Pediatric mandibular distraction osteogenesis (MDO) has become a mainstay of treatment for patients with micrognathia and retrognathia. As craniofacial surgeons have gained experience with MDO, the technique has become a safe and durable means of mandibular lengthening that avoids the significant morbidity of conventional surgical treatments. The full impact of this technique has not yet been realized for pediatric patients. Although studies have confirmed durable reconstruction of mandibular length with MDO, the range of applications of this technique is currently limited. As innovative clinicians continue to apply MDO to pediatric clinical craniofacial problems not easily treated with conventional means, the field of MDO will continue to mature. This article discusses current uses and examples of potential future applications of pediatric MDO. The development of novel and creative applications of MDO will advance the management of complex craniofacial anomalies, taking the field of craniofacial surgery into the future.

Distraction osteogenesis (DO) represents a valuable advance in the treatment of pediatric patients with mandibular deficiencies. Mandibular distraction osteogenesis (MDO) provides effective bony correction of micrognathia with concurrent soft tissue expansion. First clinically described in 1989 by McCarthy et al., MDO is becoming the treatment of choice for pediatric patients with hypoplastic mandibles by allowing generation of new bone without the significant morbidity of conventional surgical techniques. A wide variety of developmental and syndromic mandibular hypoplasias are now regularly managed using MDO, including craniofacial microsomia, Nager syndrome, Treacher Collins syndrome, and Pierre Robin sequence.

The leading pediatric indication for MDO has primarily been severe mandibular hypoplasia, resulting in functional problems and associated aesthetic deformities. A number of studies have demonstrated durable reconstruction of mandibular length with MDO. The resultant aesthetic outcomes demonstrate excellent and stable results that have been confirmed by imaging studies and cephalometric analyses. In addition, from a functional perspective, the anatomic deficits of micrognathia can be clearly ameliorated. Patients with tracheostomies for obstructive airway symptoms are frequently able to be decannulated with significant improvement in respiration.

As pediatric craniofacial surgeons develop increasing experience with distraction, the use of MDO continues to expand for a broader range of successful applications. One study has documented the ability to engineer a functional mandibular ramus and neocondyle and utilizing MDO in patients with complete agenesis of these structures. The future of craniofacial surgery will depend heavily on the continued development of these creative and novel applications of DO. Such endogenous tissue engineering techniques will allow craniofacial surgeons to offer superior solutions for a greater number of pediatric patients with traditionally difficult-to-treat issues.

The two cases presented in this article illustrate how MDO can provide improved outcomes due to the lack of adequate current conventional treatments.
cal MDO protocols have latency periods of approximately 5 to 7 days, distraction rates of 1 mm/d with a rhythm of 0.5 mm twice daily, and consolidation periods of 8 weeks (or at least double the time of distraction). However, no definitive studies have been performed that identify an optimal protocol.\(^5\)

Intraoral and extraoral MDO device types are available for clinical use. Although extraoral devices may allow MDO in progressively younger patients with better control of the distraction vector,\(^5\) the drawbacks include bulkier devices and scars that may require revision. Several studies have documented satisfactory results with intraoral transmucosal devices and buried devices.\(^12\)–\(^14\)

Clinicians have reported successful use of MDO in patients as young as 6 days of age;\(^15\) however, the typical age of most patients is more than 2 years.\(^3\),\(^16\) MDO in infancy has been used primarily to manage severe airway obstruction in newborns with micrognathia to avoid tracheotomy.\(^9\)\(^,\)\(^15\),\(^17\) Difficulties associated with infant MDO include risk of permanent dental injury due to inability to identify tooth buds, and the significant effort required from the parents and the infant during MDO.\(^4\) After age 2 years, children with hypoplastic mandibles (Pruzan-type type 2) with associated maldevelopment are generally good candidates for MDO. These typically include patients with craniofacial microsomia, Pierre Robin sequence, and Treacher Collins syndrome.\(^3\) Most patients have preoperative photographs, cephalometrics, and bite analyses performed.\(^18\) A significant portion of patients also have three-dimensional computed tomography scans to document perioperative changes.\(^3\),\(^14\)

