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PHARYNGEAL AIRWAY CHANGES FOLLOWING SYMPHYSEAL DISTRACTION OSTEOGENESIS

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ABSTRACT

Introduction: The aim of this study was to analyze the effects of mandibular symphyseal distraction osteogenesis (MSDO) on the pharyngeal airway dimensions in a group of adult patients.

Subjects and Methods: The sample consisted of digital lateral cephalograms of 10 patients (7 females and 3 males) with a mean age of 21.0± 2.5 years. Radiographs were taken before start of distraction (T1) and following distraction (T2) (12.5 days ± 2.3 days after surgery). Symphyseal distraction was done using a bone-borne distractor. The mean value of mandibular symphyseal distraction was 8.4±1.7mm. Digital lateral cephalometric tracing was done to evaluate airway changes following symphyseal distraction.

Results: Digital lateral cephalometric analysis revealed no statistically significant changes in nasopharyngeal airway (0.3± 0.1mm) (P>0.05). There were statistically significant changes in oropharyngeal and hypopharyngeal airway widths (1.2±0.3mm) and (0.7±0.4mm) respectively (P<0.01). Hyoid bone position showed insignificant changes for the value Walker P-H (-1.1±0.2mm) and H-RGN (-0.9±0.4mm)(P>0.05) while statistically significant decrease were evident for the vertical measurement H-C3RGN (-1.2±0.2mm) (P<0.01).

Conclusions: The results propose that MSDO significantly affects the lower pharyngeal airway dimensions but has no effect on the upper pharyngeal airway measurements. No significant effects on hyoid bone position were observed except mild decrease of its vertical measurement to reference planes. The normal reflex mechanisms that conserve the patency of the airway may have negated any potential changes in the hyoid bone position.

KEY WORDS: Airway changes, mandibular symphyseal distraction, midsymphyseal distraction osteogenesis, transverse mandibular deficiency.

INTRODUCTION

Distraction osteogenesis (DO) is a method of generating new bone following a corticotomy or an osteotomy and incremental traction with gradual separation of the bony segments **(Illizarov, 1989).** The distraction gap then gets filled with newly formed bone **(Peltonen et al, 1992; Sproul and Price, 1992 and Windhager et al, 1995)**.

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The tension-stress principle advocated by the russian orthopedic surgeon Illizarov in the 1960s is the foundation of this mechanism. This technique was especially useful in limb lengthening and elongation of long bones. Its applications also involve craniofacial reconstruction **(Snyder and Levine, 1973)** such as lengthening of the mandible in patients with hemifacial microsomia **(Havlik and Bartlett, 1994).**

Widening of the mandible by rapid surgical expansion to correct transverse deficiencies of the mandible has been originated by **Guerrero, 1990** and later implemented by **Santo et al, 2000** who utilyzed symphyseal tooth- and bone-borne distractors to successfully treat transverse deficiencies instead of orthognathic surgery. This is advantageous as it avoids the need for dental extractions and/or jeopardized periodontal or functional complications **(Constanti et al, 2001).**

Different types of distractors can be used for symphyseal distraction: bone-borne, tooth-borne or hybrid appliance **(Iseri & Malkoc, 2005; Alkan et al, 2007; Boccaccio et al, 2011 and de Gijt et al, 2012).** Each has its own benefits and limitations. Mechanically, bone-borne distractors provide the best results as the forces are transmitted directly to the bone and result in parallel basal mandibular bone widening and stable results **(Alkan et al, 2007; Raoul et al, 2009 and Garreau et al, 2015).** Drawbacks include high cost and need of an invasive operation for placement and removal of the distractor. On the other hand, tooth-borne and hybrid distractors are less invasive and cheaper, but do not yield pure skeletal results. They mostly yield larger dentoalveolar expansion with dental tipping **(Alkan et al, 2007; Niculescu et al, 2014 and Nadjmi et al, 2015).**

