OPEN

PRS GLOBAL OPEN

IDEAS AND INNOVATIONS

Pediatric/Craniofacial

Balancing Distraction Forces in the Mandible: Newton's Third Law of Distraction

Sameer Shakir, MD*
Sanjay Naran, MD†
Kristen M. Lowe, DDS, MS*
Scott P. Bartlett, MD*

Summary: Vertical mandibular distraction results in translation of both proximal and distal segments. The force exerted on the condylar segment not only places unwanted force on the joint but also rotates the coronoid process into the cranial base. To prevent these sequelae, we investigate the use of a "check plate" on the condylar segment in an attempt to decrease force at the Temporomandibular joint (TMJ) and prevent unwanted rotation of the coronoid. Patients with hemifacial microsomia, seen at our Children's Hospital from 2012 to 2016 having undergone unilateral vertical mandibular distraction with placement of check plate were compared with a sample of those similarly having undergone distraction without use of the plate. Preoperative and postoperative cephalometric measures and 3-dimensional computed tomography imaging were analyzed. Three subjects were identified in each group. Age and Pruzansky-Kaban classification did not differ between groups. Vertical distance from the coronoid process perpendicular to the Frankfort Horizontal did not differ between groups ($P < 0.07$); however, postoperative distance significantly differed with the coronoid process rotating upward into the cranial base in subjects without a check plate ($P < 0.005$). Preoperative angle of the coronoid process based on the Frankfort Horizontal did not differ ($P < 0.06$); however, postoperative angle significantly changed, confirming upward rotation into the cranial base ($P < 0.01$). Total regenerate did not differ ($P < 0.08$). Vertical mandibular distraction results in undesirable upward rotation of the proximal segment into the cranial base and superior displacement of regenerate. This can be prevented with the use of a check plate. *(Plast Reconstr Surg Glob Open 2018;6:e1856; doi: 10.1097/GOX.0000000000001856; Published online 14 September 2018.)*

INTRODUCTION

Mandibular hypoplasia in patients with hemifacial microsomia (HFM) is not limited to 1 vector; there is vertical and horizontal hypoplasia resulting in reduction of height and projection. Mandibular distraction osteogenesis has proven to be a powerful tool in the correction of this deformity, although not without difficulty.[1–7]

Newton's third law of motion states that for every action, there is an equal and opposite reaction. Distraction forces on the mandible are no exception. Horizontal distraction of the body pushes the angle and ramus posteriorly before exerting a distracting force that pushes the distal segment anteriorly. There is minimal anterior-posterior (AP) distance and force lost posteriorly before the pterygomasseteric sling and adjacent soft-tissue forces counteract the force of anterior distraction. Contrastingly, vertical mandibular distraction is less efficient.

When distracting the shortened ramus of the HFM mandible, the proximal segment distracting force promotes counterclockwise rotation about the condyle and temporomandibular joint (TMJ) impaction. This results in significant force wasted in rotating the coronoid cephalad before gaining height of the mandible in the caudal direction. We consequently began to utilize a "check plate" attached to the coronoid to engage the zygomatic arch during active distraction to prevent cephalad rotation and focus distraction force downward onto the mandibular ramus. We hypothesized that the addition of a check plate along the coronoid would prevent counterclockwise rotation about the condyle

*From the *Division of Plastic and Reconstructive Surgery, Department of Surgery, Children's Hospital of Philadelphia, Philadelphia, Pa.; and †Division of Plastic and Reconstructive Surgery, Advocate Children's Hospital, Park Ridge, Ill.*
Received for publication March 4, 2018; accepted May 8, 2018.

DOI: 10.1097/GOX.0000000000001856

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*

Supplemental digital content is available for this article. Clickable URL citations appear in the text.

and optimize the position of the regenerate along the newly lengthened ramus.