The amount of distraction that can be achieved with pediatric MDO has been reported to average 23.9 mm for unilateral distraction and 28.8 mm for bilateral distraction in one surgeon’s 10-year experience,\(^16\) and 16.8 mm for all types of MDO in another large multisurgeon study.\(^3\),\(^7\)

Although the complication rate has been reported to be as high as 35.6% in the largest overall study of all types of DO to date, major complications resulting in significant patient compromise comprised less than 1% of the complication rate.\(^3\) Numbness of the lip, chin, and jaw resulting from damage to the inferior alveolar nerve was the most frequent complication, occurring in 3.6% of patients in this study. Technical failure of distraction occurred in 15.6% of all patients, while failure to guide distraction in the appropriate vector occurred in 16% of the patients studied; however, a learning curve was demonstrated because experienced surgeons reported far fewer complications.\(^5\) This appears to be borne out by examining single surgeon long-term experiences, where complication rates are relatively low.\(^7\),\(^16\) Pin site infections appear to occur at a comparable rate for all surgeons regardless of experience, and most infections were generally managed successfully with oral antibiotics.\(^3\),\(^16\)

One aspect concerning pediatric MDO that will require continued study is its long-term impact on these patients in regard to relapse and subsequent craniofacial growth. While studies have confirmed there is minimal bony and soft tissue relapse 1 to 2 years after treatment,\(^16\) the question of whether there is sufficient continued growth of the mandible after MDO to maintain proper anatomic relationships with the remainder of the craniofacial skeleton is unclear. While studies have documented a certain degree of mandibular growth after treatment,\(^7\) it may be likely that MDO may not sufficiently influence the fundamentally deficient growth processes producing the micrognathia.\(^16\),\(^20\) As a result, even with initial overcorrection, patients with syndromic mandibular hypoplasia may require additional MDO or other surgical interventions in the future.

After 10 years of clinical pediatric MDO, clinicians have generally deemed the surgical technique to be safer and more effective than previous mandibular lengthening treatments for the young pediatric population. MDO avoids the morbidity of grafting, yet provides better quality and increased volume of bone.\(^16\),\(^21\)

**Two Case Presentations**

The following cases demonstrate how MDO can be applied as a novel element of a complete therapeutic plan for patients who would have suffered significant delay with conventional treatments.

**Patient 1**

Patient 1 presented to our craniofacial anomalies clinic shortly after birth with Pierre Robin sequence and associated cleft palate with a hypoplastic mandible. He did not have clinically significant airway difficulties after birth. Although the patient was moderately retrognathic at birth, the condition improved to some extent with continued monitoring of his growth, and the patient underwent a two-flap palatoplasty at age 20 months, which was without complication.

At age 25 months, the patient underwent speech language pathology evaluation. Although he had a limited vocabulary due to his age, he demonstrated mild hypernasality with nasal emission. Speech therapy was instituted, and the patient was followed yearly by the cleft palate clinic. At age 4 years, the
Patient demonstrated worsening hypernasality, and formal nasoendoscopy was performed. Evaluation demonstrated velopharyngeal insufficiency and incompetency, indicating the need for a dynamic sphincter pharyngoplasty (DSP). It was believed, however, given the family’s report of the patient’s history of snoring at night, that a DSP might exacerbate any potential airway obstruction. A nocturnal polysomnographic evaluation verified a diagnosis of obstructive sleep apnea with an overall respiratory distress index (RDI) of 5.4/h.

Mandibular distraction osteogenesis was subsequently performed, with placement of external appliances. The patient tolerated the procedure well and had no complications. A distraction protocol of 1 mm daily in the vertical vector and 1 mm daily in the anteroposterior vector was initiated, with a total distraction length of 30 mm in each vector. After completing consolidation, the patient was in class III occlusion, and the distractor appliances were removed. A DSP was performed 9 months after completion of mandibular distraction at age 5 years, 7 months. Repeat nocturnal polysomnographic evaluation demonstrated complete resolution of his obstructive sleep apnea with no snoring. On clinical evaluation, the patient’s hypernasality and overall speech had significantly improved postoperatively.

