ORIGINAL ARTICLE

Evaluation of skeletal, dental, soft tissue and airway cephalometric changes in severe class II malocclusions treated by bilateral mandibular distraction osteogenesis

A.Tehranchi
Associate professor, Dental research center, Research Institute of Dental Sciences, Dental school, Shahid Beheshti University of Medical Sciences, Tehran, Iran
H.Behnia
Professor of oral and maxillofacial surgery, Dentofacial Deformity Research Center, Research Institute of Dental Sciences, Dental school, Shahid Beheshti University of Medical Sciences, Tehran, Iran
S.Soheilifar
Postgraduate student of orthodontics, Orthodontics department, Dental school, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abstract:

Background and aim: Bilateral mandibular distraction osteogenesis (BMDO) has been suggested as a suitable method for correcting severe mandibular deficiencies. The purpose of this study was to evaluate the cephalometric changes of patients undergoing BMDO.

Materials and methods: Seven patients were selected for BMDO, all suffering from severe mandibular retrognathia as a result of previous trauma. Pre-treatment (T1), post-treatment (T2) and follow up (T3) cephalograms were obtained. The changes in skeletal and soft tissue parameters were assessed by paired t-test within two time intervals (T1-T2 and T2-T3). Results with a P value <0.05 were considered statistically significant.

Results: In patients treated by extra-oral distractor, BMDO improved jaw relationships by increasing SNB (12.1˚) and mandibular length (22.5mm) and decreasing ANB (10.3˚) and Wits (17.2mm). Lower facial height increased significantly (4.5mm). Dental relationships were changed by increasing interincisal angle (24.8˚) and decreasing IMPA (23.2˚) and overjet (8.8mm). Reduction in the distance between upper and lower lip to E-line led to changes in the soft tissue profile. Airway space analysis revealed an increase in the nasopharyngeal space (Nph2) (4.7 mm), the oropharyngeal space (Oph2) (5.4mm) and the posterior airway space (PAS) (9mm). The available cases remained stable during the follow up period.

Conclusion: BMDO improved maxillomandibular discrepancy by lengthening mandibular body. Lower anterior facial height was increased significantly. Lip prominency relative to the nose and the chin was decreased and dental relationships were corrected by the treatment. DO procedure significantly improves the pharyngeal spaces.

Keywords: distraction osteogenesis, retrognathia, cephalometry.

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Corresponder: S.Soheilifar
Orthodontics department, Faculty of Dentistry, Shahid Beheshti University of Medical Science, Daneshjou Boulevard, Evin, Tehran, Iran, P.O Box:19839
Email: se.soheilifar@gmail.com

INTRODUCTION

In 1950s, Ilozarov made Distraction Osteogenesis (DO) optimized for lengthening lower extremities[1]. McCarthy was the first person who applied *DO* for lengthening the human mandible.[2] Mandibular distraction may cause considerable gradual advancement of retrognathic mandible due to the formation of new bone between vascular surfaces of osteotomised bone segments and also, simultaneous expansion of the soft tissue envelop. Unlike conventional techniques of mandibular advancement, *DO* leads to little, though still possible, treatment relapse. Molina and Monasterio evaluated 106 cases from 3 months-3.5 years after *DO* and they observed no significant relapse in their treatment.[3] However, there are some reports regarding occurrence of relapse following *DO*. Huang et al observed some relapse in ramus lengthening, while mandibular body lengthening proved to be stable.[4] The lower recurrence rate is caused by soft tissue adaptation, which subsequently leads to lower complications such as nerve injuries, temporomandibular joint disorders and maxillofacial pains. Micrognathia, asymmetric mandible and severe class II malocclusions including patients suffering from sleep apnea are common indications of *DO*.[1]

DO procedure is accomplished by the help of devices called distractors. In contrast to extra-oral distractors, intra-oral devices are not capable of creating multidirectional forces, though being more esthetic and socially acceptable.[1, 5]

As a functional point of view, correction of occlusion during treatment is of great importance in *DO* procedure. Considering functional and esthetic requirements, all of the patients who undergo *DO* procedure need pre- and post-orthodontic treatment as well. In pre-surgical orthodontic phase, achieving maxillary arch expansion is of great importance since it decreases occlusal interferences during *DO* and also facilitates arch coordination in post-surgical orthodontics. [6, 7]

According to patients' view, successfulness of the treatment is highly influenced by symmetry of the face after treatment.[8] Controlling the mandible by multidirectional forces plays a crucial role in achieving symmetric face. In addition, effects of surgical cut directions should not to be overlooked.[9]

The purpose of this study was to assess skeletal and soft tissue changes of patient's undergoing bilateral mandibular distraction osteogenesis.

