Journal of Cranio-Maxillo-Facial Surgery 47 (2019) 195–203

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Orthognathic surgery in "older" adults with Hemi-Mandibular Elongation: Long-term occlusion outcomes

Jeffrey C. Posnick [a, b, c, *], Anish Chavda [d], Brian E. Kinard [e]

[a] Posnick Center for Facial Plastic Surgery Clinical Professor of Surgery and Pediatrics, Georgetown University, Washington, DC, USA
[b] University of Maryland School of Dentistry, Baltimore, MD, USA
[c] Howard University College of Dentistry, Washington, DC, USA
[d] Howard University Hospital, Washington, DC, USA
[e] Posnick Center for Facial Plastic Surgery, Chevy Chase, MD, USA

ARTICLE INFO

Article history:
Paper received 6 November 2018
Accepted 28 November 2018
Available online 3 December 2018

Keywords:
Hemi-Mandibular Elongation
Mandibular asymmetry
Condylar hyperactivity

ABSTRACT

Purpose: The purpose of this study was to describe a consecutive series of subjects with HME who underwent orthognathic correction after 26 years of age. The investigators hypothesized that for this group of HME subjects, bimaxillary orthognathic correction would result in a favorable initial and long-term occlusion.

Materials and methods: A retrospective cohort study was implemented. The sample included a consecutive series of HME subjects >26 years of age undergoing bimaxillary osteotomies. The outcome variables were the achievement and maintenance of a corrected occlusion after surgery. We compared the occlusion at intervals before surgery (T_1), 5 weeks postoperatively (T_2), >2 years after surgery (T_3). Descriptive and bivariate statistics were calculated. $P < 0.05$ was considered significant.

Results: 13 subjects met inclusion criteria with a mean age of 36 years. All subjects underwent maxillary advancement. All subjects underwent mandibular surgery with 92% receiving advancement. Sixty-nine percent of subjects had a maxillary occlusal cant. In 12 of 13 subjects, a favorable occlusion was maintained long-term (T_3) after surgery.

Conclusion: We confirmed that bimaxillary orthognathic surgery in HME subjects >26 years of age results in a favorable initial occlusion which is maintained long-term. These findings are similar to that previously reported in HME subjects <26 years of age.

1. Introduction

Blair was the first to report a surgical correction for unilateral condylar hyperactivity of the mandible. The surgery was performed on a 22-year-old medical student who desired correction of an asymmetric Angle class III negative overjet malocclusion and facial asymmetry. The bilateral body osteotomies with an asymmetric mandibular setback were carried out in 1897 (Blair, 1906). Condylar hyperactivity occurring during growth, resulting in an asymmetric Angle class III malocclusion was later reported by Rushton and Broadway (Rushton, 1944; Broadway, 1958). Over 100 years after the first surgical intervention, the correction of asymmetric mandibular excess remains a controversial topic in almost all aspects including the etiology, ideal classification system, age of condylar hyperactivity cessation and preferred treatment.

Obwegeser postulates that asymmetric mandibular excess is caused by unique growth regulators acting from within the condyle, presenting in two distinct clinical presentations (Obwegeser and Makek, 1986; Obwegeser, 1993, 2001; Obwegeser and Obwegeser, 2010). The first clinical pattern is a more rare form and results in what he calls Hemi-Mandibular Hyperplasia (HMH). This is characterized by an increase in volume of all parts of the affected hemi-mandible with involvement ending at the midline of the symphysis. In HMH there is no lateral shift of the mandibular dental midline to the opposite side of the face. The second, and more common form of this jaw deformity is called Hemi-Mandibular Elongation (HME). HME is characterized by an "elongation" of the affected side of the hemi-mandible with a lateral shift of both the mandibular dental midline and chin to the opposite side of the face. The two types of asymmetric mandibular

* Corresponding author. 5530 Wisconsin Ave, Suite 1250, Chevy Chase, MD 20815, USA. Fax: +301 986 1974.
E-mail address: jposnick@drposnick.com (J.C. Posnick).

https://doi.org/10.1016/j.jcms.2018.11.027
1010-5182/

overgrowth (HME and HMH) typically present during the prepubertal growth spurt and is not a result of condylar tumors.

Wolford offers a treatment algorithm for the Hemi-Mandibular Elongation based on a belief that the condylar hyperactivity will continue through the mid-twenties. He states that if orthognathic surgery is carried out prior to 26 year of age, a simultaneous condylectomy is needed to avoid a recurrent class III malocclusion (Wolford et al., 2009, 2014). Posnick and colleagues studied surgical outcomes in skeletally mature Hemi-Mandibular Elongation subjects less than 26 years of age and demonstrated that a favorable occlusion could be reliably achieved and maintained long-term using standard bimaxillary orthognathic techniques. There was no need for an ablative open joint procedure to arrest condylar growth (Posnick et al., 2017).