Airway parameters might be easily altered as a consequence of separation of the two mandibular halves. The hyoid bone is an important structure sustained by muscles and ligaments and acts as a functional interface between structures of the mandible, larynx, cranium as well as the airway passages confined by these structures. Therefore, due to closeness of the hyoid bone to the pharyngeal airway, any changes in its position due to orthodontic or surgical treatment can have significant functional effects **(Graber 1978).**

Past studies revealed that changes in mandibular position also alter the position of the hyoid bone **(Takagi et al, 1967 and Fromm & Lundberg, 1970).** The hyoid bone adapts to changes in the head and cervical posture. Previous studies stated that the relationship between the hyoid bone and cervical structures is more stable than the one with the mandible and the cranium **(Bibby and Preston, 1981).**

The hyoid bone is connected to the pharynx, mandible, and cranium through muscles and ligaments. It is the only bone of the body that has no bony articulations. The hyoid bone and its connecting muscles are also part of the oropharyngeal complex **(Biby and Preston, 1981).** The separation of the two mandibular halves can alter the pharyngeal airway dimensions as well as tongue and positions of the hyoid bone. The hyoid bone position is relatively constant within the individual throughout growth periods. It tends to preserve its relative position to the mandible from the age of three years **(Durzo and Brodie, 1962).** The position and function of the hyoid bone in response to orthodontic, orthopedic and orthognathic procedures has been previously studied by several authors. For example in surgical correction of mandibular prognathism, mandibular setback resulted in changes in hyoid bone position which moved inferiorly and posteriorly **(Takagi et al, 1967; Wolk, 1969 and Fromm & Lundberg, 1970).** Moreover, the distance between the posterior border of the mandibular symphysis and the body of the hyoid bone decreased. However, the distance between the hyoid bone and the vertebral column showed minimal changes. This led to the hypothesis that certain physiologic mechanisms exist which prevent impingement upon the pharyngeal airway.

Inspite of the presence of many reports in the literature investigating the effects of MSDO skeletally and dentally **(Santo et al, 2000),** no studies on the effects of symphyseal distraction on pharyngeal airway dimensions are available. Hence, this study was conducted to evaluate the effects of MSDO on the pharyngeal airway dimensions

SUBJECTS AND METHODS

This study was performed by analyzing the lateral cephalometric radiographs of 10 patients (7 females and 3 males) who underwent mandibular symphyseal distraction osteogenesis with a mean age 21.0+- 2.5 years obtained at T1(before start of distraction) and at T2 (after symphyseal distraction). Patients included in the study had the following criteria: **(Figure 1)**

- V-shaped mandible with severe mandibular arch crowding a minimum of 10 mm and well aligned upper teeth combined with unilateral or bilateral posterior scissorbite
- Full orthodontic records especially lateral cephalometric radiographs taken in habitual occlusion after the patient had swallowed (to avoid functional alteration of hyoid bone position)
- No periodontal diseases or TMJ disorder
- No previous orthodontic treatment
- No respiratory problems or nasal obstructions
- No past surgeries such as tonsillectomy for both groups
- No syndromes, systemic illnesses, dental anomalies

Orthodontic records included photographs, study models and radiographs (digital panorama and lateral cephalometric radiographs).

Fixed orthodontic appliances were inserted in the lower arch followed by the upper arch (preadjusted appliances, Roth 0.022 x 0.028 inches) (Ormco, West Collins, Ca-USA). Root divergence (at least 3 mm) of the lower central and lateral incisor brackets was done by inclining the brackets angulations distally or placing a V-bend in the wire. Periapical radiographs were used to detect the root approximation of the lower central and lateral incisors to decide on the most suitable site for the interdental osteotomy depending on the presence of adequate bone.

The symphyseal distraction carried out for the patients was performed with a bone-borne distractor (Rotterdam Midline Distractor, Kls Martin, Germany) **(Figure 2)** using the modified technique previously described by **Guerrero et al, 1997.** All distractors had a range of 15mm. Activation started after a latency period of 7 days following the surgery. It was done at a rate of 0.25mm expansion per 90 degrees turn for a total of 1mm/day **(Del Santo et al, 2000; Malkoc et al, 2006; Alkan et al, 2007 and Gunbay et al, 2009).** The activations were done twice a day, once in the morning and once in the evening, 2 turns per each activation. The total amount of distraction required was determined based on the amount of space needed to relieve the crowding and correct the transverse discrepancy of the maxillomandibular relationship. The surgical operation was performed by the same oral surgeon.