MATERIAL AND METHODS

This study was conducted according to the Declaration of Helsinki on medical protocol and ethics. Research and medical ethics committee of Shahid Beheshti University of Medical Sciences also approved the study protocol. Informed consent was signed by patients or their legally authorized representatives.

A total of 7 patients, 3 female and 4 male patients, with a mean age of 16 years and 8 months (range, 6-31 y), were selected for bilateral distraction osteogenesis of hypoplastic mandibles; all of them with the history of bilateral condylar ankylosis (4 patients with bony ankylosis and 3 with fibrous ankylosis). The samples had restrictive movement of mandible, airway obstruction accompanied by clinical sleep apnea, masticatory difficulties and unfavorable esthetic. Although 2 of the patients had growth potential, they were not able to protrude their mandibles due to condylar ankylosis, therefore growth modification was an impossible treatment modality. All of the patients needed considerable amount (more than 8 millimeters) of mandibular advancement. Bilateral *DO* of mandible was chosen to eliminate the potential of relapse rather than other conventional orthognathic surgery methods. One of the patients had undergone condylectomy and costocondral graft at the age of 10 but the grafted bones failed to develop normally and it was ended up in re-ankylosis with second unsuccessful condylectomy surgery.

Pre-distraction fixed orthodontic treatment was planned to eliminate all tooth prematurities and to achieve the acceptable arch coordination through adequate arch expansion.

Surgical insertion of *DO* appliances of patients were done under general anesthesia at Taleghani Hospital, by one surgical team. Bilateral distractors were placed extra-orally in 6 patients and intra-orally in one patient. Extra-oral distractors were all multidirectional allowing

the correction of vertical, antero-postrior and transverse problems simultaneously.

Precise direction and site of extra-oral incisions and osteotomies were designed according to the need for correcting mandibular dismorphology in three dimensions. Lateral cephalograms and facial photographs were used to predict the final achievable results. Considering ultimate position of tooth bearing regions, proper force vectors were determined and surgical cuts and distractor positions were planned. For intra-oral distractor, just an intra-oral incision was made over the distobuccal border of lower arch and the distractor was placed distal to the last tooth in mandibular arch, directly into the oral vestibulae. Postoperative antibiotic prescription included cephalexin (500 mg every 6h in adults and 25 mm/kg in children) for 1 week.

The latency period was assigned to be 1 week, and then, the distractors were activated two times a day (0.5mm each time).

The patients were monitored post surgically by the surgeon and orthodontist every other day in order to adjust the distractor and evaluate the amount of screw opening and elastic application to gain symmetric results. In all patients, including the one treated by intra-oral distractor, callus formation was individually directed by means of differential screw opening and inter-arch elastics. This caused a multidirectional control on skeletal morphology during *DO*. Growing patients were scheduled for minor overcorrection in order to compensate remaining growth of facial components.

Distractors were remained for 2-3 months after distraction period in order to provide enough time for bone maturation (consolidation period). Patients were instructed to mouth rinse with chlorhexidine mouthwash during distraction phase. After this period, distractors were removed through minor surgical procedure and all patients entered post-surgical orthodontic phase. In order to achieve more longitudinal data, patients records were recruited more than 1 year after surgery (range: 15-24 months). Lateral cephalometric radiographs were obtained before treatment (T1), after the consolidation period (T2), and after follow-up period (T3).

Lateral cephalometric images were analyzed by two researchers by means of Dolphin software Version 10.5. Interobserver reliability was quite high (from 0.689 for Nph1 to 0.997 for ANB with all except Nph1 above 0.75). Table I shows definition of parameters which have been used to evaluate changes.