METHODS

A retrospective case control study was performed of subjects at our Children's Hospital from 2012 to 2016 with a diagnosis of HFM who underwent unilateral vertical mandibular distraction by a single surgeon (S.P.B). Based on preoperative Pruzansky-Kaban classification, patients having undergone distraction with the application of a check plate were matched with those without a check plate. To be included, distraction course had to be completed and hardware removed. Preoperative and postoperative 3-dimensional (3D) computed tomography (CT) data were analyzed with the assistance of a craniofacial orthodontist (K.M.L) using Dolphin Imaging 11.7 (Chatsworth, Calif.). Cephalometric measures included (1) vertical distance of the affected coronoid from the unaffected Frankfort horizontal (FH) plane; (2) angle resulting from this vertical relationship; and (3) length of total distraction measured from condylion to gonion. Values were compared using 2-tailed Student's t test with a $P < 0.05$ denoting significance using StataSE 14.0 (College Station, Tex.).

Operative Technique

Following traditional oblique osteotomy and placement of a DePuy Synthes (West Chester, Pa.) internal mandible distractor device, a DePuy Synthes Matrix Midface 0.8mm L-plate is secured using 2 screws to the coronoid without pericapsular dissection. This plate is placed so that it freely abuts the zygomatic arch with the mouth in a closed position, and consequently allows normal mouth opening (Fig. 1).

RESULTS

Demographics

Three subjects met inclusion criteria in each treatment group (Table 1). Average age at the time of distraction and average time between preoperative and postoperative CT imaging did not differ between groups.

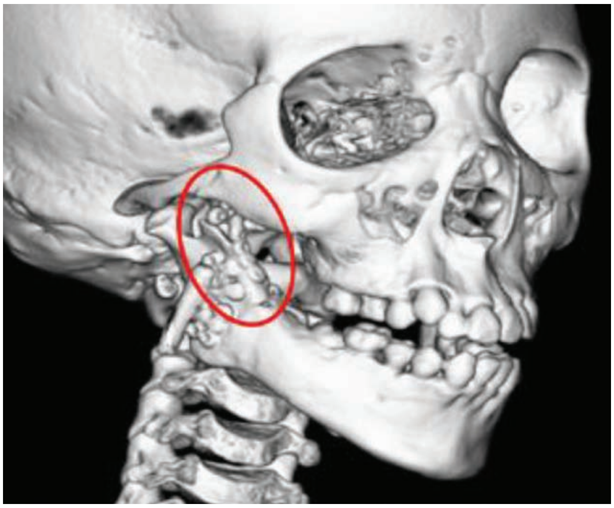

Fig. 1. Check plate prevents rotational forces about the TMJ. 3D CT reconstruction depicting use of the check plate (red oval) to engage the zygomatic arch to prevent undesirable rotational forces.

Cephalometric and CT Imaging Analyses

Preoperative vertical distance from the coronoid perpendicular to the FH on the unaffected side did not differ between groups ($P < 0.07$); however, postoperative distance significantly differed with the coronoid displacing upward in subjects without a check plate ($P < 0.005$). The preoperative angle of the coronoid based on the FH did not differ ($P < 0.06$); however, the postoperative angle significantly changed, implying upward rotation ($P < 0.01$). Total regenerate did not significantly differ between groups ($P < 0.08$) (Table 1). Postoperative 3D CT reconstruction comparing TMJ rotation and coronoid position drastically differed between subjects undergoing vertical distraction with (Fig. 2A) and without a check plate (Fig. 2B), with upward condylar rotation and cephalic displacement of the coronoid in subjects distracted without the plate. One patient in the no check plate group had evidence of condylar resorption on postoperative imaging. A case series demonstrates the efficacy of the check plate to prevent coronoid displacement and rotation (**see figure, Supplemental Digital Content 1**, which displays pre- and postoperative case study demonstrating efficacy of the check plate to prevent coronoid displacement and rotation, ***http://links.lww.com/PRSGO/A847***).

