Treatment of Maxillomandibular Deformities With Internal Curvilinear Distraction

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Abstract: Internal curvilinear distraction is successful in achieving clinically significant distraction with stable occlusion in our patient population of infants, adolescents, and adults. When distracting the mandible, the curve of the distractor, the position of the distractor, and the osteotomy site are accountable for the final result. The curved distractor can mimic part of the natural logarithmic growth of the maxillomandibular complex. In addition, the result is predictable based on this design and the internal nature of the distractor, which can be left in place longer than other distractor types. Distraction can be combined with orthognathic surgery in certain cases resulting in increased benefit. This new procedure is called distraction orthognathics.

Distraction osteogenesis or “DOG” as Paul Tessier called it, has evolved to become a common treatment for conditions like mandibular micrognathism and hemifacial microsomia. It is also well known that he preferred to use autogenous tissue for his reconstructions because you could build a foundation that could latter be added to and modified, which is almost impossible with alloplastic materials. In addition, he was very conscious, based on this, of not doing something with an early surgery that preclude a latter needed surgery or could adversely affect growth and development. Thus, he was very fond of using DOG technique and often discussed the design and implementation of such devices with me.

Distraction devices have evolved from unidirectional to bidirectional to multidirectional. External multidirectional devices allow bone displacement in several directions; however, a unidirectional distractor connected by a hinge is the basic structure. Review of the literature demonstrates that anterior and posterior open bites can be the result of linear distractor activation. Despite the apparent simplicity of the procedure, complications such as distraction failure, ankylosis, and malocclusion can occur. This risk is increased when the devices are removed from the bone surface to be distracted, such as with use of external distractors, and thus torque becomes a negative factor causing pin bending and loosening.

Moss and Rickets have indicated that mandibular growth occurs along a logarithmic spiral. Moss reported mandibular growth to be an arc of a logarithmic spiral passing through the foramen ovale, the inferior alveolar foramen, and the mental foramen. Rickets preferred the golden spiral to describe maxillomandibular growth, which he discussed with Tessier during his visit in 1987 when he was the surgical fellow in Paris. Based on this research, it can be hypothesized that mandibular growth occurs in an archial manner, which allows occlusion to be maintained while the chin advances forward. In addition, logarithmic growth allows a structure to increase in size without a drastic change in the overall shape and is common in the natural world. Bearing this in mind, the next logical step was the creation of a distractor that could be internal, with a curvilinear vector to mimic the normal mandibular growth. Since the introduction of curvilinear devices, these distractors have been used in our clinical practice (Figs. 6, 7). Curvilinear distraction is presented as an advantageous alternative that allows movement on both vertical and horizontal planes at the same time. This new device allows distraction along a single curved path instead of complicated translational and rotational movements that have difficulty duplicating the desired complex mandibular movement needed.

In this article, I discuss my experience with curvilinear distraction in the treatment of maxillomandibular deformities. This includes the treatment of congenital deformities in the neonatal and adolescent periods, and developmental deformities in mature patients. Distraction and orthognathic surgery can be combined with traditional orthognathic surgery in certain cases to achieve a combined benefit. All of my education and training influenced me in these areas; however, my surgical training as a fellow of Paul Tessier was pivotal. He was analytical and precise. His analysis of each case was thorough with extensive notes about the deformity including a written order of treatment that was brought to the operating room and marked off as each step was accomplished. I learned the importance of this method and surgery that was, at its base, functional not merely cosmetic. I also learned how a master surgeon operates efficiently, with each gesture having a purpose and

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Mandibular Distraction

Mandibular distraction is used early in cases of airway compromise, such as Pierre Robin Sequence and other congenital deformities such as Treacher-Collins and Nager’s syndrome (Figs. 8, 9). For hemifacial microsomia with no airway problems, we prefer to distract during the period of vertical facial development around years 6 to 8. Distraction can also be done in the adult period where the jaw and soft tissue deformity is major and orthognathic surgery would be difficult and include large bone grafts.

Preoperative assessment and planning are performed to decide on the type of distractor device and osteotomy appropriate for each case. If the ramus was the deficient part of the mandible, as is often the case on hemifacial microsomia, a horizontal osteotomy of the ascending ramus was performed. In those cases with mild vertical deficiency of the ascending ramus associated with a mild deficiency of the mandibular body, the osteotomy was slightly oblique at the lowest portion of the ramus. In cases of severe body and angle deficiency, the osteotomy was performed at the angle. Sagittal split osteotomy was performed on older patients because of the advantage it presents in terms of bone apposition and the possibility of shortening the latency phase.