Statistical analysis:

Cephalometric measurements (including angular and linear cephalometric variables) of patients treated by extra-oral distractors were taken and statistical analysis of paired T-test was used to assess treatment changes between T1-T2 and T2-T3 time intervals by SPSS software Version 16.0. P value was set at 0.05. Data obtained from the patient treated by intra-oral distractor reported separately.

RESULTS

DO treatment followed by post-surgical orthodontics lead to considerable changes in all patients' appearance. All of the patients mentioned improved breathing and mastication and all were satisfied with new facial appearance. 3 patients with extraoral distractor had follow up cephalograms.

Patients' treated by extra-oral distractors:

Figure 2 shows before and after treatment profiles of patients treated by extra-oral distractors.

Table II and III show the results of paired t-Test for T1-T2 and T2-T3cephalometric measurements, respectively.

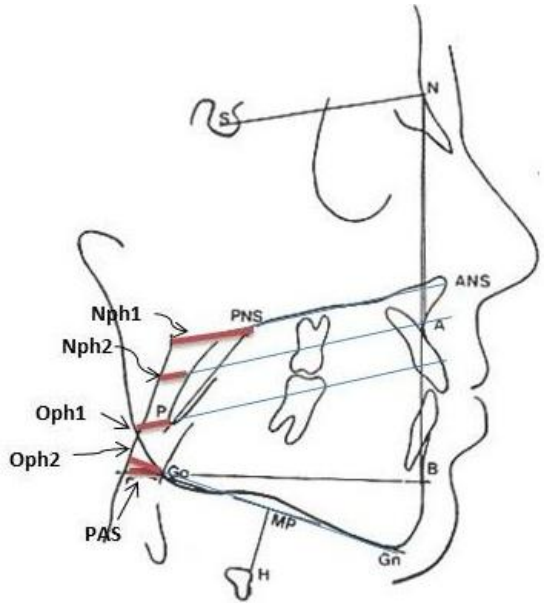


Figure 1: Illustration of method of airway analysis

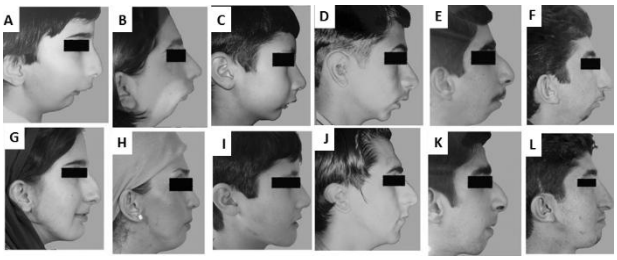


Figure 2: Profiles of patients treated by extra-oral distractor. A to F, profile views before treatment. G to L, profile views at the end of treatment.



Figure 3: Profile of the patient treated by intra-oral distractor. A, profile view before treatment. B, profile view after treatment

Maxillomandibular discrepancy:

As shown in table II, SNB angle increased (P value 0.001) and ANB angle (P value 0.004) and Wits appraisal (P value 0.009) decreased after treatment. These differences were all statistically significant. SNA angle increased during treatment; however, the difference was not statistically significant. *DO* procedure decreased maxillomandibular discrepancy.

During follow up period, SNA, SNB, ANB and Wits were decreased insignificantly. The results seem to be stable during this phase.

Mandibular dimensions:

According to cephalometric measurements, it is obvious that *DO* caused mandibular lengthening and the difference was statistically significant (P value 0.0001). Ramus height did not change significantly. *DO* caused an increase in mandibular total length from condilon to Gnathion.

During follow up period, there was a further increase in mandibular length and ramus length; however, the changes were not statistically significant.

Vertical proportion changes:

Lower facial height showed an increase after treatment and the difference was statistically significant (P value 0.026). However, Upper facial height did not change significantly. Posterior facial height to anterior facial height (Jaraback index) decreased after treatment, indicating an increase in posterior facial height or a decrease in anterior facial height. However, the difference was not statistically significant. Mandibular plane angle with palatal plane and SN plane were increased and decreased, respectively, with no statistically significant difference. Gonial angle, saddle angle and articular angle did not change significantly.

During follow up period, mandibular plane to SN, upper and lower facial height, Jaraback index, mandibular plane to palatal plane, gonial angle, saddle angle and articular angle did not change significantly.

