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Original Article

Investigation of the effects of bimaxillary surgery on the pharyngeal airway space

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Abstract

Aim: To examine the pharyngeal airway space (PAS) changes in patients with skeletal Class III anomalies treated with two different bimaxillary surgery (BMS) techniques.
Methodology: A total of 27 patients (15 females, 12 males) treated with BMS were divided into two groups: Group 1 (n=16, mean age: 20.67±2.82 years) consisted of patients who underwent maxillary-mandibular advancement (MMA), and Group 2 (n=11, mean age: 23.87±7.72 years) consisted of patients who underwent maxillary advancement and mandibular setback (MAMS). Cone-beam computed tomography (CBCT) records were taken immediately before (T1) and at least 5 months after (T2) BMS. To evaluate the postoperative PAS changes, the parameters of total volume (TV), upper volume (UV), lower volume (LV), and minimal axial area (Min-Ax) were evaluated using NemoCeph 10.4.2 software.
Results: In Group 1, postoperative increases in the TV, NV, OV, and Min-Ax were determined as 4.5%, 6.6%, 3.07%, and 5.1%, respectively, but these increases were not statistically significant ($p > 0.05$). In Group 2, the following increases were determined: 10.4% in TV, 18.4% in NV, and 5.5% in OV. A postoperative decrease of 6.2% was determined for Min-Ax. These increases and decreases were not statistically significant ($p > 0.05$). There was no statistically significant difference between groups 1 and 2 in any pre- and postoperative parameters ($p > 0.05$).
Conclusion: Neither of the BMS techniques caused any significant change in the PAS parameters.

Keywords: Bimaxillary surgery, pharyngeal airway space, orthognathic surgery, Class III malocclusion, cone-beam computed tomography

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Introduction

Skeletal Class III anomalies may cause aesthetic and functional problems in patients. These anomalies may result from maxillary hypoplasia, mandibular prognathism, or a combination of both. Regardless of the cause, orthognathic surgery (OS) is the most commonly used treatment alternative in severe skeletal Class III anomalies that cannot be treated with camouflage therapy (1).

It is known that significant changes in the surrounding soft and hard tissues due to OS also affect the posterior pharyngeal airway space (PAS) (2). Some studies have reported that treating skeletal Class III anomalies with mandibular setback surgery (MSB) causes significant reductions in pharyngeal airway volume, which can cause respiratory problems such as obstructive sleep apnea (OSA) (3, 4). Therefore, bimaxillary surgeries (BMS), including Le Fort I osteotomy and sagittal split ramus osteotomy, are performed to treat skeletal Class III anomalies caused by both the maxilla and mandible (1).

Several studies have examined the effects of BMS on PAS using two-dimensional cephalometric radiographs (5). However, examining three-dimensional (3D) complex structures with two-dimensional (2D) systems has limitations. These studies' findings have limited to linear measurements of sagittal or transverse aspects and cannot accurately represent the morphology of the airway space or the compromised areas leading to breathing disorders (6, 7). Conventional computed tomography (CT) systems often overcome these limitations. However, these systems are known to offer high radiation doses (8). Therefore, cone-beam computed tomography (CBCT), introduced in recent years, is a reliable and effective technique to quantitatively assess the volume and cross-sectional areas of the airway space and has the ability to visualize anatomic structures. CBCT is a safe system for PAS evaluation due to its advantages, such as high-quality images and lower radiation doses (9). Three-dimensional (3D) imaging technique and 3D reconstructions along with special computer software capable of rendering volumetric data and segmenting different areas of the airway, helps clinicians and researchers measure changes in the airway space that occur in response to orthodontic and orthognathic treatment and impact breathing quality (3, 10).

Studies have evaluated the 3D effects of BMS on the PAS of skeletal Class III anomalies. Some of these studies (11) have reported no significant differences in PAS, while others have reported a significant increase (3, 12) or decrease (13, 14).

Therefore, this study aims to evaluate PAS changes in patients with skeletal Class III anomalies treated with two different BMS techniques using CBCT.