DISCUSSION

We present a modification to traditional mandibular vertical distraction. The addition of a check plate (1) prevents impaction of the TMJ into the cranial base; (2) prevents cephalic rotation of the proximal segment about the TMJ; and (3) optimizes regenerate position.

Gunbay et al.[8] assessed TMJ function in transmandibular symphyseal distraction to correct transverse deficiencies.[9] Even a small degree of symphyseal expansion caused distolateral rotation, while the compensating "adaptive" response within the condyle preserved TMJ function. They argue that nonsymphyseal distraction affects the TMJ to a greater extent as the distraction force exists in a parallel (or perpendicular) plane without a similar hinge mechanism to minimize TMJ displacement, rotation, or translation. We corroborate these conclusions by demonstrating significant TMJ and coronoid rotation after vertical lengthening when distracting in a plane perpendicular to the condyle. Fan et al. previously described condylar dysmorphologies in neonates resulting from distraction forces.[10] The authors utilized class II elastics to prevent these deleterious outcomes. We present a refinement that directly opposes the vector of distraction and consequently preserves cephalometric relations.

Vertical mandibular distraction in this population aims to lengthen a congenitally shortened ramus and to correct occlusion. Ideally, distraction produces a well-projecting regenerate. Traditional distraction does not optimize regenerate position resulting in superior displacement and decreased projection. Our postoperative assessment of total regenerate volume between groups did not significantly differ, yet we demonstrated a significantly rotated proximal mandibular segment without the use of a check plate.

Table 1. Demographic and Cephalometric Data Analyses

	No Cheek Plate (n = 3)		Cheek Plate (n = 3)		
Variable	**Mean**	**SD**	**Mean**	**SD**	***P***
Age at surgery (y)	8.8	3.4	7.7	1.8	0.68
Time between imaging (mo)	11.1	7.1	16.5	16.5	0.63
Pruzanksy-Kaban I, n (%)	2 (66.7)		2 (66.7)		1.00
Pruzansky-Kaban IIa, n (%)	1 (33.3)		1 (33.3)		
Coronoid process to FH, preoperative (mm)	0.0	3.6	6.3	2.7	0.07
Coronoid process to FH, postoperative (mm)	–7.8	3.5	3.8	0.2	<0.01*
Coronoid process to FH, △ (mm)	-7.8	0.6	-2.5	2.9	0.07
Preoperative condyle rotation (deg)	0.6	4.8	11.0	4.9	0.06
Postoperative condyle rotation (deg)	–11.8	5.6	5.8	0.1	0.01*
Condyle rotation, △ (deg)	12.3	2.9	5.2	4.9	0.10
Regenerate (% of original ramus length)	32.5	2.3	21.9	7.4	0.08

Age, time to scan, and Pruzansky-Kaban classification did not significantly differ between groups. Postoperative coronoid position and rotation was significantly increased in the no check plate group.
*Denotes significance $P < 0.05$.