Dental changes:

Angles between the lower incisors and mandibular plane (IMPA) (P value 0.031) and overjet (P value 0.012) decreased and interincisal angle (P value 0.02) increased after *DO*, which was statistically significant. U1 to SN angle and overbite decreased; however, these changes were not statistically significant.

No statistically significant changes were observed in dental occlusion in the follow up period (Table III).

Soft tissue changes:

The distance between upper and lower lip to E-line were both decreased significantly (P value 0.02), which may affect the ultimate facial convexity. However, the nasolabial angle did not show any significant change in this time interval.

Considering the follow up data, nasolabial angle, upper lip and lower lip to E line distances showed no significant changes (Table III).

Upper airway changes:

Cephalometric measurements show that oropharyngeal space along the line Men-Go (Oph2) (P value 0.044) and posterior airway space along B-Go line (PAS) (P value 0.046) increased significantly after treatment. Nasopharyngeal space at PNS level (Nph1) and oropharyngeal space at the level of soft palate tip (Oph1) increased insignificantly, however nasopharyngeal space along the thickest part of soft palate (Nph2) increased

significantly (P value 0.013). Airway space improvement was stable during follow up period.

Table I: cephalometric parameters being used in this study and method of measurements

Cephalometric parameter	Method of measurement
SNA	The angle between sella, Nasion and A point
SNB	The angle between sella, Nasion and B point
ANB	The angle between A point, Nasion and B point
Wits appraisal	Linear measurement between lines which pass A and B points and are perpendicular to functional occlusal plane.
Mandibular length	The distance from condylion to Gnathion
Ramus height	The distance from Articular to Gonion
Upper facial height	The distance from Nasion to anterior nasal spine (ANS)
Lower facial height	The distance from anterior nasal spine to Menton
Jaraback index	The ratio of posterior facial height (Sella to Gonion distance) to anterior facial height (Nasion to Menton distance)
Mandibular plane to palatal plane	The angle between mandibular plane (Gonion-Menton) to palatal plane (anterior nasal spine-posterior nasal spine line)
Mandibular plane to SN	The angle between mandibular plane (Gonion –Menton) to SN (Sella-Nasion)
Gonial angle	The angle between Articular, Gonion and Menton
Saddle angle	The angle between Nasion, Sella and Articular
Articular angle	The angle between Sella, Articular and Gonion
U1 to SN	The angle between the SN and long axis of maxillary incisor.
IMPA	The angle between mandibular plane (Gonion-Menton) and long axis of mandibular incisor.
Interincisal angle	The angle between long axis of upper and lower incisors.
Overjet	Horizontal distance between incisor edges of upper and lower incisors.
Overbite	Vertical distance between incisor edges of upper and lower incisors
Upper lip to E-line	Anteroposterior position of upper lip (labrale superius) relative to the Rickett's Esthetic line (from tip of nose to soft tissue Pogonion)
Lower lip to E-line	Anteroposterior position of lower lip (labrale inferius) relative to the Rickett's Esthetic line (from tip of nose to soft tissue Pogonion)
Nasolabial angle	The angle between the lines tangent to the base of the nose and tangent to upper lip
Nph1 [10]	Linear measurement between posterior nasal spine (PNS) and posterior pharyngeal line along a line parallel to ANS-PNS
Nph2 [10]	Linear measurement between posterior pharyngeal wall and posterior surface of the soft palate at the level of thickest part of soft palate along a line parallel to ANS- PNS.
Oph1 [10]	Linear measurement between posterior pharyngeal wall and tip of soft palate along a line parallel to ANS-PNS
Oph2 [10]	Linear measurement between tongue base and posterior pharyngeal wall along Gonion-Menton line
PAS [10]	Distance from tongue base to posterior pharyngeal wall along B-Gonion line

Table II: The effect of DO on cephalometric measurements from T1 to T2.