Materials and Methods

Ethical approval was obtained from the Local Ethics Committee of Dicle University Faculty of Dentistry (Approval no: 2019/9). The material of this retrospective study consisted of adult patients with skeletal Class III anomalies (ANB<0) that were treated with BMS in the same center between 2010 and 2019. Patients with OSA, congenital anomalies, cleft lips or palates, or trauma histories were excluded from the study. The 27 patients who met the study criteria were divided into two groups according to the BMS type. Group 1 (n=16, mean age: 20.67±2.82) consisted of patients who underwent maxillary-mandibular advancement (MMA), and Group 2 (n=11, mean age: 23.87±7.72) consisted of patients who underwent maxillary advancement and mandibular setback (MAMS). CBCT records were taken immediately before (T1) and at least 5 months after (T2) the BMS. The distribution of the age and gender of the patients in the study is shown in Table 1.

Table 1. Mean age and gender of individuals included in the study

Group	Gender	n	Mean Age		p
1 (MMA)	F	8	21.03±2.66	20.67±2.82	0.139
	M	8	20.31±3.10		
2 (MAMS)	F	7	24.76±9.70	23.87±7.72	
	M	4	22.30±2.23		

*Note: MMA = maxillary-mandibular advancement; MAMS = maxillary advancement and mandibular setback.

CBCT images were obtained with an i-CAT device (Imaging Sciences International, Hatfield, Pa). In the routine imaging protocol, the patients were seated upright on the CBCT device, their heads were brought to their natural positions with the help of the mirror directly opposite them, and their heads were fixed using the tape attached to the device. The CBCT scan was performed with the jaws in the centric relationship. The patients' lips were naturally rested after the Frankfurt horizontal (FH) plane was positioned parallel to the ground. CBCT images were acquired by setting the device to 5.0 mA, 120 kV, 0.3 mm voxel thickness, 360° rotation, and 9.6 seconds scan time.

In the current study, the region between the borders in Figure 1 was defined as the total PAS volume (TV): The anterior border was a vertical plane that passed through the posterior nasal spine. The posterior border was defined as the posterior pharyngeal wall. The upper border was defined as the roof of the pharynx. A horizontal plane passing through the third vertebra's most anterior and inferior point was defined as the inferior border. After identifying the borders, the PAS was cropped (Figure 2) and divided into two parts by a parallel plane passing through the first vertebra's most anterior and lowest part. The upper part was defined as the nasopharyngeal volume (NV), and the lower part was defined as the oropharyngeal volume (OV). The narrowest cross-sectional area of the PAS, defined as the minimal axial area (Min-Ax), was also evaluated. Finally, these four parameters were assessed using NemoCeph 10.4.2 software (Nemotec Dental Systems, Madrid, Spain).

Figure 1. Borders of the pharyngeal airway

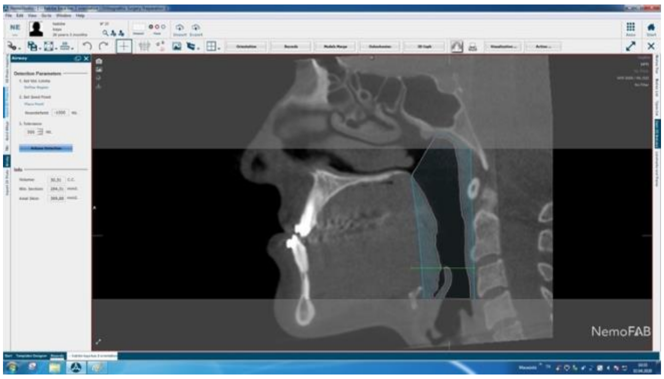
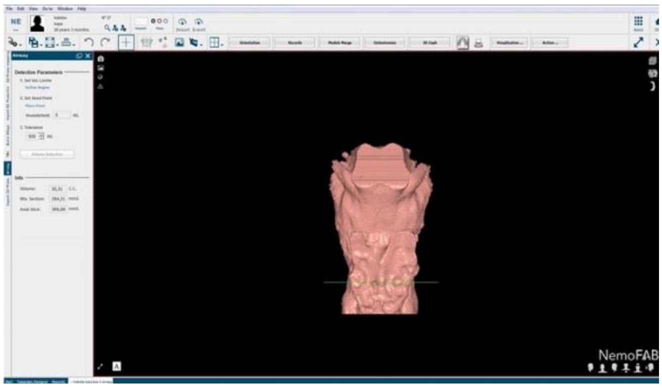


Figure 2. 3D view of the pharyngeal airway



Statistical analysis

The homogeneity of variance and the compatibility of the continuous variables were evaluated using Kolmogorov-Smirnov and Levene's tests, respectively. An independent samples t-test was used to compare the differences between the means of the independent variables, and a paired samples t-test was used to compare the differences between the means of the dependent variables. The descriptive statistics and test analyses were performed using the free software provided by The R Project for Statistical Computing (R version 3.2.3, www.r-project.org.), and the results were statistically significant at $p < 0.05$.

