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Changes of the Posterior Airway Space Following Orthognathic Surgery in Class III

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Abstract

Objective: Adaptation of the pharyngeal airway space does occur after different surgical strategies of class III patients including mandibular setback, maxillary advancement and bimaxillary surgery. The aim of this study is to conduct a detailed cephalometric evaluation of the alterations taking place in the morphology of the pharyngeal airway space after treatment of class III skeletal deformity via different surgical procedures (i.e. mandibular setback, maxillary advancement, bimaxillary surgery) in both males and females.

Methods: This study is a before-after cross sectional retrospective research. One hundred and twenty consecutive patients who were diagnosed as having skeletal class III deformity. All patients included in this study were adults who had completed their growth and had cephalograms within a month prior to operation (T_1) and 1 month to 9 months post-surgery (T_2) taken in the natural head position. Patients were divided according to the type of surgery undertaken in three groups: group 1 (bimaxillary), group 2 (mandibular setback) and group 3 (maxillary advancement) surgeries. Posterior airway size was evaluated at both T1 and T2 in each group. The results were compared by paired t and one-way ANOVA tests.

Results: Airway size decreased significantly in group 1 and 2 ($p<0.05$) but increased in group 3($p<0.05$).

Conclusion: Airway dimension and morphology as well as head and neck posture changed significantly in different surgical treatments of class III deformity,

Key words: Airway space, Angle Class III, Malocclusion, Orthognathic Surgery.

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Introduction:

Class III problems are those caused by some combination of maxillary hypoplasia (deficiency) and mandibular hyperplasia (excess) (1). Historically, the surgical correction of class III deformities was achieved by mandibular setback alone, but as knowledge and techniques advanced, corrective surgery progressed into combined mandibular setback and maxillary advancement procedures (i.e. bimaxillary) (2). Treatment of class III dentofacial deformities with jaw osteotomy has an effect on oropharyngeal morphology as well as position of bony facial skeleton and hard-tissue-soft tissue relationships. One aspect of surgical treatment of class III skeletal deformity which has gained prominence over the past 20 years is the effect of skeletal movement in different surgical strategies of treatment on the pharyngeal [posterior] airway space (PAS) (3,4). There are different studies concerning effects of mandibular setback surgery on PAS. *Chen et al.* (2015) reported mandibular setback surgery caused a statistically significant decrease in airway size at the oropharyngeal and hypopharyngeal levels (5). Kawakami *et al.* (2005) showed a significant pharyngeal narrowing 3 months after surgery and no significant tendency to recovery in the average rate of pharyngeal narrowing at either 6 months or 1 year after surgery. They also found narrowing of upper pharyngeal airway immediately following mandibular setback surgery and reported tendency toward its original morphology 1 year postoperative (6). Hwang *et al.* (2010) assessed changes in pharyngeal airway in 15 patients who had mandibular setback, they found pharyngeal airway size became significantly narrower both in short-term and over 1 year long-term following ups (7). It seems that previous studies clarifed the changes of posterior airway space after mandibular set back surgery to some extent but there is still concern about any possible sexual dimorphism after mandibular setback osteotomy procedures.

In contrast, advancement of the maxilla causes widening of the airway in the nasopharyngeal and retropalatal dimensions and increases the superior pharyngeal volume. de souza carvalho *et al.* (2012) assessed posterior airway space in 20 patients who had maxillomandibular advancement, they found there was an increase in posterior airway Space in immediate and late postoperative periods (8). Previous studies also evaluated the effect of bimaxillary surgery in post-palatal airway dimensions. Some found significant decrease in airway size after surgery (3, 9-11) and assumed that it was probably due to mandibular setback component causing a posterior repositioning of the soft palate; thus narrowing the post-palatal airway dimension. It was assumed that it is relative to the amount of mandibular setback movement. Chen *et al.* (2007) evaluated both short-term and long-term changes of PAS in class III patients. They found that the bimaxillary surgery caused an increase at the nasopharyngeal level and decreases at both the oropharyngeal and hypopharyngeal levels in short-term. But no significant changes were seen in the long-term observations (12). Still others showed the bimaxillary surgery resulted in widening of the PAS dimensions (13, 14, 15). Therefore there is not any consensus over the exact PAS changes after bimaxillary surgery. Furthermore any differences between two genders should be evaluated more thoroughly.

The aim of this study is to conduct a detailed cephalometric evaluation of the alterations taking place in posterior airway space after treatment of class III skeletal deformity via different surgical procedures (i.e. mandibular setback, maxillary advancement, bimaxillary surgery) and to assess differences in airway changes following surgery in males and females.

Methods:

This is a before-after cross sectional retrospective study of 120 consecutive patients who were diagnosed as having skeletal class III deformity. All patients included in this study were adults who had completed their growth. They were 41 male and 79 female patients with the average age of 23.4 years and the range of 18-31 years old at the onset of the treatment. All of the patients studied had undergone fixed orthodontic treatment with edgewise appliances both before surgery and after surgical procedure for correction of their jaw deformities. The subjects were selected by random sampling of each surgical technique from the files of patients at the orthodontic departments of Shiraz University of Medical Sciences and Shahid Beheshti University of Medical Sciences and one private clinic in Shiraz. For each group 40 patients were selected randomly. In addition, the records of all 120 patients were retrospectively selected on the basis of the following criteria:

1- Availability of lateral cephalograms both within a month prior to operation (T_1) and up to 9 months post-surgery (mean time of 6 months) (T_2) with all cephalograms included the second and fourth cervical vertebrae. A minimum 1-month interval between surgery and the acquisition of post surgical cephalograms was required to minimize any effects from postoperative swelling and edema which may adversely affect the airway dimensions.