Classification	Cephalometric measurements	Mean before	Mean after	Mean difference T1-T2	P value
Maxillomandibular discrepancy	SNA (degree)	74.1±4.7	75.8±3.3	1.7±3.4	0.263
	SNB (degree)	61.2±6.6	73.3±6.8	12.1±3.2	0.001*
	ANB (degree)	12.87±4.3	2.5±4.2	-10.3±4.9	0.004*
	Wits appraisal (mm)	14.4±8.2	-2.9±8.7	-17.2±8.2	0.009*
Mandibular dimensions	Mandibular length (Co-Gn) (mm)	86.8±7.2	109.4±9.1	22.5±5.8	0.0001*
	Ramus height (Ar-Go) (mm)	37.2±6.8	36.5±5.5	-0.7±4.7	0.725
	Upper facial height (N-ANS) (mm)	56.2±5.8	57.5±4	1.2±2.7	0.325
Vertical proportion changes	Lower facial height (ANS-Men) (mm)	66.7±8.8	71.2±7.7	4.5±3.5	0.026*
	Jaraback Index (SGo-NMe)	57.6±9.8	53.5±7.7	-4.2±5.1	0.103
	Mandibular plane to palatal plane (degree)	34.7±10.6	33.3±9.7	-1.4±7.5	0.669
	Mandibular plane to SN (degree)	51±19.2	49.9±13.3	-1.2±11.8	0.818
	Gonial angle (degree)	140.2±12.6	139.7±14.1	-0.56±9.9	0.894
	Saddle angle (degree)	121.8±3.4	118±3.5	-3.8±4.7	0.106
	Articular angle (degree)	152.7±3.4	154.6±8.4	-1.9±4.6	0.362
Dental changes	Upper 1 to SN (degree)	98±6.7	99.8±.8	1.8±2.5	0.136
	IMPA (degree)	95.9±14.7	72.7±9	-23.2±19.1	0.031*
	Interincisal angle (degree)	109.8±21.1	134.6±17.8	24.8±18.1	0.02*
	Overjet (mm)	14.1±7.4	5.4±.3	-8.8±5.5	0.012*
	Overbite (mm)	0.6±4	0.9±1.7	0.2±3.6	0.874
Soft tissue changes	Upper lip to E line (mm)	4±1.1	-3.2±2.2	-7.3±2.8	0.02*
	Lower lip to E line (mm)	3.3±5.8	-0.8±4.3	-4.1±3	0.02*
	Nasolabial angle (degree)	95.2±16.3	94±14.5	-1.25±19.6	0.889
Upper airway changes	Nph1** (mm)	23.8±5.3	24.9±2.9	1.2±5.3	0.612
	Nph2** (mm)	11.8±3.9	16.5±1.4	4.7±3.1	0.013*
	Oph1** (mm)	12±3	13.8±2	1.8±3.9	0.309
	Oph2** (mm)	8.6±2.9	14±2.9	5.4±4.9	0.044*
	PAS** (mm)	7.6±3.7	16.7±7.1	9±8.4	0.046*

*Statistically significant
**Refer to Figure 1 for illustration.

