surgical neurosensory deficit[7,64,77,92,95,104]. The risk of permanent neurosensory disturbance after

DO seems to be less, but requires substantiation by clinical studies[96]. Animal studies showed that mandibular DO at a rate of 0.5–1 mm/day did not result in significant long-term damage to the inferior alveolar nerve, even in the case of large advancements[5,31,32,93]. This observation may be a result of stretch injury within the physiological limit of the nerve to recover, and probably less manipulation of the nerve intraoperatively, but still has to be proven in humans[5,31,32,93].

BSSO with advancements of up to 7 mm in patients with a low or normal mandibular plane angle with rigid fixation are considered stable[19,20,25,44,56,65,70,75,78]. BSSO advancements exceeding 7 mm and BSSO in high mandibular plane angle patients are high-risk cases and still an area of concern with regard to relapse[25,27,56,70,78,97]. DO advocates promise less relapse due to gradual stretching of the soft tissues, placement of the osteotomy site distal to the pterygo-masseteric muscular sling and less periosteal stripping during surgery[53,83,91]. Although the results are promising, especially for large advancements (>10 mm), an exemption has to be made for high mandibular plane angle patients, who are thought to be at risk of significant relapse after DO as well as BSSO[83]. There is still discussion about the aetiology of PCR occurring after BSSO, reflected by the many influencing factors that have been mentioned in the literature[1,9,30,54,58,75]. Although distraction rates not exceeding 1 mm/day seemed to be within the physiological capacity of the temporomandibular joint, thus causing reversible injury, this has not been proven in human studies[51,52,89,106].

Patient-centred outcome has an important place in modern medicine and dentistry[15,22,66,98]. There seems to be slightly more patient distress inherent to the technique of DO than when the mandible is advanced by BBSO. Although reports have mentioned a shorter hospital stay and shorter orthodontic treatment for DO, the question remains as to whether this compensates for the intensive active distraction period and second surgical intervention for device removal mentioned in other studies[3,12,69,81,82,91]. It is difficult to compare the two techniques in this respect, due to the many influencing factors and the lack of sound comparable studies from the patients' perspective.

There is good evidence that DO and BSSO are both appropriate techniques for treatment of mandibular retrognathia in non-syndromic patients with a nearly comparable level of patient distress. There is still insufficient scientific evidence predicting the potentially better results of mandibular DO for treatment of mandibular retrognathia when compared to BSSO. Considering the literature available, there is support for the assumption that DO might have advantages over BSSO in mandibular retrognathia in low and normal mandibular plane angle patients needing larger advancements, as BSSO treatment in these patients is associated with a higher risk of nerve damage and relapse. In such patients, the advantages of DO may outweigh the disadvantages, such as higher costs and slightly more encountered distress. In all other patients with mandibular retrognathia (advancements ≤ 7 mm, high mandibular plane angle patients) there seems to be no real advantage of DO over BSSO. There is a need for randomized clinical trials comparing DO with BSSO in all types of mandibular retrognathia, in order to provide evidence-based guidelines for selecting which retrognathia cases are preferably treated by BSSO or DO.

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