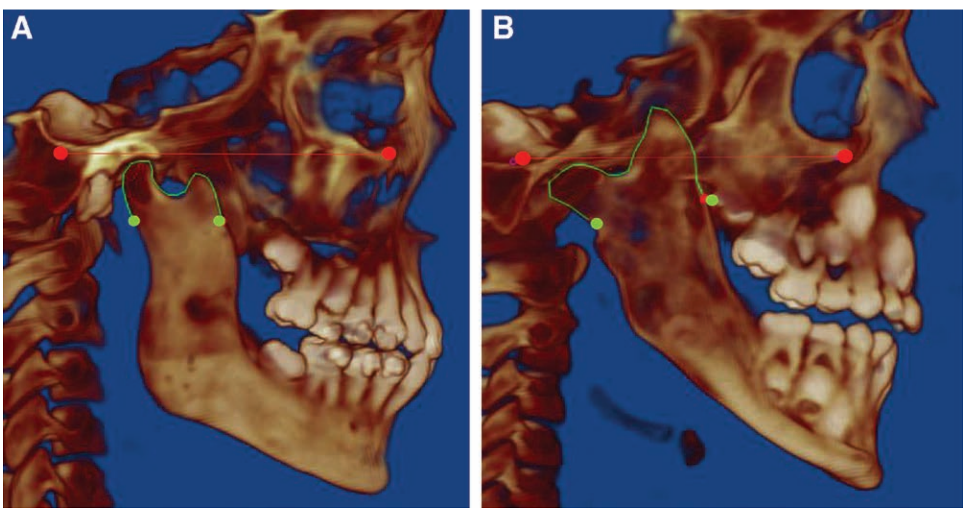

Fig. 2. Check plate prevents upward rotation of the proximal mandibular segment during vertical distraction. A, Postoperative 3D CT depicting preserved anatomic position of the proximal mandibular segment (green outline) with relation to the cranial base in a subject having undergone distraction with a check plate. B, Proximal mandibular segment (green outline) with superior rotation abutting the cranial base in a subject having undergone distraction without use of a check plate. (*Red line representing the FH was created from the unaffected side.)

Use of a check plate was not associated with these complications. In a larger cohort with longer follow-up, check plate use may translate to a reduction in more frequently associated long-term outcomes such as ankylosis and impaired TMJ function.

We acknowledge several study limitations. Our small sample size and lack of power prevents us from drawing generalizable conclusions. We present short-term follow-up data; long-term results will allow for additional commentary on the incidence of malocclusion, need for orthognathic correction, TMJ function, and further comment on the "adaptive" nature of the mandibular condyle.

CONCLUSIONS

Fixation of a check plate to engage the zygomatic arch during traditional vertical mandibular may prevent undesirable and potentially harmful upward rotation of the proximal segment and regenerate displacement.

Scott P. Bartlett, MD
Children's Hospital of Philadelphia
University of Pennsylvania
3400 Civic Center Boulevard
Philadelphia, PA 19104
E-mail: bartletts@email.chop.edu

REFERENCES

1. McCarthy JG, Schreiber J, Karp N, et al. Lengthening the human mandible by gradual distraction. *Plast Reconstr Surg.* 1992;89:1–8; discussion 9.
2. Verlinden CR, van de Vijfeijken SE, Jansma EP, et al. Complications of mandibular distraction osteogenesis for congenital deformities: a systematic review of the literature and proposal of a new classification for complications. *Int J Oral Maxillofac Surg.* 2015;44:37–43.
3. Master DL, Hanson PR, Gosain AK. Complications of mandibular distraction osteogenesis. *J Craniofac Surg.* 2010;21:1565–1570.
4. Feng S, Zhang Z, Shi L, et al. Temporal bone resorption: an uncommon complication after mandibular distraction. *J Craniofac Surg.* 2015;26:e185–e187.

5. Ascenço AS, Balbinot P, Junior IM, et al. Mandibular distraction in hemifacial microsomia is not a permanent treatment: a long-term evaluation. *J Craniofac Surg*. 2014;25:352–354.
6. Hollier LH, Kim JH, Grayson B, et al. Mandibular growth after distraction in patients under 48 months of age. *Plast Reconstr Surg*. 1999;103:1361–1370.
7. Suh J, Choi TH, Baek SH, et al. Mandibular distraction in unilateral craniofacial microsomia: longitudinal results until the completion of growth. *Plast Reconstr Surg*. 2013;132:1244–1252.
8. Gunbay T, Akay MC, Aras A, et al. Effects of transmandibular symphyseal distraction on teeth, bone, and temporomandibular joint. *J Oral Maxillofac Surg*. 2009;67:2254–2265.
9. Guerrero CA, Bell WH, Contasti GI, et al. Mandibular widening by intraoral distraction osteogenesis. *Br J Oral Maxillofac Surg*. 1997;35:383–392.
10. Fan K, Andrews BT, Liao E, et al. Protection of the temporomandibular joint during syndromic neonatal mandibular distraction using condylar unloading. *Plast Reconstr Surg*. 2012;129:1151–1161.