Table III: The effect of DO on cephalometric measurements from T2 to T3

Classification	Cephalometric measurements	Mean after	Mean follow up	Mean difference T2-T3	P value
Maxillomandibular discrepancy	SNA (degree)	76.1±2.1	75±2.3	-1.1±3.9	0.668
	SNB (degree)	71.6±2	69.9±2.4	-1.7±1.6	0.216
	ANB (degree)	4.5±2	5±1.1	0.53±2.8	0.73
	Wits appraisal (mm)	4.3±4	3.6±2.3	-0.7±1.8	0.656
Mandibular dimensions	Mandibular length (Co-Gn) (mm)	105±11.1	112.8±10.5	7.8±3.4	0.059
	Ramus height (Ar-Go) (mm)	37.6±2.3	39.1±5	1.5±3.3	0.508
	Upper facial height (N-ANS) (mm)	58.5±.5	62.4±5.1	3.9±1.3	0.169
Vertical proportion changes	Lower facial height (ANS-Men) (mm)	72.8±8.9	70.6±5	-2.2±4.2	0.453
	Jaraback Index (SGo-NMe)	52.2±0.9	51±3.2	-1.2±3.4	0.591
	Mandibular plane to palatal plane (degree)	33.4±11.2	38.9±12.5	5.5±6.2	0.269
	Mandibular plane to SN (degree)	51.5±11.8	56.2±9	4.7±3	0.112
	Gonial angle (degree)	156.7±4.7	145.9±11.9	-9.1±5	0.088
	Saddle angle (degree)	119±7	123.2±8.1	4.3±8.4	0.470
	Articular angle (degree)	136.8±16.2	147.1±10.7	9.6±7.3	0.15
Dental changes	Upper 1 to SN (degree)	101.8±1.6	97±3.9	-4.8±2.3	0.067
	IMPA (degree)	73.9±11.7	79.8±15.2	5.9±16.7	0.605
	Interincisal angle (degree)	131.5±18.5	127.3±11.6	-4.3±16.3	0.695
	Overjet (mm)	7.3±6	4±1.7	-3.3±5.1	0.382
	Overbite (mm)	1.4±2.4	2.3±0.6	0.9±2.7	0.599
Soft tissue changes	Upper lip to E line (mm)	-2.1±2.6	-4.2±2.8	-2.1±1.2	0.098
	Lower lip to E line (mm)	1.4±5.4	-0.8±1.8	-2.2±4	0.434
	Nasolabial angle (degree)	86.3±11.7	79.6±10	-6.7±13	0.469
Upper airway changes	Nph1**(mm)	24.7±1.4	25.1±2.8	0.4±1.8	0.733
	Nph2** (mm)	16.1±1.3	16±3.1	-0.33±1.8	0.978
	Oph1** (mm)	14.4±2.9	12.8±2	-1.7±3.6	0.502
	Oph2 ** (mm)	15.2±2.8	18.4±4.5	3.3±2	0.110
	PAS** (mm)	18.3±19.1	15.8±4.4	-2.5±6.1	0.547

*Statistically significant

**Refer to figure 1 for illustration

Table IV: Cephalometric changes in the patient treated by intra-oral distractor

Classification	Cephalometric measurements	Before	After	Difference
Maxillomandibular discrepancy	SNA (degree)	74.2	75	0.8
	SNB (degree)	66.3	69.4	3.1
	ANB (degree)	7.9	3.9	-4
	Wits appraisal (mm)	10.7	1.6	-9.1
Mandibular dimension	Mandibular length (Co-Gn) (mm)	109	119	10
	Ramus height (Ar-Go) (mm)	38.1	40.2	2.1
Vertical proportion changes	Upper facial height (N-ANS) (mm)	54.7	54.4	-0.3
	Lower facial height (ANS-Men) (mm)	66	69.3	3.3
	Jaraback Index (SGo-NMe)	60.8	58.6	-2.2
	Mandibular plane to palatal plane (degree)	24.3	28.2	3.9
	Mandibular plane to SN (degree)	39.7	42.9	3.2
	Gonial angle (degree)	131.1	138.2	7.1
	Saddle angle (degree)	131.6	129.7	-1.9
	Articular angle (degree)	139.4	128.5	-10.9
Dental changes	Upper 1 to SN (degree)	98	83.6	-14.4
	IMPA (degree)	88.3	84	-4.3
	Interincisal angle (degree)	129.5	140.7	11.2
	Overjet (mm)	15.9	2.3	-13.6
	Overbite (mm)	6.8	2.4	-4.4
Soft tissue changes	Upper lip to E line (mm)	2.5	-3.5	-6
	Lower lip to E line (mm)	-2.5	-5.9	-3.4
	Nasolabial angle (degree)	109	90.5	-18.5
Upper airway changes	Nph1* (mm)	20.7	32	11.3
	Nph2* (mm)	16.8	23	6.2
	Oph1* (mm)	25.6	23	-2.6
	Oph2* (mm)	17.7	33.3	15.6
	PAS* (mm)	16.8	35.8	19

Patient treated by intra-oral distractor:

Figure 3 shows before and after treatment profile of the patient treated by intra-oral distractor.

Table IV shows cephalometric measurements for the patient treated by intra-oral distractor. As it is shown in the table IV, sagittal discrepancy did decrease after *DO*. Considering the mean values of cephalometric measurements at T1, it appears that the severity of the mandibular deficiency was less remarkable compared with other 6 patients with extraoral distractors.

Anterior lower facial height increased after treatment. Gonial angle increased by 6.1 degrees. The intra-oral distractor led to dental changes similar to extra-oral distractor. Pharyngeal airway show an increase in area, as determined by increased Nph1, Nph2, Oph2, PAS. However, Oph1 showed a slight decrease in amount.