Curvilinear devices are defined by their “radii of curvature.” Recently published literature based on computer analysis suggests that a limited pool of distractors with different “radii of curvature” would suffice in the treatment of various mandibular deformities10 (Fig. 3).

Of the 5 different curves available for distraction of the mandible, the type of distraction device was systematically chosen based on the patient’s mandibular growth curve. In our retrospective review of 22 consecutive patients undergoing distraction between June 1997 and October 2003, a complete cephalometric analysis was performed on 13 of these 22 patients (Fig. 11). The mean age at the time of distraction was 14.8 years of age (range, 6–44). The records obtained consisted of lateral cephalometric x-rays and panographs.

The first cephalogram was obtained before distraction; the second taken as short-term follow-up; and the third was taken as a long-term follow-up (average 22 months of distraction). Cephalometric analysis consisted of measurements of vertical (condyle to gonion) and horizontal (gonion to menton) length of the mandible. In addition, SNB, y-axis (growth angle), and Co-Go-Me angles were measured.

There were 14 females and 8 males. Eleven patients underwent unilateral distraction, and 11 patients underwent bilateral distraction. Two patients underwent distraction on 2 different occasions, one because of poor compliance with the initial treatment and the other because of a need for greater vertical height.

We identified 3 age groups in this patient population. One-third of the patients (n = 5) underwent distraction before age 10, two-thirds of the patients underwent distraction between the ages of 10 and 20 (n = 12), and the last group underwent distraction at an age greater than 20 (n = 5).

Indications for distraction included hemifacial microsomia (n = 15), isolated micrognathia (n = 4), Treacher Collins (n = 1), and 2 other patients with no-named multiple congenital anomalies and associated micrognathia. Of 15 patients with hemifacial microsomia, 4 underwent bilateral distraction because of severe retrognathia bilaterally.

We used 5 distractors with different “radii of curvature.” Based on the growth curve identified on the cephalometric preoperative x-ray, 10 patients were treated with the 52 mm distractor (47.6%), 6 patients were treated with the 36 mm distractor (28.5%), 5 patients with the 24 mm distractor (23.8%), and 1 patient was treated with the 18 mm (4.7%).

Osteotomy site was chosen based on the age of the patient and type of mandibular deficiency. The most common procedure was sagittal osteotomy in 8 out of 22 patients (36.3%), a ramus osteotomy was performed in 5 patients (22.7%), mandibular angle osteotomy was performed in 4 patients (18.1%), and 1 patient (4.5%) underwent osteotomy at the mandibular body. No clear information was available on the records of the remaining 4 patients.

For analysis purposes, the results were divided among unilateral and bilateral distraction cases. Complete records (preoperative, short-term, and long-term follow-up) of unilateral cases were found on 5 patients (out of 11) and 8 patients (out of 11) bilateral cases.

In the unilateral group, the average postoperative long-term follow-up was 22 months. Total vertical gain of the mandible was 21 mm and horizontal gain was 5.4 mm (Table 1).

In the bilateral group, the average long-term follow-up was 21 months, with a total vertical gain of 9.9 mm and a total horizontal gain of 9.1 mm (Table 1). No significant changes were identified when serial cephalograms were compared in terms of SNB, Ar-Go-Me, and growth angles. Of 22 patients, 16 were brought back for long-term follow-up examinations. Eleven of them had class 1 occlusion; mandibular midlines were in position or within 1 mm deviation on 11 patients. Four patients had midlines deviated greater than 1 mm (2 and 3 mm).

Major complications included technical failure (n = 1) and anterior open bite (n = 1). Minor complications included hypertrophic scar (n = 3). Two patients required further distraction. The purpose of this study was to examine our experience of curvilinear distraction on 22 consecutive patients. This study is based on retrospective analysis of records from patients who underwent distraction by the senior author between June 1997 and October 2003 with the curvilinear distraction system.