When treating HME in subjects greater than 26 years of age, "older" adults, questions remain concerning details of their presenting skeletal dysmorphology, extent of presenting malocclusion, the natural progression of their condylar hyperactivity, and orthognathic surgical outcomes. Review of the literature reveals limited critical analysis of this pattern of developmental jaw deformity in "older" subjects (Higginson et al., 2018; Ghawsi et al., 2016). To our knowledge, no studies have yet documented the long-term occlusion outcomes in "older" HME subjects after orthognathic surgery.

The purpose of this study was to document a consecutive series of subjects with HME who underwent orthognathic correction after 26 years of age. We hypothesized that for this subset of patients, bimaxillary orthognathic correction would result in a favorable initial and long-term occlusion. We also theorize that the long-term occlusion in "older" adults (>26 years) should be similar to those documented in "younger" adults (<26 years). The specific aims were to 1) review each "older" HME subject's occlusion and radiographs prior to surgery, assessing for patterns of malocclusion and mandibular dysmorphology, 2) document the maxillary and mandibular surgical change planned for each subject undergoing bimaxillary orthognathic surgery, 3) assess each subject's occlusion at intervals including prior to surgery (**T_1**), 5 weeks post-op (**T_2**), then >2 years after surgery (**T_3**), and 4) compare the long-term occlusion results in our "older" subjects to that previously reported in "younger" HME subjects after bimaxillary orthognathic surgery (Posnick et al., 2017).

2. Materials and methods

2.1. Study design and sample

To address the research objective a retrospective cohort study was designed and implemented. The sample was derived from patients treated by a single surgeon (JCP) in a private practice setting (Posnick Center) with surgery carried out at a single hospital (MedStar Georgetown University Hospital, Washington, DC) between January 1999 and June 2013. Subjects were included when meeting the criteria for the diagnosis of HME (see below diagnostic criteria for HME) and having undergone bimaxillary osteotomies to correct their dentofacial deformity. Subjects were excluded if their jaw asymmetry was not secondary to HME (e.g. trauma sequelae, syndromic, clefting, or present since birth for any reason) or if there was radiographic evidence of condylar changes consistent with a benign or malignant tumor. No study subjects underwent or had previously undergone a TMJ or orthognathic surgical procedure. The diagnosis of Hemi-Mandibular Elongation required:

(1) Radiographic confirmation of deviation of the mandibular dental midline to the contralateral side (with reference to the maxillary dental midline) and presence of increased height of the condyle-condylar neck complex on the ipsilateral side (compared to the contralateral side).
(2) Clinical findings of a lateral shift of the chin to the contralateral side of the face (with reference to the upper facial midline).
(3) Malocclusion findings in centric relation (CR) of mandibular dental midline deviation to the contralateral side (with reference to the maxillary dental midline), Class III (canine) pattern on the ipsilateral side, a lesser degree of Class III (canine) pattern on the contralateral side, molar crossbite (or tendency) on the contralateral side, and a variable degree of incisor negative overjet and abnormal overbite. The degree of secondary ipsilateral posterior maxillary vertical hyperplasia was expected to vary, often resulting in either canting (maxilla down on the ipsilateral side) or ipsilateral posterior open bite.

All HME study subjects underwent perioperative orthodontics and orthognathic reconstruction that at a minimum included maxillary Le Fort I osteotomy and bilateral sagittal ramus osteotomies of the mandible. Design of the Le Fort I and sagittal ramus osteotomies and methods of fixation were consistent for all study subjects and previously described (Posnick, 2014; Posnick et al., 2017). Other indicated simultaneous maxillofacial procedures were carried out according to clinical need. The Georgetown Institutional Review Board approved the study protocol (IRB # 2014-1208).

The subgroup of HME subjects under 26 years of age (N = 76/89, 85% of subjects) was studied separately and the results have previously been reported (Posnick et al., 2017). The current study includes the subgroup of HME subjects older than 26 years of age at the time of operation (N = 13/89, 15% of subjects).

2.2. Predictor variables

The predictor variable categories included demographic, anatomic, and operative. The demographic variables included age of the subject at the time of operation and sex. The anatomic variables included the side of mandibular condylar hyperactivity (left or right), mandibular dysmorphology, and occlusion findings. Review of the pre-surgical panoramic radiograph for each subject was carried out to assess for patterns of variation in HME mandibular dysmorphology. This included analysis of condyle-condylar neck height, condyle-condylar neck shape, gonial angle, ramus height, and mandibular canal position. The ipsilateral side of the mandible was compared to the contralateral side for each variable. The methods used to measure and categorize each mandibular morphologic variable have previously been described (Posnick et al., 2017).

Each subject's occlusion prior to orthognathic surgery was analyzed to document 6 key parameters including incisor overjet, incisor overbite, canine Angle classification, coincidence of maxillary to mandibular dental midlines and left and right transverse and vertical first molar occlusion. The pre-operative occlusion data (**T_1**) were gathered by review of facebow mounted dental models on a semi-adjustable articulator into centric relation.