DISCUSSION

Short term results:

The results indicated that lengthening of the mandible was highly attributable to the increase in mandibular body length. This is mainly because of the orientation of surgical cuts and use of multidirectional distractors in order to cause horizontal elongation of the mandible. Although these patients did not need lengthening of the ramus, this change in mandibular size is possible since it has been shown that, in contrast to conventional methods, increasing ramus height via *DO* can be stable due to adaptation of pterygomasseteric sling.[11] El-Bialy et al reported increase in total mandibular length (5.9 mm), and corpus length (4.5 mm) with a tooth borne distractor.[12] Dolanmaz et al observed 14.5 mm increase in mandibular body length.[11] It seems that *DO* effect on correcting maxillomandibular discrepancy is definite, however absolute amounts of correction is not comparable between the articles, because of the fact that the patients' initial skeletal features were not comparable and also other distinct methodological differences between different articles.

Regarding vertical dimension changes, although absolute vertical dimensions increased after treatment, vertical proportions did not changed significantly. In a computer model, Samchukov et al showed that distractors which are placed parallel to the inferior border of the mandible lead to an increase in lower anterior facial height.[13] Considering the three dimensional shape of the mandible, it seems obvious that lengthening of the mandible mainly by increasing mandibular body length would increase lower anterior facial height. El Bialy et al reported an increase in lower anterior facial height in patients treated by tooth borne bilateral distractors, which was attributed to increase in anterior and posterior dental height.[12] In addition, they found a strong correlation between changes of anterior total facial height and changes in 4 other skeletal measurements including mandibular body length, mandibular total length, and the angle between mandibular plane and Frankfort horizontal line.[12]

El-Bialy et al [12], Hamada et al [14] and Gonzalez et al [15], all of them utilizing intra-oral distractors, reported increase in mandibular plane angle. In addition, Vendittelli et al observed that in cases with horizontal vector of distraction, there is a tendency to clockwise rotation of the mandible and creation of anterior open bite, while a vertical vector can lead to counterclockwise rotation of the mandible and closure of the anterior open bite.[16] Interestingly, we observed that, in the patient treated by intra-oral distractor, an increase in mandibular plane and a decrease in overbite (but not actual open bite) occurred during *DO*. In patients treated by extra-oral distractor the opposite was seen, although the changes were not statistically significant. This proves the importance of vector control during *DO*.

Available data regarding the effect of *DO* on gonial angle were so controversial. Dolanmaz et al assessed the changes in gonial angle in 2 patients treated with unilateral distraction osteogenesis. Although both patients had undergone oblique osteotomies, one of them had an increase in gonial angle, while the other one had a decrease in the so called angle.[11] Helmy et al evaluated this issue in sheep. They compared horizontal and oblique vectors and observed a large variability in gonial angle changes which made it impossible to determine the definite effect of *DO* on gonial angle.[17] It seems that multiple factors, other than vector direction, control the gonial angle. One explanation can be the orientation and position of the osteotomy relative to the masseteric muscle.

During treatment, IMPA and the angle between upper incisor and SN decreased and subsequently inter-incisal angle increased. Changes in IMPA were statistically

significant while upper incisor angle decreased insignificantly. These outcomes reflex the de-compensations which were done during pre-surgical orthodontics. In contrast to our study, El Bialy et al observed an increase in IMPA immediately after tooth-borne *DO*.[12] This difference may be due to the forces applied by tooth borne distractor to teeth, while in our study the forces where applied directly to bone segments. In our patients, overjet decreased significantly during treatment (8.8 mm). Mean difference of this parameter was calculated according to pre-treatment (initial) and post-treatment cephalograms. Since a significant decrease in IMPA observed during orthodontic de-compensation of teeth, actual increase in overjet is probably more. Overbite decreased insignificantly. Breuning et al observed that opening of the bite during mandibular lengthening by intra-oral distractors is a common outcome. They explained some factors which may cause anterior bite opening, including vector control, musculature effect, tongue contribution and occlusal interferences.[18] As Peltomaki et al described, by use of inter-maxillary elastic during active distraction period, mandibular plane angle would decrease and bite opening would be avoided.[19] It seems logical that by the use of extra-oral distractors and good control of the vectors, it is possible to decrease the amount of bite opening.