A total of 22 patients underwent distraction. Ages ranged from 6 to 44 years. The most common diagnosis on this population was hemifacial microsomia. Most distractions were performed with the 52 mm device, although 5 different curves were available. The average total gain of mandibular length was 22 mm.
Curvilinear distraction was successful in achieving clinically significant distraction with stable occlusion on our patient population. When distracting the mandible, the curve of the distractor, the position of the distractor, and the osteotomy site are accountable for the final result (Figs. 4–6). The distractor activating pin can be exited intraorally when the distraction is more horizontal, whereas a vertical distraction needs a vertical orientation of the distractor and the activating pin then needs to exit extraorally. This is frequently needed in cases of hemifacial microsomia, where the affected ramus is vertically short. Also in these cases we prefer to use a modified sagittal split ramus osteotomy when possible, as this results in a better bone interface between the segments (Fig. 12).

**INFANT DISTRACTION**

In a subsequent series, we studied internal curvilinear mandibular distraction in the neonate. A smaller-sized 52-mm curved distractor was developed for infants, as this curve best matched the infant ramus and mandibular body. The activating pin was also changed to exit in the superior preauricular area where it would be best tolerated (Figs. 5A, B).

**Patients**

In all, 12 patients with micrognathia underwent mandibular distraction at Lucile Packard Children’s Hospital between March 2005 and May 2006. Patient ages ranged from 9 days to 8 months, with a median of 3.5 months. Seven patients were diagnosed with isolated Pierre Robin Sequence, 2 with hemifacial microsomia with type III mandible, and the other 3 were syndromic with associated neurologic deficit. Maxillomandibular discrepancy preoperatively ranged from 4 to 12 mm with a median of 7 mm. All patients were evaluated by a multidisciplinary team before undergoing mandibular distraction.

**Surgical Technique**

After induction of general anesthesia, the patient is intubated orally. Intravenous antibiotics are given, typically cefazolin. The endotracheal tube is secured to the maxillary alveolus with a 2-0 silk
suture. Incisions are marked 2 to 2.5 cm in length and slightly inferior and parallel to the posterior aspect of the inferior mandibular border. A standard submandibular dissection is performed with the aid of a nerve stimulator until the bony mandible is identified. A wide subperiosteal exposure of the mandibular ramus and body is critical for device placement. The curvilinear distractor is then


introduced into the wound, and the ideal osteotomy site is marked with methylene blue. The device is then removed and a lateral corticotomy is performed with a reciprocating saw. A thin straight osteotome is then used to carefully complete the osteotomy while taking care to preserve the inferior alveolar nerve. Blunt dissection is then carried up toward the temporal scalp and a stab incision is made for the introduction of the activation arm. Bony stabilization is then performed with 6 mm length screws along the inferior border and 4 mm screws superiorly (Fig. 6). Ease of distraction is then confirmed by turning the activation rod. The incision is closed in a layered manner and steri-strips applied.

**Postoperative Protocol**

Patients are typically extubated immediately or within 5 days postoperatively depending on their diagnosis and severity of preoperative respiratory compromise. Antibiotics are continued for 1 week postoperatively with local wound care and topical antibiotics at the pin sites. Active distraction is started the next day at a rate of 2 mm per day (1 mm BID). Distraction is continued until overcorrection is achieved with a slight class III malocclusion (Fig. 9). Activation rods are then removed at bedside and the pin exit wounds allowed to heal by secondary intention. Oral feeding is introduced under the direction of the occupational therapist. Patients are typically planned for discharge from the hospital once a stable airway is maintained and a feeding regimen determined. Patients are followed up routinely in the postoperative period, and device removal scheduled after a 2 to 3 month consolidation period. A follow-up 3D computed tomography scan is obtained during this hospitalization.

**Results**

All patients tolerated the surgical procedure well without complication. There were no postoperative complications such as premature consolidation, pin-site infection, device loosening, open bite deformity, etc. One patient experienced temporary unilateral facial nerve paresis that resolved in 2 months. All patients showed improvement from their obstructive sleep apnea. In the first 6 patients, this was documented by continuous pulse oximetry and records from nursing personnel. The last 6 patients in this study had this documented by pre- and postoperative polysomnograms. The average preoperative apnea-hypopnea index for these patients was
19.2. Postoperative apnea-hypopnea index was less than 1.5 in all patients. One patient with an associated neurologic syndrome had persistent central apnea, requiring prolonged oxygen administration. Another patient with associated neurologic deficit had a postoperative polysomnogram which showed improvement from both obstructive and central apnea and was able to be discharged from the hospital with a stable airway, although he was unable to be weaned from the nasogastric feeds. All other patients with nonsyndromic micrognathia were weaned from tube feeds within 2 months. Two of the patients who were dependent on tube feeding were able to be completely transitioned to oral feeds prior to discharge from the hospital. Patients with neurologic deficit were unable to be weaned from nasogastric feeds totally within the follow-up period of this study. Patient data and results are presented in Table 1.