2- In order to correct class III deformity the patients received maxillary, mandibular or maxillomandibular surgery. All the patients with mandibular setback surgery had undergone bilateral sagittal split ramus osteotomy (BSSRO). The subjects with maxillary advancement surgery received LeFort I advancement osteotomy without impaction. The bimaxillary surgical patients had undergone combined LeFort I maxillary advancement osteotomy without impaction and BSSRO mandibular setback surgery. All the patients had rigid internal fixation (RIF) with fixation screws and/ or plates following either maxillary or mandibular osteotomies. All of the mandibular setback surgeries and bimaxillary surgeries were accomplished by one surgeon.

3- The patients having one or more of these criteria were excluded from the study: History of trauma to the face and the jaws , absence of completely normal dentition with no missing teeth except those that were extracted for orthodontic purposes and the third molars, apparent facial asymmetry, presence of any syndrome related to orofacial region, cleft lip and/or palate, obstructive sleep apnea (OSA) or even habitual snoring, chronic upper respiratory tract infections and diseases, previous history of orthognathic or facial cosmetic procedures including mandibular inferior border osteotomy (genioplasty) and previous history of adenoidectomy/ tonsillectomy. The data for excluding these criteria were gathered from patient's medical and dental history, cephalograms (including lateral and posteroanterior views) and facial and intra oral photographs available in the files. Patients were divided according to the type of surgery undertaken in three groups:

Group 1: Those who received combined maxillary advancement and mandibular setback surgery.

Group 2: Subjects who received mandibular setback osteotomy.

Group 3: Patients who received maxillary advancement surgery.

Lateral cephalograms:

The cephalograms were hand traced on 0.003 inches thick , 8×10 inches matte acetate tracing paper (Truvision, Ortho Technology Inc., Tampu, Florida, USA; distributed by Emergo Europe, Molenstraat, Netherlands) with 3H drawing pencil.

Skeletal Landmarks:

The land marks used to measure the data include Sella (S), Nasion (N), Point A, Basion (Ba), Point B and PNS (Posterior Nasal Spine) (16).

Soft Tissue Landmarks:

PPW_1: The intersection of the line ANS-PNS and the posterior pharyngeal wall (3).

PPW_2: A point on the posterior wall of pharynx at the level of minimum airway dimension behind soft palate (3).

PPW_3: A point on the posterior pharyngeal wall at the same level of uvula (Tip of soft palate) (3).

PPW_4: A point on the posterior wall of the pharynx that the airway behind the base of tongue is in minimum size anteroposteriorly (3).

APW_1: A point on the anterior wall of the pharynx corresponding to the point PPW_4 (3).

U: Tip of the soft palate (Uvula) (17).

V: The deepest point of vallecula on the anterior pharyngeal wall (7).

Ep: Tip of the epiglottis (3).

SO: Midpoint of the sella-basion line (17).

Ad_1 (Linder-Aronson point 1): Intersection of the line PNS-Ba and the posterior nasopharyngeal wall (17).

Ad2 (Linder-Aronson point 2): Intersection of the line PNS-SO and the posterior nasopharyngeal (17).

Reference Lines:

VRL: The line which is drawn through the most anterior point of the second cervical vertebra (axis or C_2) parallel to the edge of the cephalometric film (18).

HRL: The line which is drawn through point sella at right angle to the edge of the cephalometric film (18).

Dento-Skeletal Measurements:

To assess the hard tissue relationships and comparing pre surgical to post treatment data the following linear and angular measurements were measured:

SNA, SNB, ANB (degree)

Overbite, Overjet (mm)

Maxillary advancement (mm): the distance from point A to vertical reference line.

Mandibular setback (mm): the distance from point B to vertical reference line.

Soft Tissue Measurements:

To evaluate the soft tissue of the airway the following linear quantifications were used: (Figure 1)

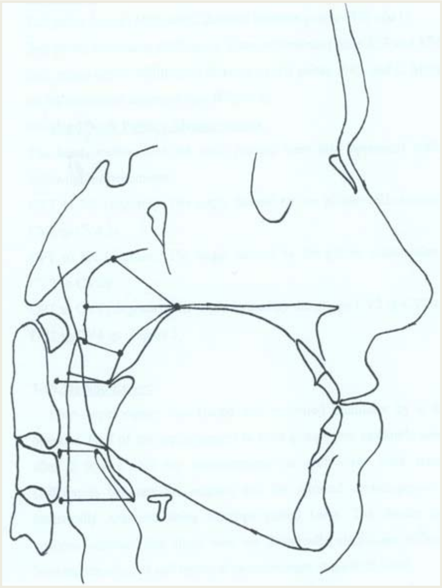

Figure 1– Posterior Airway Space Measurements

Ad_1- PNS (mm): the distance from PNS to ad_1 (airway dimension at the level of Ba-PNS plane).

Ad_2-PNS (mm): The distance from PNS to ad2 (airway dimension at the level of the line PNS-SO).

Minimum palatal airway (mm): the distance from PPW_2 to SP_2 (minimum airway dimension behind soft palate).

Airway at U (mm): The distance between PPW_3 and U (the airway dimension at the level of the tip of the soft palate).

VRL to U (mm): The distance from vertical reference line to the tip of soft palate (uvula).

Minimum lingual airway (mm): the distance from PPW_4 to APW_1 (minimum airway dimension behind base of the tongue).