Lateral cephalometric landmarks and measurements for assessment of the pharyngeal airway and hyoid bone position were as follows: **(Figure 3)**

UPW- upper pharyngeal wall: Intersection of the line Ptm-Ba with posterior pharyngeal wall

MPW- middle pharyngeal wall: Intersection of perpendicular line on Ptm perpendicular from “U” with posterior pharyngeal wall.

LPW- lower pharyngeal wall: Intersection of perpendicular line on Ptm perpendicular from “V” with posterior pharyngeal wall.

The airway widths were measured as follows:

Nasopharyngeal airway width (NAW): The linear distance between Ptm and UPW.

Oropharyngeal airway width (OAW): The linear distance between U and MPW.

Hypopharyngeal airway width (HAW): The linear distance between V and LPW

Landmarks for hyoid bone measurements were as follows:

H: most prominent point on the body of the hyoid bone

C3: third cervical vertebra

RNG: Retrognathion or the most prominent point of mandibular symphyseal posterior border

Walker point: the most prominent point on the anterior bony outline of sella turcica

Fig. (1) Showing pretreatment intraoral photos of a patient with bilateral posterior scissorbite

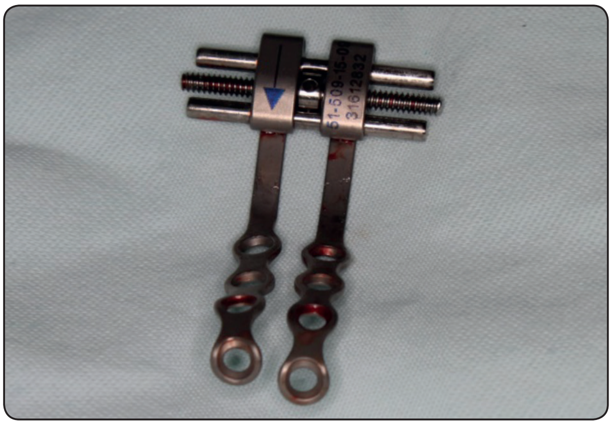

Fig. (2) Rotterdam midline distractor

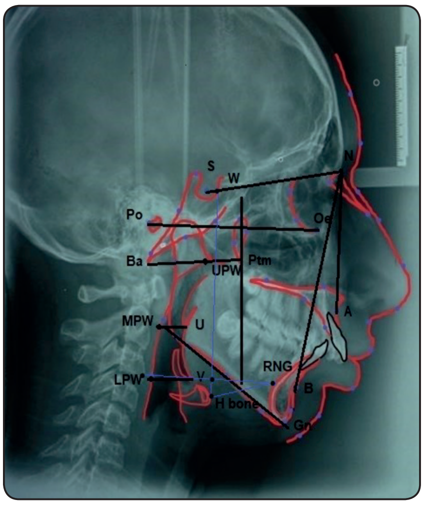

Fig. (3) Showing pretreatment digital lateral cephalometric xray with reference planes and landmarks for the pharyngeal airway and hyoid bone measurements:

Ptm: pterygomaxillary fissure; Ptm vertical: a vertical line passing through Ptm perpendicular to Frankfurt horizontal; Ba: Basion; U: Uvula; V: Vallecula; UPW: Upper pharyngeal width and is formed by intersection of the line Ptm-Basion with posterior pharyngeal wall perpendicular on Ptm vertical; MPW: Middle pharyngeal width which is the horizontal distance between the Uvula and intersection with the posterior pharyngeal wall perpendicular to Ptm vertical; LPW: Lower pharyngeal width which is the horizontal distance between the Vallecula and the intersection with the posterior pharyngeal wall perpendicular to Ptm vertical; Walker P-H (mm), the vertical distance of the hyoid bone to the Walker point; H-C3RGN(mm): the vertical distance of the hyoid bone to the line connecting points C3 (third cervical vertebrae) and retrognathion (the most prominent point of mandibular symphyseal posterior border; H-RGN(mm): the horizontal distance from the hyoid bone to retrognathion.