The operative variable studied was planned surgical skeletal change. The planned maxillary and mandibular surgical change was dictated by the presenting jaw deformity and malocclusion. Each patient underwent "maxillary first" analytic model planning 2–6 weeks prior to surgery (Park and Posnick, 2013). The vector data points planned for change in the maxilla reported in this study include the horizontal and vertical incisor position, pitch and roll orientation, and the dental midline position (with reference to the upper face midline). For the purpose of this study, the only mandibular vector data point reported was the horizontal change at the incisors. The data were recorded, maintained, and retrieved for this study from each patient's medical record and articulated dental models.

2.3. Outcome variables

The primary outcome variables studied were the initial postoperative occlusion achieved (**T_2**) and the occlusion maintained long-term (**T_3**). The occlusion initially achieved (**T_2**) was considered successful when it was within ±0.5 mm variance compared to that planned on the articulated surgical models in CR for each of the 6 parameters evaluated. The long-term occlusion in centric relation (**T_3**) was judged to accepted standards for each of the 6 parameters. The postoperative occlusion (**T_3**) documented in each subject long-term included: incisor overjet (excess [>3 mm], normal [1–3 mm], edge-to-edge, or negative); incisor overbite (deep [>2 mm], normal [1–2 mm], edge-to-edge, or open); coincidence of maxillary to mandibular dental midlines (±0.5 mm); canine Angle classification (Class I, II, III); first molar lateral occlusion on the left and right sides (normal cuspal relationship, edge-to-edge, or crossbite); and first molar vertical occlusion on the left and right sides (closed [occlusal surfaces touching] or open).

2.4. Collection, management, and analysis of data

The data were abstracted and recorded on a standardized data collection form by 2 of the researchers/observers (JP and AC) from the hospital and outpatient medical records. This included a review of specific radiographs prior to and after treatment. Each patient had a lateral cephalometric and panoramic radiograph taken within 2 months before and approximately 5 weeks after surgery. The preoperative radiographs were used for planning purposes as well as to assess dental anatomy and mandibular dysmorphology. The postoperative radiographs were reviewed for confirmation of osteotomy design, fixation hardware placement, jaw and condylar position, dental injury, absence of foreign bodies, and overall morphology. Each subject had standardized facial and intraoral photographs in CR within 2 months before surgery (**T_1**), 5 weeks after surgery (**T_2**), and >2 year follow-up occlusion records (**T_3**).

The data were entered into a database created using Microsoft Excel (Microsoft Inc., Redmond, WA). Descriptive statistics and bivariate analysis was performed. $P < 0.05$ was considered significant.

During the time frame of the study, no Hemi-Mandibular Elongation patients operated on by the primary investigator (JCP) and that underwent bimaxillary surgery were excluded or lost to follow-up and no data points were missing for any of the study parameters for any of the subjects.

3. Results

Thirteen subjects met the inclusion criteria and were included in the study. The mean age at operation was 36 years (range 27–52 years) and the study included 8 females (62%) (Tables 1A and 1B). All subjects had a minimum follow-up of 2 years after orthognathic correction.

The condylar hyperactivity was on the right side in 6 of 13 subjects (46%) (Table 1B). The condyle-condylar neck complex on the side of hyperactivity was always greater in height compared to the contralateral side. Details of condylar dysmorphology varied but patterns included tall and thick (6/13, 46%), tall and thin (4/13, 31%), and tall and posteriorly angled (3/13, 23%) (Table 2). Variations in the gonial angle anatomy were assessed (comparison of the ipsilateral to the contralateral side) (Table 2). Forty-six percent of the involved sides (6/13 subjects) were documented to have an obtuse gonial angle compared to the contralateral side. Ipsilateral ramus height was increased in comparison to the contralateral side in 3 of the 13 subjects (23%) (Table 2). The mandibular canal position was also studied. At the level of the second molar the mandibular canal was closer to the inferior border of the mandible on the involved side in 62% (8/13) of subjects (Table 2). In our HME subjects, the specific pattern of mandibular dysmorphology did not seem to have an effect on the extent of malocclusion (Table 3), the planned surgical changes designated to correct the identified maxillo-mandibular deformities (Table 4) or the long-term occlusion outcome (Table 5).

Table 3 presents each subject's occlusion prior to surgery according to the parameters outlined in the methods section. The analytic model planning in preparation for surgery for each study subject was reviewed (Table 4). The model planning data showed that all subjects underwent maxillary advancement as measured at the incisors (average 5 mm; range 2–8 mm). Four of the 13 subjects (31%) underwent correction of maxillary plane (pitch) orientation. The directional maxillary pitch change was always clockwise rotation. Nine of the subjects (69%) required cant (roll) orientation correction of the maxilla (range 2–4 mm). In each case, the maxilla was found to be lower on the ipsilateral side. For most subjects, vertical change at the maxillary incisors was carried out to improve smile aesthetics and lip competence and ranged from negative 3 mm (intrusion to diminish “gummy” smile) to positive 5 mm (lengthening to increase dental show). In 6 of the 13 subjects, (46%) the maxillary dental midline did not match the upper face midline and therefore required (yaw) surgical correction. In each case, the maxillary dental midline was deviated to the contralateral side.