VRL to EP (mm): The distance from vertical reference line to the tip of epiglottis.

VRL to V (mm): The distance from vertical reference line to the deepest point of vallecula.

Method Error:

Each cephalogram was traced and measured manually by a single operator. Half of the cephalograms in each group were randomly selected after 2 weeks. All the measurements in each case were repeated. Intraclass correlation coefficient in the revised manuscript was performed. The value of ICC ($r_{ICC}=0.899$, $p<0.001$) showed the high level of reliability between the two measurements. The results of the analysis indicated that there were no statistically significant differences between the original and repeated measurements at the 0.05 level. Therefore the original measurements that were used for the analysis of the airway space were reliable.

Statistical Analysis:

Data was gathered and analysed by using the following tests: Comparisons of group (according to type of surgery) characteristics were done with one way ANOVA test (for variable of age) and chi-square test (for variable of sex). For comparing of dependent variables

(CVT to SN, VRL to EP ...) before and after of surgery, paired t- test and for comparing of mean differences of dependent variables between groups ANOVA test were used. We evaluated the effect of group on mean differences of dependent variables after adjustment of other independent variables (age, sex, advancement, setback, face height) with multiple linear regression models. Because 2 independent variables, advancement and setback, were not defined for all groups (advancement defined for group 1 and 3; setback defined for group 1 and 2), for evaluation of group effect on mean differences of dependent variables after adjustment of advancement, subjects of group 1 and 3 and for controlling of setback, groups of 1 and 2 selected and entered to multiple linear models. In multiple linear models, variable of group entered to models with enter method and other variables with stepwise method. Assumption of normal distribution was assessed with one Kolmogorov- Smirnov test and results showed that data were normally distributed for all variables measured before and after surgical intervention in all groups (all *p*>0.05). Box plots were used to visualize the results. Statistical tests, using a two- sided P value (The level of statistical significance was set at *p*<0.05) were conducted with the SPSS programme (version 16).

Results:

The demographic data of class III patients in groups I to III are shown in table 1.

Table 1– Demographic data of class III patients treated with surgery

Parameter		**Group 1**	**Group 2**	**Group 3**	**P value**
Sex Number(percent) (percent)	Male	12 (30)	13 (32.5)	16 (40)	0.618$^{(1)}$
	Female	28 (70)	27 (67.5)	24 (60)	
Face height Number(percent)	Normal	14 (35)	17 (42.5)	14 (35)	0.129$^{(1)}$
	Long	18 (45)	12 (30)	9 (22.5)	
	Short	8 (20)	11 (27.5)	17 (42.5)	
Age (mean (SD))		22.99 (4.53)	22.73 (3.29)	24.48 (2.53)	0.064$^{(2)}$
Advancement (mean (SD))		4.04 (1.78)	-----------	4.33 (1.5)	0.371$^{(3)}$
Setback (mean (SD))		3.3 (1.49)	4.35 (1.29)	-----------	0.001$^{(4)}$

(1) Chi square test (2) ANOVA (3) Mann-Whitney U test (4) two sample test

Overall airway changes in three different groups are illustrated in table 2. Minimum lingual airway VRL to U and airway dimension at point U Were decreased significantly in group I (bimaxillary group) whereas minimum palatal airway size, VRL to EP , VRL to V, ad1 to PNS and ad2 to PNS was not changed significantly. When the patients in this group are splitted according to sex differences into male and female subgroups the results are seen in tables 3 and 4. In females subgroup, minimum palatal airway, minimum lingual airway, VRL to U and airway at U were decreased significantly whilst there were no changes in airway dimensions at nasopharynx (ad1 to PNS and ad2 to PNS) and hypopharynx (VRL to V and VRL to EP) . On the other hand, male patients showed no changes in airway dimension at nasopharyngeal, oropharyngeal and hypopharyngeal levels. In group II (mandibular setback group) the oropharyngeal and hypopharyngeal airway sizes are decreased as seen in minimum palatal airway, minimum lingual airway, VRL to U, airway at U, VRL to EP and VRL to V decreases. Similar to group I, there is not any change in nasopharyngeal area (ad1 to PNS and ad2 to PNS). In contrast to group I, there were no sex differences in pharyngeal airway space at nasopharyngeal, oropharyngeal and hypopharyngeal levels.