DISTRACTION ORTHOGNATHICS

The stable functional result in mandibular surgery is based on the temporomandibular joint and the most difficult cases are those who exhibit idiopathic condylar resorption. Frequently, the etiology

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FIGURE 11. Preoperative facial views. A, Frontal Face demonstrating bilabial incompetence and increased incisor show. The lower face height is also decreased. B, Smile. C, Profile; Retruded lower face which is also long. Lateral cephalometric radiograph- presurgical.

FIGURE 12. Vertical excess of the maxilla and severe mandibular retrusion with microgenia can be seen. Notice the decreased vertical ramus height.

FIGURE 13. Panorex radiograph-preoperative: Note the condylar malformations.
of condylar resorption is unclear, in addition the clinical course is equally unpredictable (Fig. 15). Those with skeletal malocclusions that have exhibited condylar resorption prior to surgery are the most difficult cases for whom to develop a treatment plan. Frequently, this condition is exacerbated or reactivated following the orthognathic surgery, resulting in an unstable occlusion and subsequent relapse. Traditionally, most relapses have been thought to occur in the early postoperative period. However, studies have demonstrated that skeletal changes consistent with relapse may occur years after the original surgery. DOG is a proven and recommended treatment for major maxillofacial skeletal deformities, as the incremental increase of bone allows the soft tissues to adapt. This results in a more stable outcome. Animal studies also show that the insult to the condyle is less than that found in routine mandibular orthognathic surgery and is generally reversible (Fig. 14). The logical deduction is that distraction osteogenesis would be beneficial in the treatment of these complex skeletal malocclusions, especially with associated idiopathic condylar resorption. However, we have treated several cases of idiopathic condylar resorption by mandibular distraction with excellent, stable results with no reactivation of the disease.

Orthognathic surgery certainly can correct some of the skeletal deformity in both the maxilla and mandible, resulting in both improved aesthetics and function. Long-term stability is the concern here, and reactivation of the condylar resorption is possible, resulting in further loss of posterior facial height and relapse of the mandible into a class II condition. Relapse of the mandible under ideal conditions is a known complication with mandibular advancements and more likely in high mandibular plane angle cases with open bite. DOG studies generally show a more stable result with mandibular advancement. Gradual lengthening of the soft tissues and a generally less invasive procedure are considered beneficial to the postoperative stability. Recent research also indicates that the pressure effect on the condylar head is less and more gradual with distraction than conventional mandibular advancement. Condylar head pressure is a known cause of condylar resorption. Relapse can occur with distraction, especially in high angle cases. This is most likely due to early removal of the distraction device prior to the bone regeneration achieving the mature architecture and to the nature of simple linear distractors. In addition, the devices were unidirectional and postoperative open bites required elastic therapy to close, which is an inherently unstable procedure. In our series of over 40 cases where an internal curved distractor is left in place for at least 6 months we have not seen this relapse, and the chance of postoperative open bite is essentially nonexistent. Of course, distraction is a new treatment modality, and we will neither know all of its possibilities nor long-term results for some time yet. Distraction can be thought of as still in a formative stage, much as orthognathic surgery was in the 1980s. The long-term results of distraction are at present unknown. These large movements are difficult surgically to accomplish by regular orthognathic surgery and potentially unstable, even without recurrent condylar problems. It is for these reasons that we feel DOG is indicated in this and similar cases.