All study subjects underwent bilateral sagittal ramus osteotomies with 12 of the 13 (92%) requiring advancement at the incisors (range 1–4 mm). Yaw orientation change of the mandible (i.e. dental midline correction) to improve jaw/facial symmetry was required in all cases. The anterior mandibular dental midline correction was always toward the side of condylar hyperactivity.

Other simultaneous procedures carried out in the study group included segmentation of the Le Fort I osteotomy (3-segments, (38%) and 2-segments (46%)), osseous genioplasty (77%), septoplasty (69%), reduction of inferior turbinates (69%), removal of third

Table 1A
Hemi-Mandibular Elongation: Comparison of demographic and follow-up data by age at operation.

Demographics	Subjects under 26 years of age	Subjects over 26 years of age	P-value
Subjects (n)	76	13	
Age at operation (mean ± SD)	18.3 ± 2.5 years	36.2 ± 8.5 years	<0.0001
Sex			
Male (%, N)	42% (32)	38% (5)	0.81
Female (%, N)	58% (44)	62% (8)	
Side of condylar hyperactivity			
Right (%, N)	55% (42)	46% (6)	0.56
Left (%, N)	45% (34)	54% (7)	
Occlusion follow-up after surgery (mean ± SD)	61 ± 42 months	43 ± 35 months	0.14

Table 1B
Hemi-Mandibular Elongation: Subject's demographics.

#	Sex	Side	Age at Surgery	Premolar Extractions	Le Fort Type	Simultaneous Procedures
72	F	R	52	#5, 12, 21, 28	3 segments	BSSO/Genio Septo/ITR Neck Lift
15	F	L	27	None	2 segments	BSSO/Genio Extract 3rd molars
80	M	L	27	#5	1 segment	BSSO/Genio Septo/ITR
40	F	L	31	#5, 12, 28	2 segments	BSSO/Genio Extract 3rd molars
20	F	L	27	None	3 segments	BSSO/Genio Septo/ITR
50	M	L	45	#5, 12, 21, 28	1 segment	BSSO/Genio Septo/ITR Neck Lift
56	M	L	34	None	2 segments	BSSO/Genio Septo/ITR
27	F	R	35	#5, 12, 21, 28	2 segments	BSSO/Genio Septo/ITR
81	F	L	41	None	3 segments	BSSO
90	F	R	48	#5, 12, 21, 28	2 segments	BSSO Septo/ITR Neck Lift
48	F	R	27	None	3 segments	BSSO/Genio
9	M	R	38	None	3 segments	BSSO Septo/ITR
88	M	R	38	None	2 segments	BSSO/Genio Septo/ITR Extract 3rd molars

Abbreviations: BSSO, bilateral sagittal split osteotomies; Genio, osteotomy of chin; Septo, septoplasty; ITR, inferior turbinate reduction.

Table 2
Hemi-Mandibular Elongation: Comparison of radiographic data by age at operation.

Mandibular morphology	Subjects under 26 years of age	Subjects over 26 years of age	P-Value
	% (n)	% (n)	
Condyle-condylar neck shape			
Tall and thin	39% (30)	31% (4)	0.38
Tall and posteriorly angled	32% (24)	23% (3)	
Tall and thick	22% (17)	46% (6)	
No significant difference	7% (5)	0	
Ramus height			
No significant difference	63% (48)	62% (8)	0.03
Increased	36% (27)	23% (3)	
Decreased	1% (1)	15% (2)	
Gonial Angle			
No significant difference	74% (56)	54% (7)	0.15
Obtuse	26% (20)	46% (6)	
Acute	0% (0)	0% (0)	
Mandibular canal to inferior border distance			
No significant difference	74% (56)	38% (5)	0.02
Closer to inferior border	21% (16)	62% (8)	
Farther from inferior border	5% (4)	0% (0)	

*Condylar hyperactivity side in comparison with "normal" contralateral side.

molars (23%), and interpositional bone graft to the maxilla (23%) (Table 1B).

3.1. *Occlusion achieved early after surgery (subjects > 26 years of age at operation)*

Findings confirmed that the post-operative occlusion after initial maxillo-mandibular healing ($\mathbf{T_2}$) met objectives (±0.5 mm) for each parameter analyzed in the majority of subjects. Four of the subjects were documented to have a mandibular to maxillary dental midline discrepancy (range 1–2 mm) and two subjects had posterior (molar) vertical/transverse discrepancies. Active orthodontics was reinitiated in all subjects within 5 weeks after surgery ($\mathbf{T_2}$). The above stated malocclusions at $\mathbf{T_2}$ were corrected and maintained long-term ($\mathbf{T_3}$) in all but 1 subject (S#40) (Table 6) (Fig. 1).

3.2. *Occlusion achieved long-term after surgery (subjects > 26 years of age at operation)*

In 12 of the 13 subjects, a favorable anterior occlusion (overjet, overbite, canine Angle class) and a favorable posterior occlusion (transverse and vertical first molar position on each side) was achieved and maintained long-term (Table 5). In one subject (S#40), the $\mathbf{T_2}$ malocclusion (non-coincident dental midlines, ipsilateral canine Class III, and bilateral first molar open bites) persisted long-term (Table 5, Fig. 1).