Statistical Methods:

All Data were collected, tabulated and subjected to statistical analysis. Statistical analysis was performed by SPSS in general (version 17), while Microsoft office Excel was used for data handling and graphical presentation.

Fig. (4) Showing the surgical osteotomy procedure for placement of the distractor

Quantitative variables were described by the Mean, Standard Deviation (SD), the Range (Minimum – Maximum), Standard Error (SE) and 95% confidence interval of the mean.

Qualitative categorical variables were described by proportions and Percentages.

Shapiro-Wilk test of normality was used to test normality hypothesis of all quantitative variables for further choice of appropriate parametric and non parametric tests. Mostly the variables were found normally distributed allowing the use of parametric tests. Paired samples t test was used for comparing the Post and Pre within the study group.

Significance level was considered at P < 0.05 (S); while for P < 0.01 was considered highly significant (HS). Two Tailed tests were assumed throughout the analysis for all statistical tests.

RESULTS

A good clinical outcome was obtained in all subjects. Distraction was successful and the required amount of expansion was achieved with a mean bony distraction value of (10.43mm). The distraction gap was symmetric (Figure 5). Widening of the lower arch was evident and elimination of the arch length discrepancy without the need for dental extraction was obtained (Figure 6). A good occlusal outcome was obtained and proper interdigitation was achieved with elimination of the posterior scissorbite. Overjet and overbite were significantly improved with a reduction of the overjet from 10mm to 5 mm and correction of the overbite to around 30% were attained.

As shown in Table 1, regarding airway measurements, no statistically significant differences were observed for nasopharyngeal or upper pharyngeal airway dimensions (UPW) (0.3± 0.1 mm) (P>0.05). Statistically significant increases were recorded for both oropharyngeal or middle pharyngeal airway (MPW) (1.2±0.3mm) (P<0.01) and hypopharyngeal airway or lower pharyngeal airway (LPW) (0.7±0.4mm) (P<0.01).

Regarding hyoid bone measurements, statistically insignificant changes were recorded for the vertical measurement (Walker P-H) (1.2±0.2mm) (P>0.05) and horizontal distance between hyoid bone and retrognathion (H-RGN) (-1.9±0.4mm), whereas statistically significant decrease was recorded for the vertical distance between the hyoid bone and a horizontal line joining cervical vertebra 3 and retrognathion (H-C3RGN) (-1.2±0.2mm).

Table (1) Pharyngeal airway and hyoid bone measurements at T1 and T2 showing mean changes and level of significance

Pharyngeal airway and Hyoid bone measurements (mm)	T1		T2		Mean changes	P-Value
	Mean	SD	Mean	SD		
UPW	14.2	5.4	14.5	5.7	0.3± 0.1	NS
MPW	9.3	3.2	10.5	3.1	1.2±0.3	0.005*
LPW	9.6	3.1	10.3	3.0	0.7±0.4	0.003*
Walker P-H	109.8	11.8	108.8	12.5	-1.1±0.2	NS
H-C3RGN	14.3	5.4	13.1	6.5	-1.2±0.2	0.007*
H-RGN	38.6	6.5	37.7	5.9	-0.9±0.4	NS