**SURGICAL TECHNIQUE**

The details of the surgical technique used in the present series have already been described by Schendel et al in previous reports. Distractor type and placement are predetermined by either the traditional tracing technique and templates or by the following computer preplanning technique. In bimaxillary surgery, the maxilla is first mobilized and placed into the desired position and rigidly fixed with miniplates. Following this, the technique is similar for both bimaxillary and single mandible cases. The mandible is osteotomized by the sagittal split ramus osteotomy technique and placed into the desired final occlusion with the maxilla using intermaxillary fixation. This is most frequently facilitated by a surgical splint. The curved distractor, based on the desired movement, is then chosen and fixed to the proximal segment. Note that at this time the desired activating rod is also chosen and inserted into the distractor after placing the silicone sleeve in place. The rod, however, is not inserted sufficiently to engage the sliding component of the distractor. This allows the distractor to be expanded freely until it can be fixed to the distal component. Once both sides are placed, the intermaxillary fixation is released and the distractors collapsed until about 5 to 8 mm of distraction is present and the medial and lateral sagittal split segments are still overlapping. The activating rod is then rotated until it engages the sliding component of the distractor. Distraction is then begun after a latency period of 3 days and at a rate of 1 mm a day in the young adult or older patient.
This young woman was diagnosed at age 5 with juvenile rheumatoid arthritis affecting the temporomandibular joints and the cervical vertebrae. Radiographs demonstrated fusion of the vertebral arches from C2 to C5. She underwent medical management of the juvenile rheumatoid arthritis, including treatment with methotrexate and mobic, without improvement. She was first seen in consultation in 2002 by J. F. Tulasne, at which time the patient demonstrated a class II division 1 malocclusion with a mandibular opening of 32 mm. Clinically and radiographically, she presented with vertical maxillary excess and severe mandibular retrusion (Figs. 9, 10, 11–13). All 4 first premolars were extracted in preparation for the orthodontic treatment. Orthodontic treatment was initiated in 2004 by Dr. Edith Lejoyeux and consisted of maxillary expansion using a quad helix, and dental alignment using the bioprogressive technique of Ricketts. The presurgical condition of the condyles consisted of severe resorption and loss of vertical height (Fig. 14).

Surgery was performed in June 2006 after fiberoptic nasoendotracheal intubation. The maxilla was impacted 8 mm and advanced another 5 mm by a Le Fort I osteotomy and fixed with 4 miniplates. Bilateral sagittal split osteotomies were performed in the mandible and the Logic 52 mm distractors placed. The distractors were immediately opened 10 mm. The surgical technique of distractor placement is as described in the article. A jumping bone flap genioplasty (Tessier type) was also done for an advancement of 14 mm. It was secured by 3 bone screws. Distraction was started at postoperative day 10, at which time the mental sensation was noted to be normal. Distraction continued at 1 mm a day for 10 days, resulting in a total mandibular advancement of 20 mm (2 cm). The distraction activation wires were then removed 5 days after the completion of distraction, and class II elastics were used for 8 weeks. The result has been a stable class I occlusion and the orthodontic appliances were removed by the end of February 2007. Jaw function has been normal (Figs. 15–17).

**DISCUSSION**

DOG is now a widely recognized treatment modality that aims for correction of the occlusal plane, and mandibular size, as well as improvement of soft tissue hypoplasia by simultaneous tissue expansion.

The ideal distractor device would be internally located and in close proximity to the bone, which allows for more efficient movement and prevents external scars and social stigma, and would mimic the growth of the native mandible. The distractor would thus prevent problems such as anterior open bites, which are virtually impossible to address orthodontically. This ideal device would be biocompatible, biodegradable (which would allow for a single operative stage), with have enough strength and duration to allow for proper distraction and healing of the newly formed bone, thereby preventing future setbacks. Preferably, this device would distract in 3 dimensions.

There are multiple interdependent factors that dictate the ultimate result of distraction treatments. These include direction of distraction (dictated by both distractor type, position of the device, and osteotomy site), amount of distraction, and correction of malocclusion. Traditionally, the direction of distraction has been determined by the type of deformity and main goal positional changes.
future studies should also examine postdistraction growth in case groups versus a control group in the pediatric population.

CONCLUSION

Curvilinear distraction is successful in the treatment of mandibular deformities. The desired result can be obtained and maintained by using internal curvilinear distraction. A meticulous preoperative plan and correct design of the osteotomy site account for a successful result with stable occlusion preventing complications like the open bite. Complications are low and the morbidity, especially when compared with external distraction, is reduced. A limited pool of distractors based on a logarithmic spiral was sufficient to treat our patient population according to the treatment protocols. In addition, mandibular distraction with a curved device can be combined with traditional maxillary orthognathic surgery for added advantage and is called distraction orthognathics.

REFERENCES

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