3.3. *Comparison of HME subjects and long-term occlusion outcomes by age at operation*

HME subjects were subgrouped into those <26 years of age at operation and those >26 years of age at the time of surgery. The

Table 3
Hemi-Mandibular Elongation: Subjects' pre-surgical occlusion[a].

Anterior						Posterior (Ipsilateral)		Posterior (Contralateral)	
#	Incisor Overjet	Incisor Overbite	Mandibular to Maxillary Dental Midline	Ipsilateral Canine Angle Class	Contralateral Canine Angle Class	Vertical	Transverse	Vertical	Transverse
72	Edge–Edge	Edge–Edge	L 2.5 mm	C-III	C-I	Closed	NL	Closed	Crossbite
15	Negative	Open	R 2.5 mm	C-III	C-I	Closed	NL	Closed	Crossbite
80	Edge–Edge	Edge–Edge	R 3 mm	C-III	C-I	Closed	NL	Closed	Crossbite
40	Negative	Open	R 4 mm	C-III	C-III	Closed	NL	Open	Crossbite
20	Edge–Edge	Edge–Edge	R 0.5 mm	C-III	C-I	Closed	NL	Closed	Edge–Edge
50	Negative	NL	R 2 mm	C-III	C-III	Closed	Edge–Edge	Open	Crossbite
56	Edge–Edge	Edge–Edge	R 5.5 mm	C-III	C-III	Closed	NL	Open	Edge–Edge
27	Negative	Edge–Edge	L 0.5 mm	C-III	C-III	Closed	Crossbite	Closed	Edge–Edge
81	Negative	Open	R 5 mm	C-III	C-II	Closed	NL	Closed	Crossbite
90	Edge–Edge	Edge–Edge	L 4 mm	C-III	C-II	Closed	NL	Closed	Edge–Edge
48	Edge–Edge	Edge–Edge	L 2 mm	C-III	C-I	Closed	NL	Closed	Edge–Edge
9	Edge–Edge	Edge–Edge	L 3.5 mm	C-III	C-I	Open	NL	Open	Crossbite
88	Negative	Edge–Edge	L 4 mm	C-III	C-III	Closed	NL	Closed	Crossbite

Abbreviation: NL, normal ± 0.5 mm variance; R, right; L, left.
[a] The pre-operative occlusion data (**T_1**) were gathered by review of facebow mounted dental models on a semi-adjustable articulator into centric relation.

Table 4
Hemi-Mandibular Elongation: Subjects' planned skeletal change[a].

#	Maxillary Horizontal Advancement	Maxillary Incisor Vertical Change	Maxillary to Facial Midline Change	Pitch Correction	Cant Correction	Maxillary Transverse Widening	Mandibular Horizontal Advancement
72	+8 mm	+5 mm	0	No change	No change	0	+4 mm
15	+5 mm	+2 mm	R 2 mm	No change	No change	+2 mm	+1 mm
80	+3 mm	0	L 2 mm	No change	4 mm	0	+4 mm
40	+5 mm	0	L 2 mm	CW 2 mm	3 mm	+1 mm	+1 mm
20	+5 mm	+3 mm	L 2 mm	No change	4 mm	+1 mm	+4 mm
50	+6 mm	0	0	No change	2 mm	0	0
56	+5 mm	+4 mm	0	CW 2 mm	4 mm	+2 mm	+1 mm
27	+7 mm	−4 mm	0	No change	No change	+3 mm	+1 mm
81	+5 mm	0	L 1 mm	CW 3 mm	3 mm	0	+6 mm
90	+5 mm	−3 mm	0	No change	4 mm	0	+5 mm
48	+2 mm	0	0	No change	4 mm	0	+1 mm
9	+6 mm	+3 mm	0	CW 3 mm	No change	+2 mm	+1 mm
88	+8 mm	0	L 1 mm	No change	2 mm	0	+1 mm

Abbreviations: CW, clockwise rotation.
[a] The occlusion initially achieved (**T_2**) was considered successful when there was less than ± 0.5 mm variance compared to that planned on the articulated surgical models in CR for each of the 6 parameters evaluated (see text).

Table 5
Hemi-Mandibular Elongation: Subjects' long term postoperative occlusion[a].

Anterior						Posterior (Ipsilateral)		Posterior (Contralateral)		F/U of Occlusion S/P Surgery
#	Molar Overjet	Molar Overbite	Mandibular to Maxillary Dental Midline	Ipsilateral Canine Angle Class	Contralateral Canine Angle Class	Vertical	Transverse	Vertical	Transverse	
72	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs, 5 mo
15	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	11 yrs, 7 mo
80	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs
40	NL	NL	R 2 mm	C-III	C-I	Open	NL	Open	NL	2 yrs, 4 mo
20	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs, 9 mo
50	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	7 yrs, 2 mo
56	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs
27	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	3 yrs, 6 mo
81	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs
90	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs, 1 mo
48	NL	NL	L 0.5 mm[a]	C-I	C-I	Closed	NL	Closed	NL	6 yrs, 1 mo
9	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs, 2 mo
88	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL	2 yrs, 9 mo

Abbreviation: NL, normal ± 0.5 mm variance; Yrs, years; Mos; months.
[a] The long-term occlusion in CR (**T_3**) was judged to accepted standards (+/−0.5 mm variance) for each of the 6 parameters (see text).