Table 2– Overall airway changes in three different groups

Parameter	Group	T1 (before)	T2 after	T1 - T2	P value
AD1 –PNS	Group 1	27.50 (5.29)	28.05 (5.31)	-0.55 (4.20)	0.413
	Group 2	29.13 (4.21)	29.82 (5.95)	-0.69 (4.23)	0.313
	Group 3	24.65 (4.65)	26.95 (4.56)	-2.30 (3.91)	**0.001**
AD2-PNS	Group 1	23.82 (4.73)	24.45 (5.32)	-0.62 (4.30)	0.364
	Group 2	27.72 (4.74)	27.18 (5.98)	0.54 (4.25)	0.434
	Group 3	24.02 (5.27)	25.55 (4.97)	- 1.52 (3.69)	0.013
minimum palatal airway	Group 1	9.43 (4.43)	10.73 (16.59)	- 1.3 (15.56)	0.6
	Group2	11.53 (3.39)	7.98 (3.29)	3.55 (3.31)	**0.0001**
	Group 3	8.03 (2.33)	10.05 (3.28)	- 2.03 (2.59)	**0.0001**
minimum lingual airway	Group 1	11.5 (4.08)	9.6 (3.81)	1.9 (2.84)	**0.0001**
	Group 2	13.28 (3.16)	9.98 (2.97)	3.3 (3.01)	**0.0001**
	Group 3	10.48 (3.29)	10.71 (3.95)	- 0.24 (3.34)	0.656
Airway at U	Group 1	11.47 (4.46)	10.12 (3.38)	1.35 (2.94)	**0.006**
	Group 2	13.77 (3.65)	9.90 (3.41)	3.87 (2.44)	**0.000**
	Group 3	13.25 (3.36)	13.55 (4.07)	-0.3 (3.71)	0.612
VRL to U	Group 1	16.02 (6.69)	13.12 (3.50)	2.90 (5.03)	**0.001**
	Group 2	17.65 (4.11)	14.27 (3.58)	3.37 (2.45)	**0.000**
	Group 3	13.15 (3.74)	14.52 (4.05)	-1.37 (4.04)	**0.038**
VRL to EP	Group 1	10.10 (4.11)	9.50 (3.70)	0.6 (3.84)	0.329
	Group 2	11.75 (4.8)	8.32 (4.12)	3.43 (2.81)	**0.0001**
	Group 3	10.44 (4.00)	10.33 (2.79)	0.10 (3.45)	0.854
VRL to V	Group 1	17.35 (5.54)	17.73 (4.91)	- 0.38 (4.45)	0.597
	Group 2	18.65 (4.98)	15.28 (4.64)	3.38 (2.38)	**0.0001**
	Group 3	20.88 (4.88)	21.4 (5.34)	- 0.53 (5.27)	0.532

Table 3- Female airway changes in three different groups

Parameter	Group	T1 (before)	T2 after	T1 - T2	P value
minimum palatal airway	Group 1	11.15 (2.67)	8.26 (3.44)	2.43 (3.17)	**0.006**
	Group2	11.14 (2.30)	7.92 (3.02)	3.22 (2.69)	**0.0001**
	Group 3	7.75 (4.05)	10.42 (3.35)	-2.64 (3.77)	**0.0001**
minimum lingual airway)	Group 1	13.26 (2.93)	9.98 (4.37)	3.28 (3.41)	**0.001**
	Group 2	13.92 (3.68)	9.63 (2.40)	3.63 (3.29)	**0.0001**
	Group 3	10.39 (3.61)	10.75 (3.68)	-0.44 (3.17)	0.471
Airway at U	Group 1	11.83 (5.17)	10.17 (3.21)	1.67 (3.52)	0.130
	Group 2	13.74 (3.38)	9.85 (3.44)	3.89 (2.45)	**0.000**
	Group 3	12.87 (3.43)	13.12 (4.01)	-0.25 (3.60)	0.737
VRL to U	Group 1	17.42 (8.84)	14.00 (3.46)	3.42 (6.36)	0.90
	Group 2	17.74 (3.90)	14.44 (3.84)	3.30 (2.38)	**0.000**
	Group 3	12.79 (3.92)	14.17 (4.24)	-1.37 (3.66)	0.131
VRL to EP	Group 1	11.41 (4.21)	9.68 (3.40)	1.71 (3.44)	0.0252
	Group 2	10 (3.82)	7.78 (3.39)	3.63 (3.72)	**0.0001**
	Group 3	18.75 (5.71)	18.50 (3.52)	0.25 (3.79)	0.75
VRL to V	Group 1	18.33 (4.83)	17.82 (4.90)	0.32 (3.89)	0.668
	Group 2	20.54 (4.05)	15.26 (4.54)	5.07 (3.65)	**0.0001**
	Group 3	20.56 (5.56)	19.75 (4.54)	0.79 (3.80)	0.318
AD1-PNS	Group 1	29.54 (3.98)	28.11 (5.30)	1.44 (0.4)	0.142
	Group 2	24.58 (4.29)	30.54 (6.43)	-5.95 (4.54)	0.272
	Group 3	24.08 (4.29)	26.96 (3.99)	-2.87 (4.02)	**0.002**
AD2-PNS	Group 1	23.14 (4.64)	24.32 (5.21)	-1.18 (4.26)	0.155
	Group 2	27.69 (5.35)	28.00 (6.58)	-0.31 (4.20)	0.712
	Group 3	23.25 (5.18)	25.08 (4.31)	-1.83 (3.33)	**0.013**

In group III, the nasopharynx and retropalatal area showed significant increases as seen increase of ad1 to PNS, ad_2 to PNS and minimum palatal airway. While oropharynx and hypopharynx dimensions were not changed significantly.

In female subgroup, the airway size increased in minimum palatal airway, ad1 to PNS and ad2 to PNS dimensions but is not changed in airway at point U, VRL to point U, minimum lingual airway, VRL to EP and VRL to V measurements. In male subgroup only minimum palatal airway size is increased significantly whereas other pharyngeal dimensions remain unchanged.