The distance between upper and lower lip to E-line decreased significantly, that means both lips were placed behind the E-line after treatment. This may be due to the increase in chin prominence during treatment which moves E-line anteriorly. In addition, in growing patients nose growth would have been occurred too, which in turn may change the line position geometrically. Furthermore, as El Bialy et al reported, there is a strong correlation between IMPA and lower lip to E-line distance. This implies that decreasing incisor pro-inclination would reduce lip protrusion relative to nose and chin. Our results are similar to those of El Bialy in case of the reduction in lower lip distance to E-line.[12] Nasolabial angle decreased insignificantly during treatment which may reflex the insignificant decrease in the pro-inclination of upper incisors.

Airway analysis revealed that linear distance between posterior pharyngeal wall and PNS (Nph1) increased insignificantly. This can be justified by the fact that no skeletal change was occurred in midfacial region. In contrast, the distance between posterior pharyngeal wall and thickest part of the soft palate (Nph2) increased significantly. This result is consistent with the results observed by Battagel et al [20] and Liu et al [21] which have used mandibular advancement splint and repositioner, respectively. Battagel et al reported that this effect is seen unless the soft palate is thick.[20] Achilleos et al reported a more upright position of soft palate after surgical mandibular advancement, nevertheless they reported that this change was transient.[22] In addition, Robertson observed a reduction in length and thickness of the soft palate after mandibular advancement[23], and Liu et al showed that cross sectional area of the soft palate was decreased after the use of mandibular repositioner[21]. The increase in Nph2 may be attributed to more upright position of the soft palate and reduction in soft palate thickness. The distance between posterior pharyngeal wall and soft palate tip increased insignificantly. When considering the report of Achilleos[22], this result seems controversial, since more upright position of the soft palate would increase Oph1 too. This may be explained by the fact suggested by Robertson: soft palate length would decrease after mandibular advancement.[23] This means that *before* and *after* treatment calculations were done along different levels and assessing this parameter would be misleading. Linear measurements between posterior pharyngeal wall and tongue base along Men-Go line (Oph1) and B-Go line (PAS) proved an increase in post-tongue pharyngeal space. This would be directly due to mandibular advancement which can place the mandible, tongue and subglossal muscles more anteriorly and thus can increase airway space.

Long term results:

Long term results of El-Bialy study on relapse rate of bilateral tooth borne distractors, showed no significant changes in sagittal position of mandible, mandibular total length, and IMPA between debonding appointment and follow up period of 8 years[12]; which is in agreement with the result of the current study in this regard.

In our study, dental occlusion was stable during post-*DO* follow up period and none of the patients came up with subsequent anterior open bite. These results are not similar to that of Breuning's, as they observed that 44% of their patients experienced recurrence of anterior open bite at follow up.[18] The underlying reason as they have stated, is that open bite was mostly treated during post-

DO orthodontic phase primarily by tooth extrusion; which is an unstable orthodontic movement in nature. However, we controlled bite opening during distraction phase mainly by clinical adjustment of callus formation.

Comparing intra-oral and extra-oral distractors:

It has been stated previously that extra-oral distractors are preferable for multidirectional distraction osteogenesis.[24] However, in the case treated by intra-oral distractor, we were able to achieve proper facial appearance and dental occlusion. It is obvious that although vector control is facilitated by multidirectional distractor, they are not the only mean. Precise clinical evaluation and good coordination between surgeon and orthodontist are the key factors for success.

Finally, it is worth saying that all of these patients had limitation in mouth opening, which affects their ability to maintain their oral hygiene. In addition, some of them need tooth extraction for pre-surgical orthodontics in order to do de-compensations. Furthermore, difficulty of creating planned osteotomies and placing distractors in hypoplastic mandible inevitably caused to some extractions during surgical phase.

CONCLUSIONS

DO improved maxillomandibular discrepancy by lengthening the mandibular body. Lower anterior facial height increased significantly. Dental relationships were improved by reduction in incisor pro-inclination, overjet and overbite. Distance between both lips and E-line increased while nasolabial angle remain constant. Posterior pharyngeal space increased, which may have reduced patients' respiratory problem. The results were stable during post distraction follow up period.

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