<26 years of age cohort data has been previously reported by our research group (Posnick et al., 2017). Table 1A summarizes separated demographic data for the two HME subgroups. Aside from age at operation, there were no significant differences between the two subgroups in regards to sex, side of condylar hyperactivity or length of occlusal follow-up. Differences did exist between the two subgroups for ramus height and the distance from the mandibular canal to the inferior border of the mandible at the level of the

Table 6
Hemi-Mandibular Elongation: Subjects' Immediate (5 weeks) Postoperative Occlusion[a].

Anterior						Posterior (Ipsilateral)		Posterior (Contralateral)	
#	Incisor Overjet	Incisor Overbite	Mandibular to Maxillary Dental Midline	Ipsilateral Canine Angle Class	Contralateral Canine Angle Class	Vertical	Transverse	Vertical	Transverse
72	NL	NL	R 1 mm	C-I	C-III[a]	Closed	NL	Closed	NL
15	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL
80	NL	NL	R 1 mm	C-I	C-I	Closed	NL	Closed	NL
40	NL	NL	R 2 mm	C-III	C-I	Open	NL	Open	NL
20	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL
50	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL
56	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL
27	NL	NL	L 0.5 mm[a]	C-I	C-I	Closed	NL	Closed	NL
81	NL	NL	R 2 mm	C-III[a]	C-II[a]	Closed	NL	Closed	NL
90	NL	NL	On	C-I	C-I	Open	Edge–Edge	Open	Crossbite
48	NL	NL	L 0.5 mm[a]	C-I	C-I	Closed	NL	Closed	NL
9	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL
88	NL	NL	On	C-I	C-I	Closed	NL	Closed	NL

Abbreviation: NL, normal ± 0.5 mm variance.
[a] The occlusion initially achieved (**T$_2$**) was considered successful when it was within ± 0.5 mm variance compared to that planned on the articulated surgical models in CR for each of the 6 parameters evaluated (see text).

second molar. There were more subjects <26 years of age with an increased ipsilateral ramus height and with an increased ipsilateral distance from the mandibular canal to the inferior border of the mandible. Tables 7 and 8 summarizes a comparison of the occlusion documented long-term in each subgroup. There were no significant differences in the maintenance of a long-term favorable occlusion for HME subjects older than 26 years of age when compared to those younger than 26 years of age at time of operation ($p < 0.05$).

4. Discussion

The purpose of this retrospective study was to identify a cohort of "older" adult Hemi-Mandibular Elongation subjects (>26 years of age) who underwent bimaxillary orthognathic reconstruction and then assess the initial occlusion achieved (**T$_2$**) and the long-term occlusion maintained (**T$_3$**). The study confirmed that for most "older" HME adults (>26 years of age) a corrected occlusion can reliably be achieved and then maintained long-term after bimaxillary orthognathic surgery.

By comparing the 5-week postoperative occlusion (**T$_2$**) to that planned in each subject, we confirmed a high success rate in achieving the surgical objective (±0.5 mm variance) for each of the 6 key parameters reviewed. All subjects achieved an initial favorable post-operative incisor overjet and incisor overbite. All but two achieved an ideal transverse and vertical molar occlusion on each side. One of the two subjects with a molar discrepancy at 5 weeks after surgery achieved correction with ongoing orthodontics and then maintained the result long term. Three of the four subjects documented to have mandibular to maxillary dental midline discrepancies (range 1–2 mm) at **T$_2$** were corrected through finishing orthodontics and then maintained the result long term. The one subject with a suboptimal long-term occlusion (S#40) was recognized to have the same level of malocclusion at **T$_2$** (at the time of splint removal) (Fig. 1). The patient had occluded evenly into the splint during the initial 5 weeks after surgery. She was presumed to have a fully corrected occlusion until splint removal. Despite re-initiation of orthodontics at **T$_2$** (5 weeks after surgery), a degree of malocclusion recognized at splint removal persisted long term (**T$_3$**). Interestingly, this patient had undergone an initial phase of orthodontics (included extractions of 3 premolars) prior to graduating high school (Table 1B).

Obwegeser suggests subdividing HME into "slender type" and "non-slender type" based on variations in gonial angle morphology (Obwegeser, 2001). He postulated that the gonial angle "type" could be an indicator for progression of the deformity. For this reason, we studied the pre-surgical panoramic radiographs for each of our Hemi-Mandibular Elongation subjects. In our study subjects, we identified a limited spectrum of variation (side to side) in condyle-condylar neck height, condylar shape, gonial angle, ramus height, and mandibular canal position (Table 2). We found the patterns of mandibular morphology in our HME subjects (>26 years of age) to be similar to that previously reported in HME subjects <26 years of age (Posnick et al., 2017). Just as in younger HME subjects (<26 years of age), the documented mandibular dysmorphology had no measurable influence on treatment decisions and no effect on the long-term occlusion outcomes (Posnick et al., 2017).