Table 4 - Male airway changes in three different groups

Parameter	Group	T1 (before)	T2 after	T1 - T2	P value
minimum palatal airway	Group 1	8.83 (4.53)	16.50 (29.91)	-7.67 (27.91) 674.23 (1.23)	0.362
	Group2	12.31 (4.55)	8.08 (3.90)	4.23 (1.23)	0.005
	Group 3	8.06 (2.43)	10.06 (3.27)	-2 (2.85)	0.013
minimum lingual airway	Group 1	10.92 (4.27)	8.92 (1.93)	2 (3.62)	0.082
	Group 2	13.31 (3.73)	10.69 (3.90)	2.61 (3.43)	0.018
	Group 3	11.31 (2.47)	11.25 (4.40)	0.062 (3.97)	0.951
Airway at U	Group 1	11.32 (4.22)	10.11 (3.51)	1.21 (2.71)	0.052
	Group 2	13.85 (4.30)	10.00 (3.49)	3.84 (2.51)	0.000
	Group 3	13.81 (3.29)	14.19 (4.21)	-0.37 (4.00)	0.713
VRL to U	Group 1	14.43 (5.62)	12.75 (3.51)	1.68 (4.46)	0.064
	Group 2	17.46 (4.68)	13.92 (3.09)	3.54 (2.66)	0.000
	Group 3	13.69 (3.50)	15.06 (3.82)	-1.37 (3.76)	0.164
VRL to EP	Group 1	6.42 (5.19)	9.08 (4.46)	0.33 (5.14)	0.826
	Group 2	12.46 (5.95)	9.46 (5.32)	3 (2.12)	0.0001
	Group 3	11.13 (4.31)	11.27 (3.01)	-0.13 (2.92)	0.726
VRL to V	Group 1	15.50 (4.81)	17.50 (5.16)	-2 (5.32)	0.22
	Group 2	19.31 (5.42)	15.31 (5.02)	4 (2.31)	0.0001
	Group 3	21.37 (6.02)	23.87 (5.63)	-2.50 (6.57)	0.149
AD1-PNS	Group 1	28.75 (4.57)	27.38 (4.75)	0.83 (4.53)	0.537
	Group 2	28.31 (4.68)	28.38 (4.75)	-0.08 (3.61)	0.94
	Group 3	25.50 (5.16)	26.94 (5.45)	-1.44 (3.69)	0.140
AD2-PNS	Group 1	25.42 (4.76)	24.75 (5.82)	0.67 (4.29)	0.601
	Group 2	27.77 (3.39)	25.54 (4.29)	2.23 (3.98)	0.066
	Group 3	25.19 (5.37)	26.25 (5.90)	-1.06 (4.25)	0.333

Discussion:

The effect of mandibular setback osteotomy on pharyngeal airway dimensions was the aim of many studies. In this study, we selected patients who had mandibular setback surgery via bilateral sagittal split ramus osteotomy (BSSRO) which is more commonly used and accepted in the contemporary surgical literature instead of extra oral or intraoral vertical ramus osteotomy which is used in some previous studies. We assessed the pharyngeal (posterior) airway space at 3 distinct levels - the nasopharynx, the oropharynx and the hypopharynx- because obstruction of the upper airway is reported to occur at different levels. The minimal depth of the oropharyngeal airway space and the hypopharyngeal depth are the main levels reported to be narrowed in OSA but the oropharyngeal depth is the level that is most changeable in the pharyngeal airway (9). In the present study, minimum palatal airway at point U, VRL-U and minimum lingual airway measurements as well as VRL-EP and VRL-V measurements decreased significantly after mandibular setback surgery, which indicates airway narrowing both at oropharyngeal and hypopharyngeal levels. In contrast the nasopharyngeal airway dimension, as measured by AD1-PNS and AD2-PNS, didn't change significantly after surgery. This is in agreement with previous studies (19-22). Turnbull and Battagel (2000) found that there was a decrease in the intermaxillary space and an increase in tongue proportion following mandibular setback surgery. Also, they reported a significant decrease of retropalatal (middle) airway dimension at size weeks postoperatively which they assumed that this reduction in PAS is caused by posterior repositioning of the soft palate due to mandibular setback repositioning (9). Eggensperger *et al.* (2005) found that following initial decrease after surgery; the size of the lower pharyngeal airway space remained almost unchanged. In contrast, the upper and middle pharyngeal airway sizes continued to decrease over 12 year follow-up (23). Chen *et al.* (2007) evaluated short-term (3-6months) and long-term (at least 2 years) postoperative follow-up. They found significant constriction of the pharyngeal airway at both oropharyngeal and hypopharyngeal levels in both short-term and long-term intervals (12). Muto *et al.* (2008) also reported a mean reduction of 2.6 mm retropalatally and 4mm retrolingullay following mandibular setback osteotomy in class III subjects (21). Gokce *et al.* (2014) also reported setback procedures produce anteroposterior narrowing of the pharyngeal airway space at the oropharyngeal and hypopharyngeal levels and the middle and inferior pharyngeal volumes (15). Park *et al.* (2010) evaluated linear PAS changes after mandibular setback surgery using cephalometry . From the linear analysis, they found a significant decrease in pharyngeal depth (20). Hwang *et al.* (2010) assessed changes in PAS. They suggested that PAS dimension became significantly narrower both in 1-month and 1-year postoperative follow-ups (24). Similar results were reported in other studies whereas Saitoh (2004) reported the PAS narrowing of 2.7 mm and 3.9 mm at the oropharyngeal and hypopharyngeal levels respectively (25). Eggensperger *et al.* (2005) also measured the pharyngeal narrowing and showed that the postoperative size of upper middle and lower thirds were reduced 0.5 mm, 1.1 mm and 1 mm respectively at 6 months post surgery (23). Muto *et al.* (2008) reported that the PAS narrowed postsurgically and the mean reduction was 2.6mm retropalatally and 4mm retrolingually (21).