**Patient 2**

Patient 2 presented to our cleft lip and palate clinic at age 10 months. She was followed by an outside hospital where she was diagnosed with Pierre Robin sequence and a cleft palate. Her airway obstruction prompted a tongue–lip adhesion that was subsequently taken down at age 9 months after clinical improvement. At her initial presentation to our institution, however, her family reported continued sleep difficulties. A nocturnal polysomnographic evaluation demonstrated severe obstructive sleep apnea with an RDI of 18.6/h with heavy snoring. Cleft palate repair, although indicated at this time, was deemed unsafe due to her continued airway obstruction. Continuous positive airway pressure (CPAP) therapy was instituted; however, the pa-
The patient’s family reported that it was poorly tolerated (Figs 1, 2, 3, and 4).

The patient underwent MDO at age 2 years, 10 months with placement of external fixators. A distraction protocol of 1 mm daily in the vertical vector and 1 mm daily in the anteroposterior vector was completed without complication for a total length of 25 mm in each vector (Figs 5 and 6). Distactor appliances were removed 4 months later after completion of consolidation (Figs 7, 8, and 9). A follow-up nocturnal polysomnographic evaluation demonstrated significant reduction of her obstructive sleep apnea, with an RDI of 3.6/h with no snoring. The patient subsequently underwent a two-flap palatoplasty at age 4 years without complication. A maxillofacial computed tomographic (CT) scan verified increased anteroposterior mandibular length compared with a preoperative CT scan (Figs 10 and 11).

**DISCUSSION**

These two case presentations demonstrate that MDO was effective for treating pediatric cleft palate patients who required either primary cleft palate repair or a pharyngoplasty to improve speech functioning but who were poor surgical candidates due to obstructive airway problems. Delays in surgical treatment would have exacerbated impaired speech development for both patients. In addition, other traditional treatments for sleep apnea, such as CPAP, were poorly tolerated and could only be considered temporizing measures at best. Both patients successfully underwent MDO with documented resolution of obstructive airway symptoms, and then were able to tolerate subsequent surgical correction of cleft palate or velopharyngeal insufficiency without reaggravation of airway obstruction.
Mandibular distraction osteogenesis was incorporated into a complete therapeutic plan that included regular monitoring of speech development, regular nocturnal polysomnographic evaluations, and nasoendoscopy with formal speech language pathology evaluation. Although formal anatomic studies such as cephalometrics and CT scans were also obtained to evaluate the degree of retrognathia in each patient, the guiding principle for treatment remained improved speech development and avoidance of obstructive sleep apnea.

**Summary**

Craniofacial surgeons have accumulated increasing experience with MDO. Review of previous studies has shown that MDO is an effective and durable technique for management of hypoplastic mandibles, it is frequently the initial choice for pediatric patients with severe functional difficulties secondary to micrognathia. The present use of MDO, although associated with a learning curve, results in a decreased rate of relapse and morbidity compared with conventional bone grafting and simultaneous soft tissue expansion.

Multiple studies have demonstrated the utility of MDO to allow early decannulation or even prevent tracheostomies in infants with severely hypoplastic mandibles, allowing for critical language skill development. The use of MDO to allow for timely planning of surgical procedures such as DSP or cleft palate repair is an extension of this application.

The concept of endogenous tissue engineering, of which MDO is one type, will continue to change the scope of craniofacial surgery. These principles of generating new tissue will provide surgeons with significantly improved techniques to manage traditionally difficult clinical problems. Creative and novel applications of techniques such as MDO will advance the management of complex craniofacial anomalies, taking our field from the present into the future.

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**Fig 9** Occlusal photograph at age 3 years, 8 months demonstrates stable mandibular advancement with the patient in class III occlusion.

**Figs 10 and 11** Follow-up three-dimensional CT scan reconstructions confirm correction of retrognathia after MDO.
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