As a group, our HME study subjects (>26 years of age) had many similarities with each other in the planned surgical change to the maxilla and mandible. All maxillae required horizontal advancement at the incisors (range 3–8 mm) and 69% underwent cant correction (range 2–4 mm). Maxillary skeletal arch form anomalies required segmental osteotomies in 11 of the 13 subjects. The mandible was horizontally advanced in 12 of 13 subjects (92%).

Proffit and colleagues make a compelling argument for the frequent occurrence of ramus remodeling with skeletal relapse in Class III subjects undergoing isolated mandibular procedures (Proffit et al., 1991a, 1991b, 2012). Eggensperger et al. confirmed Proffit's findings in a 12-year follow-up investigation of long-term stability and relapse patterns in a group of Class III subjects who underwent isolated mandibular procedures to correct their jaw deformity (Eggensperger et al., 2005). All of our HME (Class III) study subjects underwent bimaxillary orthognathic surgery. As with HME subjects <26 years of age, we documented for "older" subjects, the successful maintenance of a corrected occlusion without the high frequency of recurrent class III independently reported by Proffit, Eggensperger, and Wolford for subjects undergoing isolated mandibular procedures (Proffit et al., 1991a, 1991b, 2012; Eggensperger et al., 2005; Wolford et al., 2009).

It is often argued that performing an "interceptive" destructive condylar procedure (i.e. condylectomy or "condylar shave") early in the disease process significantly limits facial disfigurement that the patient might otherwise develop while waiting for cessation of mandibular growth and that doing so will not have long-term detrimental effects. The literature supporting this hypothesis is limited (Higginson et al., 2018; Ghawsi et al., 2016; Mouallem et al., 2017; Farina et al, 2015, 2016). We document that subjects who were followed through their presumed jaw growth phase without interceptive condylar surgery can undergo standard bimaxillary orthognathic surgery that is not substantially different than in

Fig. 1. A 31-year old female with Hemi-Mandibular Elongation (S#40) (left side condylar hyperactivity) underwent orthognathic correction (Le Fort I in 2 segments, sagittal ramus osteotomies, genioplasty). She is shown before and 2 years after treatment. She is the only study subject with a long-term suboptimal occlusion. A) Frontal smile views before and six years after surgery. B) Views of occlusion: prior to re-treat orthodontics s/p 3 premolar extractions; immediate pre-surgery; 5 weeks postoperative; and 6 years postoperative. C) Lateral cephalometric radiographs before orthodontic decompensation and 5 weeks after surgery.

Table 7
Hemi-Mandibular Elongation: Comparison of anterior occlusion long-term after surgery according to age at operation.

Occlusion Parameter	Subjects under 26 years of age	Subjects over 26 years of age	
Incisor overjet	% (n)	% (n)	P-Value
Normal[a]	99% (75)	100% (13)	1.0
Edge to Edge	1% (1)	0% (0)	
Open	0% (0)	0% (0)	
Incisor overbite			
Normal[a]	99% (75)	100% (13)	1.0
Edge to edge	0% (0)	0% (0)	
Open	1 (1%)	0% (0)	
Mandibular dental midline deviation			
Match[b]	100% (76)	92% (12)	
To right (mean and range)	0 mm (0.0 mm)	2.0 mm (2.0 mm)	

Once the orthodontic appliances were removed (5–12 months post op), no active orthodontics, dental work, or surgical interventions were instituted.
[a] Variance (±1 mm).
[b] Dental midlines coincide (±1 mm).

Table 8
Hemi-Mandibular Elongation: Comparison of posterior occlusion long-term after surgery according to age at operation[a].

Occlusion Parameter	Side of Condylar Hyperactivity			Contralateral Side		
	Subjects under 26 years of age	Subjects over 26 years of age		Subjects under 26 years of age	Subjects over 26 years of age	
Canine Angle Class	(%, N)	(%, N)	P-value	(%, N)	(%, N)	P-value
Class I	100% (76)	92% (12)	0.15	99% (75)	100% (13)	1.0
Class II	0%	0%		1% (1)	0%	
Class III	0%	8% (1)		0%	0%	
First Molar Vertical						
Normal[b]	100% (76)	92% (12)	0.15	100% (76)	92% (12)	0.15
Open	0%	8% (1)		0%	8% (1)	
First Molar Transverse						
Normal[b]	95% (72)	100% (13)	1.0	94% (71)	100% (13)	1.0
Edge to edge	5% (4)	0%		5% (4)	0%	
Crossbite	0%	0%		1% (1)	0%	

[a] Once the orthodontic appliances were removed (5–12 months post op), no active orthodontics, dental work, or surgical interventions were instituted.
[b] Variance (±1 mm).

those with other common patterns of developmental dentofacial deformities (i.e. long face, primary maxillary deficiency and primary mandibular deficiency) and with similar favorable long-term occlusion outcomes (Posnick et al., 2017, 2018a, 2018b, 2018c).

Limitations of this study include sample size, single center study and inherent bias associated with retrospective studies.