It is interesting that some changes after mandibular setback surgery are similar to the characteristics of OSA patients, such as narrowing of airway, PAS size less than 11 mm $^{\text{and}}$ minimal airway size of less than 5mm (10). In our study although the mean minimal airway dimension at the oropharyngeal and hypopharyngeal levels were both well below 11 mm, which were 7.97 mm and 8.33 respectively, both the PAS dimensions are still larger than 5mm which leads to only moderate increase in respiratory disturbance index (RDI) of patients. On the other hand, a mandibular setback of 12 mm or more may suffice to cause relevant pharyngeal narrowing and cause obstructive sleep-related breathing disorder which is not the case in most mandibular setback movements except extreme mandibular prognathisms (7). In contrast to mandibular setback surgery which is known to cause narrowing of the pharyngeal airway, combined maxillary advancement and mandibular setback may have some benefits concerning both airway changes and esthetics. In our study oropharyngeal airway dimensions including airway at point U, VRL to U and minimum lingual airway measurements showed significant decreases after bimaxillary surgery which confirm previous studies by Samman *et al.*(2002)(3), Chen *et al.* (2007)(12) and Foltan *et al.* (2009)(10).

Furthermore, we found that hypopharyngeal airway, which is measured by VRL to EP and VRL to V, and postpalatal airway, as measured by minimum palatal airway, dimensions as well as nasopharyngeal airway size, which is measured by AD_1 to PNS and AD_2 to PNS, did not show any significant changes after 2-jaw surgery. This is in contrast with other studies by Samman *et al.* (2002)(3), Turnbull an Battagel (2000)(9), *Lee et al.*(2012)(11) and Marsan *et al.* (2009)(13), but in agreement with Cakarne *et al.* (2003)(14). It is obvious that unlike mandibular setback surgery, there were no significant upper and lower airway changes after bimaxillary surgery.

Turnbull and Battagel (2000) was the first to evaluate the effect of bimaxillary surgery in post-palatal airway dimensions (9). They found significant decrease in airway size after surgery and assumed that it was probably due to mandibular setback component causing a posterior repositioning of the soft palate; thus narrowing the post-palatal airway dimension. *Lee et al.* (2012) also assessed the effects of bimaxillary surgery in class III patients (11). They concluded that the bimaxillary surgery caused an increase (12.35%) in the upper part and a decrease (14.07%) at the lower part of the PAS with a statistically significant difference 6 months after surgery. Samman *et al.* (2002) also evaluated PAS changes in class III patients treated with bimaxillary surgery (3). They also reported significant airway narrowing at the oropharyngeal and hypopharyngeal levels. Chen *et al.* (2007) evaluated both short-term and long-term changes of PAS in class III patients. They found that the bimaxillary surgery caused an increase at the nasopharyngeal level and decreases at both the oropharyngeal and hypopharyngeal levels in short-term. But no significant changes were seen in the long-term observations (12). Foltan *et al.* (2009) evaluated bimaxillary surgery in a group of class III patients who were treated surgically. They found that 2-jaw surgery worsened breathing function during sleep and decreased the PAS to 75% of its original volume (10). Gokce *et al.* (2012) also evaluated Bimaxillary orthognathic surgery (BOS) in the correction of severe Class III deformities. They showed that airway space narrowed at the levels of oropharynx and hypopharynx and widened at the nasopharynx and velopharynx levels significantly ($p<0.05$). Their findings aslso indicated decreased airway resistance and better airflow (4). Still other studies did not show that the bimaxillary surgery caused narrowing of the PAS dimensions. Cakarne *et al.* (2003) studied female patients treated with bimaxillary surgery. They reported that no significant change occurred in the oropharyngeal and hypopharyngeal airway sagittal measurements postoperatively. Yet a statistically significant increase was observed in nasopharyngeal level of the PAS (14). Marsan *et al.* (2009) also found that the bimaxillary surgery caused an increase in the upper retropalatal airway in the class III female patients treated with bimaxillary surgery (13).

This is postulated due to four key issues. Firstly, maxillary advancement results in adaptive changes of the soft palate in order to maintain velopharyngeal seal and palatal function. The second matter concerns the posterior and superior movement of the tongue from the mandibular setback which comes into contact and displaces the soft palate backwards and upwards. Combining the two factors, the soft palate becomes longer and thinner and the palatal angle increases. Therefore, the maxillary advancement may not gain a significant enlargement of the retropalatal dimension and coupled with the mandibular setback, there may even be a narrowing of the retropalatal airway (26). Another reason for unchanged nasopharyngeal airway dimension may be that the advancement of the velum and velopharyngeal muscle caused by LeFort1 osteotomy partly decreased the constricted effect of BSSRO (7). The last reason is that the constancy of hypopharyngeal airway size may be due to the fact that the extent of mandibular retraction was less in bimaxillary surgery than in mandibular retraction alone surgery (8). In this study significantly less mandibular retraction was shown in the bimaxillary group.

In maxillary advancement surgery alone, the PAS changes were somewhat different from bimaxillary group. Our study showed that the nasopharynx, which is measured by AD1 to PNS and AD_2 to PNS, and retropalatal airway as measured by minimum palatal airway showed significant increases while oropharynx, as measured by airway at point U, VRL to U, and minimum lingual airway, and hypophargnx, as measured by VRL to EP and VRL to V, did not change significantly following maxillary advancement. The increase in PAS at the level of nasopharynx and retropalatal airway space was thought to be a result of advancement of velum and velopharyngeal muscle. Our findings were in agreement with previous studies. Turnbull and Battagel (2000) evaluated the effect of maxillary advancement surgery on PAS and quality of sleep (9). They found that this surgery neither produced an increase in retropalatal airway diameter nor affected significantly on the sleep quality. Pereira-Filho *et al.* (2011) retrospectively evaluated PAS changes in patients with skeletal Class III deformity. They analyzed the cephs before surgery, 1 week after it, and at least 1 year postoperatively. They concluded that after maxillary advancement, there was an increase in the oropharynx and nasopharynx that remained long-term (27). Samman *et al.* (2002), Pereira-Filho *et al.* (2011) and Gokce *et al.* (2014) also found that the maxillary advancement surgery alone increased the nasopharyngeal dimension of airway space postsurgically (3, 27, 15).