P>0.05 (NS) , * P< 0.05, ** P<0.01

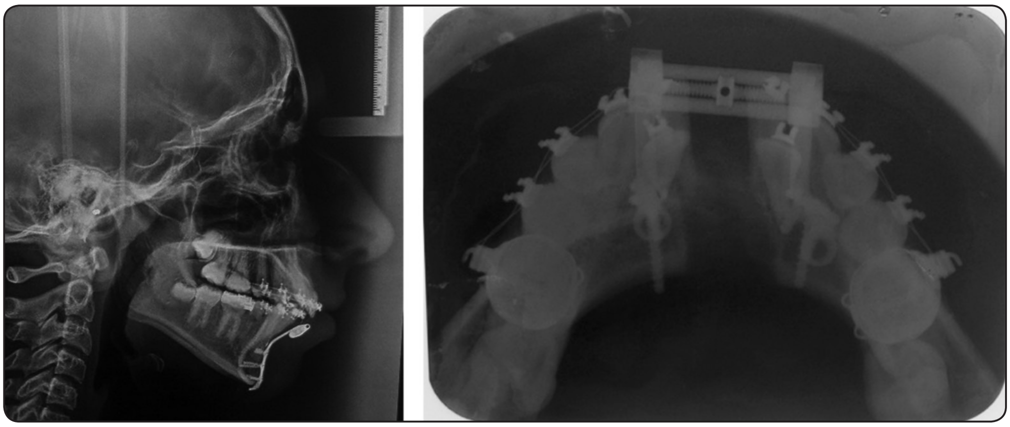

Fig. (5) Lateral cephalometric radiograph and occlusal radiograph at the end of distraction

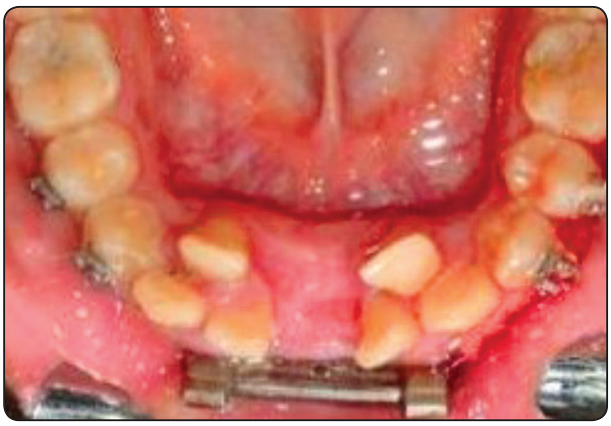

Fig. (6) Clinical photograph showing the lower diastema at the end of distraction

DISCUSSION

Minor transverse mandibular discrepancies are corrected by orthodontic dental arch expansion, extraction or interproximal dental stripping, whereby severe mandibular transverse discrepancies entail surgical intervention due to the early synostosis of the mandibular midline suture **(Little, 1990, Housley et al, 2003 and de Gijt et al, 2012).** Surgical transverse mandibular widening with lateral rotation of the two mandibular halves and grafting is predictable for treatment of moderate discrepancies. Nonetheless, it is contraindicated in cases with severe transverse mandibular discrepancies due to high risk of periodontal complications and relapse tendency **(Conley & Legan, 2003 and Alkan et al, 2007).**

It is a well-known fact that orthopedic mandibular expansion is impossible due to the very premature synostosis of the mandibular midline suture. Orthodontists are therefore challenged with two options: orthodontic expansion but this carries a periodontal risk or undergoing other means of space gaining by extraction or interdental stripping. Mandibular symphyseal distraction provides a different prospect in that the discrepancy can be corrected by simultaneously expanding both the dentoalveolar and the basal bone levels. An intentional surgical bone fracture is made after which progressive traction of the two mandibular halves is initiated. This provides mechanical stimulation for new bone formation. This new bone formation leads to successful increase of the inter-canine width with no risk of relapse **(Pascon et al, 2016).**

The hyoid bone forms the anterior limit of the pharyngeal airway space. Thus, the position of hyoid bone and position of tongue can be considered determinants of pharyngeal airway space.