5. Conclusion

In "older" adult Hemi-Mandibular Elongation subjects (>26 years of age) using standard bimaxillary orthognathic techniques, a favorable occlusion can be reliably achieved initially after surgery and then maintained long-term. These findings are similar to that previously reported in HME subjects <26 years of age.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements and conflicts of interest statement

There are no acknowledgements or conflicts of interest for either author associated with this manuscript.

References

Broadway RT: Two cases of unilateral hyperplasia of the mandibular condyle. Proc R Soc Med 51: 23–25, 1958
Blair VP: Report of a case of double resection for the correction of protrusion of the mandible. Dental Cosmos 48: 817–820, 1906
Eggensperger N, Raditsch T, Taghizadeh F, Iizuka T: Mandibular setback by sagittal split ramus osteotomy: a 12-year follow-up. Acta Odontol Scand 63: 183–188, 2005
Farina R, Pintor F, Perez J, Pantoja R, Bemer D: Low condylectomy as the sole treatment for active condylar hyperplasia: facial, occlusal and skeletal changes. An observational study. Int J Oral Maxillofac Surg 44: 217–225, 2015
Farina R, Olate S, Raposo A, Araya I, Alister JP, Uribe F: High condylectomy versus proportional condylectomy: is secondary orthognathic surgery necessary? Int J Oral Maxillofac Surg 45: 72–77, 2016
Ghawsi S, Aagaard E, Thygesen TH: High condylectomy for the treatment of mandibular condylar hyperplasia: a systematic review of the literature. Int J Oral Maxillofac Surg 45: 60–71, 2016
Higginson JA, Bartram AC, Banks RJ, Keith DJW: Condylar hyperplasia: current thinking. Br J Oral Maxillofac Surg 56: 655–662, 2018
Mouallem G, Vernex-Boukerma Z, Longis J, et al: Efficacy of proportional condylectomy in a treatment protocol for unilateral condylar hyperplasia: a review of 73 cases. J Craniomaxillofac Surg 45: 1083–1093, 2017
Obwegeser HL: Descriptive terminology for jaw anomalies. Oral Surg Oral Med Oral Pathol 75: 138–140, 1993
Obwegeser HL: Mandibular growth anomalies: terminology-aetiology-diagnosis-treatment. NY: Springer-Verlag Berlin Heidelberg, 2001
Obwegeser HL, Makek MS: Hemimandibular hyperplasia-hemimandibular elongation. J Maxillofac Surg 14: 183–208, 1986
Obwegeser HL, Obwegeser JA: New clinical-based evidence for the existence of 2 growth regulators in mandibular condyles: hemimandibular elongation in hemifacial microsomia mandible. J Craniofac Surg 21: 1595–1600, 2010
Park N, Posnick JC: Accuracy of analytic model planning in bimaxillary surgery. Int J Oral Maxillofac Surg 42: 807–813, 2013
Posnick JC: Sequencing of orthognathic procedures: step-by-step approach. In: Posnick JC (ed.), Orthognathic surgery: principles and practice. St. Louis: Elsevier, 441–474, 2014 Ch 15
Posnick JC, Egolum N, Tremont TJ: Primary mandibular deficiency dentofacial deformities: occlusion and facial aesthetic surgical outcomes. J Oral Maxillofac Surg 76, 2018a 2209e1-e15
Posnick JC, Liu S, Tremont TJ: Long-face dentofacial deformities: occlusion and facial esthetic surgical outcomes. J Oral Maxillofac Surg 76: 1291–1308, 2018b
Posnick JC, Makan S, Bostock D, Tremont TJ: Primary maxillary deficiency dentofacial deformities: occlusion and facial esthetic surgical outcomes. J Oral Maxillofac Surg 76: 1966–1982, 2018c

Posnick JC, Perez J, Chavda A: Hemimandibular elongation: is the corrected occlusion maintained long-term? Does the mandible continue to grow? J Oral Maxillofac Surg 75: 371–398, 2017

Proffit WR, Phillips C, Dann CIV, Turvey TA: Stability after surgical-orthodontic correction of skeletal class III malocclusion: 1. Mandibular setback. Int J Adult Orthodon Orthognath Surg 6: 7–18, 1991a

Proffit WR, Phillips C, Turvey TA: Stability after surgical-orthodontic correction of skeletal class III malocclusion: 3. Combined maxillary and mandibular procedures. Int J Adult Orthodon Orthognath Surg 6: 211–225, 1991b

Proffit WR, Phillips C, Turvey TA: Stability after mandibular setback: mandible-only versus 2-jaw surgery. J Oral Maxillofac Surg 70: 408–414, 2012

Rushton MA: Growth at the mandibular condyle in relation to some deformities. Br Dent J 76: 57–68, 1944

Wolford LM, Morales-Ryan CA, García-Morales P, Perez D: Surgical management of mandibular condylar hyperplasia type 1. Proc (Bayl Univ Med Cent) 22: 321–329, 2009

Wolford LM, Movahed R, Perez DE: A classification system for conditions causing condylar hyperplasia. J Oral Maxillofac Surg 72: 567–595, 2014