In the present study, in mandibular setback group there was no sex dimorphism in airway dimensions. Both male and female patients showed significant reduction in both oropharyngeal and hypopharyngeal airway dimensions. Our results were in agreement with other studies that revealed although various variables of pharyngeal airway demonstrated sex dimorphism, oropharyngeal space and minimal pharyngeal airway space did not demonstrate sex dimorphism (28, 29) Samman *et al.* (2003) suggested that although the majority of airway measurements demonstrate sex dimorphism, those that are most important to the patency of the airway as oropharyngeal space and minimal pharyngeal airway are not dimorphic (28). They reported that minimal pharyngeal, hypopharyngeal and oropharyngeal spaces were decreased after surgical correction in male class III subjects. They also revealed that in male class III subjects, the most notable changes were decreases in the dimension of minimal pharyngeal airway and hypopharyngeal spaces; while there was a decrease in the total pharyngeal area but no change in the dimension of the nasopharyngeal space in female class III subjects after correction by mandibular setback surgery alone Değerliyurt *et al.* (2009) also found that oropharyngeal airway changes at the level of soft palate and base of tongue are not dimorphic (29) thus it supported the findings of our study. They found that in mandibular setback group, the pharyngeal airway at the level of the soft palate and base to tongue were significantly reduced for both men and women.

Our findings in bimaxillary group revealed that although female patients showed significant decreases in oropharyngeal dimensions, but males didn’t show any changes in nasopharyngeal, oropharyngeal and hypopharyngeal dimensions. Therefore in 2-jaw surgery, whilst the PAS changes at the level of soft palate and base of the tongue were different between genders, changes at the nasopharyngeal and hypopharyngeal levels were not dimorphic. Our results were somewhat in agreement with the study of Değerliyurt *et al.* (2009) but were in contrast with previous study by Samman *et al.* (2002). Samman *et al.* (2002) declared that some gender differences in the airway changes were evident after bimaxillary surgical procedures in a cephalometric study (3). They reported that male subjects displayed a decrease in the dimension of minimal pharyngeal airway and oropharyngeal spaces whereas no significant change was noted in female class III subjects after correction by 2-jaw surgery. Değerliyurt *et al.* (2009) also evaluated the effect of bimaxillary surgery on pharyngeal airway among different genders (29). They evaluated computed tomography images of subject’s pre and post operatively and found that in bimaxillary group midsagittal dimensions at both soft palate and base of tongue were significantly decreased for males and females but the cross sectional area at both levels didn’t change significantly. In our study the sexual dimorphism that we reported may be due to the difference in sample sizes between males and females. Although female population were large enough for statistical analyses (28 subjects) male population were quite limited (12 subjects) which could be less than needed for the statistical results to become meaningful.

Moreover in maxillary advancement group, both men and women showed significant increase in nasopharyngeal airway size whereas the oropharyngeal and hypopharyngeal airway didn’t change significantly either in male or female patients. Therefore the maxillary advancement osteotomy changed the airway dimensions similarly in both genders. Unfortunately, there was not a study evaluating the sex dimorphism in pharyngeal airway dimensions performed on a population who received maxillary advancement surgery so we were not able to compare our findings.

Conclusion:

Pharyngeal airway space (PAS) It was reduced at middle and lower levels and unchanged at upper level after mandibular setback. After bimaxillary, PAS was reduced at middle level and unchanged at both upper and lower levels. Finally, after maxillary advancement, PAS was increased at upper level and unchanged at middle and lower levels. With a history of snoring or breathing problems in patients needing mandibular setback, the bimaxillary surgery would favor. Furthermore, in the patients having far less mandibular protrusion than maxillary retrusion the choice would be the maxillary advancement alone.

Conflict of Interest: “None Declared”

References:

1. Proffit WR, White RP, Sarver DM. (eds) Contemporary treatment of dentofacial deformity. 1st Ed. St Louis: Missouri: The C.V. Mosby Co. 2003; Chap 8: 235-236.
2. Proffit WR, White RP, Sarver DM. (eds) Contemporary treatment of dentofacial. 1st Ed. St Louis: Missouri: The C.V. Mosby Co. 2003; Chap 17: 695-701.
3. Samman N, Tang SS, Xia J. Cephalometric study of the upper airway in surgically corrected class

III skeletal deformity. Int J Adult Orthodon Orthognath Surg 2002; 17:180-190.