The hyoid bone is attached by the suprahyoid and infrahyoid muscles to the mandibular, cranial and laryngeal structures. Its location is in close proximity to the pharyngeal airways. Moreover, it adapts its position under natural circumstances to accommodate alterations in head posture and cervical spine inclination and thus inflicts vital physiologic consequences. Therefore, a good understanding of the elements affecting its position is fundamental in perceiving the effects of orthognathic surgical mandibular procedures, orthopedic treatment as well as influences on obstructive sleep apnea **(Graber 1978).**

To our knowledge, no previous studies have investigated the effects of mandibular symphyseal distraction osteogenesis persee on the pharyngeal airway dimensions except one by **Malkoc et al, 2007** who evaluated the combined effects of MSDO and rapid palatal expansion (RPE) in patients with constricted maxillary and mandibular arches. Their results showed that MSDO causes small changes in the pharyngeal airway measurements or the hyoid bone position in adult patients.

The sample in this study included 10 patients with a mean age of 21.0 years (range, 15.5-25.7 years); consequently, no significant growth changes were anticipated. Lateral cephalometric radiographs have repeatedly been used for evaluating dentofacial structures as well as the pharyngeal airway with considerable accuracy and reproducibility **(Lowe et al, 1986; Bacon et al, 1988 and Malkoc et al, 2005).** Therefore, they were used in this study as a means of evaluation of the airway structural changes that follow symphyseal distraction osteogenesis.

Airway changes were measured according to the method previously described by **Jena et al, 2012** to quantify changes in the nasopharyngeal, oropharyngeal and hypopharyngeal airways. No consideration was given for measuring the distance between the hyoid bone and the vertebral column as any slight variation in patient's posture could change the vertebral position and hence result in significant error. Therefore, this measurement would be regarded as unreliable.

As previously reported in past studies **(Wolk, 1969),** with posterior mandibular movements the hyoid apparatus moves inferiorly but is stable anteroposteriorly. Therefore the functional integrity of the airway is maintained through morphologic adaptation. The vertical position of the hyoid bone was evaluated relative to Walker point and not the mandibular plane as any changes in the mandibular plane angle due to treatment would falsely affect this measurement.

According to the results of this study, there were statistically significant differences in lower pharyngeal airway measurements between T1 and T2. The changes were small but clinically significant. This can be attributed to the fact that transverse mandibular expansion produces an increase in the oral capacity to create more space for the forward movement of the tongue and thus releases the pharynx. Mandibular advancement in itself, excluding any transverse expansion, results in an increase in pharyngeal airway and modification of its shape **(Brown et al, 2013).** Therefore symphyseal distraction osteogenesis results in betterment of the posture of the tongue. This suggests that MSDO could be an efficient treatment modality for patients with obstructive sleep apnea (OSA). This is in agreement with the results of Bianchi et al, 2016 who used maxillomandibular transverse osteodistraction (MMTOD) for patients with OSA. Very few reports exist in the literature regarding the effectiveness of MMTOD in the management of OSA **(Guilleminaut & Li, 2004 and Conley & Legan, 2006)**. However, the results of **Malkoc et al, 2007** are in disagreement with ours since they concluded that MSDO does not significantly affect the pharyngeal airway dimensions due to a counteractive natural reflex mechanism that maintains the patency of the airway. In this study, there were insignificant changes of the hyoid bone position with the exception of a decrease in the vertical distance of the body of the hyoid bone to the line between the third cervical vertebra and retrognathion. However, this decrease is believed to be a reaction to the slight posterior mandibular body rotation that occurs with symphyseal distraction and not due to actual elevation of the hyoid bone **(Iseri & Malkoc, 2005 and Malkoc et al, 2006)**.

The tensionon the hyoid bone due to muscular stretching is thought to be counteracted by another technique to maintain the stability of its position.

CONCLUSIONS

MSDO is an effective technique to correct transverse mandibular deficiency and resolve dental crowding without the need for extraction. It is a procedure that also improves esthetics and provides good stability without adverse side effects. It positively influences the lower pharyngeal airway and results in increased airway patency which could be used to improve the symptoms for patients with obstructive sleep apnea. However, it has no influence on the hyoid bone position.

RECOMMENDATIONS

Future studies including more subjects and evaluating the effects of MSDO on the long-term should be carried out.

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