4. Gokce SM, Gorgulu S, Gokce HS, Bengi O, Sabuncuoglu F, Ozgen F, et al. Changes in posterior airway space, pulmonary function and sleep quality, following bimaxillary orthognathic surgery. Int J Oral Maxillofac Surg 2012; 41: 820-829.
5. Chen CM, Lai S, Chen KK, Lee HE. Correlation between the pharyngeal airway space and head posture after surgery for mandibular prognathism. Biomed Res Intl 2015; 2015: 251021.
6. Kawakami M, Yamamoto K, Fujimoto M, Ohgi K, Inoue M, Kirita T. Changes in tongue and hyoid positions, and posterior airway space following mandibular setback surgery. J Craniomaxillofac Surg 2005; 33: 107-110.
7. Hwang S, Chung CJ, Choi YJ, Huh JK, Kim KH. Changes of hyoid, tongue and pharyngeal airway after mandibular setback surgery by intraoral vertical ramus osteotomy. Angle Orthod 2010; 80: 302-308.
8. De Souza Carvalho AC, Magro Filho O, Garcia IR Jr, Araujo PM, Nogueira RL. Cephalometric and three-dimensional assessment of superior posterior airway space after maxillomandibular advancement. Int J Oral Maxillofac Surg 2012; 41: 1102-1111.
9. Turnbull NR, Battagel JM. The effects of orthognathic surgery on pharyngeal airway dimensions and quality of sleep. J Orthod 2000; 27: 235-247.
10. Foltan R, Hoffmannova J, Donev F, Vlk M, Sedy J, Kufa R, *et al*. The impact of Le Fort I advancement and bilateral sagittal split osteotomy setback on ventilationduring sleep. Int J Oral Maxillofac Surg 2009; 38: 1036-1040.
11. Lee Y, Chun YS, Kang N, Kim M. Volumetric changes in the upper airway after bimaxillary surgery for skeletal class III malocclusions: a case series study using 3-dimensional cone-beam computed tomography. J Oral Maxillofac Surg 2012; 70: 2867-2875.
12. Chen F, Terada K, Hua Y, Saito I. Effects of bimaxillary surgery and mandibular setback surgery on pharyngeal airway measurements in patients with class III skeletal deformities. Am J Orthod Dentofacial Orthop 2007; 131: 372-377.
13. Marşan G, Vasfi Kuvat S, Oztaş E, Cura N, Süsal Z, Emekli U. Oropharyngeal airway changes following bimaxillary surgery in Class III female adults. J Craniomaxillofac Surg 2009; 37: 69-73.
14. Cakarne D, Urtane I, Skagers A. Pharyngeal airway sagittal dimension in patients with class III skeletal dentofacial deformity before and after bimaxillary surgery. Stomatologija 2003; 5: 13-16.
15. Gokce SM, Gorgulu S, Gokce HS, Bengi AO, Karacayli U, Ors F. Evaluation of pharyngeal airway space changes after bimaxillary orthognathic surgery with a 3-dimensional simulation and modeling program. Am J Orthod Dentofac Orthop 2014; 146: 477-492.
16. Jacobson A, Jacobson RL. (eds) Radiographic Cephalometry from Basics to 3-D Imaging. 2nd Ed. Chicago, Illinois: Qiuntessence 2006; Chap 4: 49-51.
17. Graber TM, Vanarsdall R, Vig KWL (eds). Orthodontics: Current Principles and Techniques. 4th Ed. St.Louis: Missouri: The C.V. Mosby Co. 2005; Chap 4: 130-132.
18. Tselnik M, Pogrel MA. Assessment of the pharyngeal airway space after mandibular setback surgery. J Oral Maxillofac Surg 2000; 58: 282-284
19. Kawamata A, Fujishita M, Ariji Y, Ariji E. Three-dimensional computed tomographic evaluation of morphologic airway changes after mandibular setback osteotomy for prognathism. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000; 89: 278-287.
20. Park JW, Kim NK, Kim JW, Kim MJ, Chang YI. Volumetric, planar, and linear analyses of

pharyngeal airway change on computed tomography and cephalometry after mandibular setback surgery. Am J Orthod Dentofacial Orthop 2010; 138: 292-299.

21. Muto T, Yamazaki A, Takeda S, Sato Y. Effect of bilateral sagittal split osteotomy setback on the soft palate and pharyngeal airway space. Int J of Oral and Maxillofac Surg 2008; 37: 419-423.
22. Achilleos S, Krogstad O, Lyberg T. Surgical mandibular setback and changes in uvuloglossopharyngeal morphology and head posture: a short and long-term cephalometric study in males. Eur J Orthod 2000; 22: 383-394.
23. Eggensperger N, Smolka W, Iizuka T. Long-term changes of hyoid bone position and pharyngeal airway size following mandibular setback by sagittal split ramus osteotomy. J Craniomaxillofac Surg 2005; 33: 111-117.
24. Hwang S, Chung CJ, Choi YJ, Huh JK, Kim KH. Changes of hyoid, tongue and pharyngeal airway after mandibular setback surgery by intraoral vertical ramus osteotomy. Angle Orthod 2010; 80: 302-308.
25. Saitoh K. Long-term changes in pharyngeal airway morphology after mandibular setback surgery. Am J Orthod Dentofacial Orthop 2004; 125: 556-561.
26. Mohsenin V. Effects of gender on upper airway collapsibility and severity of obstructive sleep apnea. Sleep Med 2003; 4: 523-529.
27. Pereira-Filho VA, Castro-Silva LM, De Moraes M, Gabrielli MF, Campos JA, Juergens P. Cephalometric evaluation of pharyngeal airway space changes in class III patients undergoing orthognathic surgery. J Oral Maxillofac Surg 2011; 69: 409-415.
28. Samman N, Mohammadi H, Xia J. Cephalometric norms for the upper airway in a healthy Hong Kong Chinese population. Hong Kong Med J 2003; 9: 25-30.
29. Değerliyurt K, Ueki K, Hashiba Y, Marukawa K, Simsek B, Okabe K, *et al*. The effect of mandibular setback or two-jaw surgery on pharyngeal airway among different genders. Int J Oral Maxillofac Surg 2009; 38: 647-652.