To assess the method error, measurements were repeated 4 weeks after the first measurement by the same researcher. The intraclass correlation coefficient was used to evaluate the differences between measurements.

Results

The demographic data of the individuals included in the study are given in Table 1. There were no statistically significant age differences between the groups ($p > 0.05$). The mean interval between BMS and T2 was 11.19±2.81 months and 10.18±4.94 months for Group 1 and Group 2, respectively. No significant difference was found between the groups ($p > 0.05$).

The intraclass correlation coefficient showed good reproducibility, with a minimum value of 0.952 for the amount of skeletal movement and 0.998 for airway measurements.

The amount of skeletal movement that occurred in the groups after BMS is shown in Table 2. In Group 1, the mean forward movement of the maxilla and mandible relative to points a and b was 6.27±2.17 mm and 2.50±2.54 mm, respectively. In Group 2, the mean maxillary forward movement was 2.79±2.16 mm relative to point a, and the mean mandibular setback was 4.10±2.20 mm relative to point b.

Table 2. Mean amount of skeletal movement

Movement (mm)	Group 1	Group 2
Maxillary advancement	6.27±2.17	2.79±2.16
Mandibular advancement	2.50±2.54	
Mandibular setback		4.10±2.20
Maxillary impaction	1.24±1.76	
Maxillary extrusion		0.79±1.39
Mandibular anterior rotation	2.20±3.22	
Maxillary posterior rotation		0.46±3.00

The descriptive statistics, including the means and standard deviation (SD) in Group 1's T1 and T2 periods, are given in Table 3. According to the results, the TV, NV, OV, and Min-Ax parameters increased by an average of 1,09±5,91 cm^3, 0,67±2,54 cm^3, 0,42±3,89 cm^3, and 12,41±99,38 cm^2, respectively; however, these increases were not statistically significant ($p > 0.05$). Compared to the T1 period, increases of approximately 4.5%, 6.6%, 3.07%, and 5.1% occurred in the TV, NV, OV, and Min-Ax parameters, respectively, during the T2 period.

The descriptive statistics, including the mean and SD in Group 2's T1 and T2 periods, are given in Table 4. According to the results, the mean increases in the TV, NV, and OV parameters were 2,15 ±7,67 cm^3, 1,65 ±2,47 cm^3, and 0,5±5,63 cm^3, respectively, while the mean decrease in the Min-Ax parameter was 12,43±94,94 cm2. The TV, NV, and OV values increased by 10.4%, 18.4%, and 5.5%, respectively, while a decrease of 6.2% occurred in the Min-Ax parameter; however, these changes were not statistically significant ($p > 0.05$).

The comparisons of the data obtained from both groups in the T1 and T2 periods are shown in Tables 5 and 6, respectively. The results showed no significant differences in any parameter between the groups in the T1 and T2 periods ($p > 0.05$).

Table 3. Descriptive statistics and comparison of preoperative and postoperative airway volumes of Group 1

		T0		T1		T0-T1		
Parameters (cm^3)	n	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	p
TV	16	23.78	9.69	24.87	8.85	1.09	5.91	0.47
NV	16	10.1	3.43	10.76	3.85	0.67	2.54	0.3
OV	16	13.68	6.73	14.11	5.52	0.42	3.89	0.67
Min-Ax (mm^2)	16	239.54	150.36	251.96	131.69	12,41	99.38	0.62

* Note: TV = Total volume; NV = Nasal volume; OV = Oropharyngeal volume; Min-Ax = Minimal axial area; T0 = Before surgery; T1 = After surgery; SD = Standard deviation.

Table 4. Descriptive statistics and comparison of preoperative and postoperative airway volumes of Group 2

		T0		T1		T0-T1		
Parameters (cm^3)	n	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	p
TV	11	20.61	4.07	22.76	8.5	2.15	7.67	0.37
NV	11	8.94	3	10.58	3.8	1.65	2.47	0.051
OV	11	11.67	2.92	12.17	5.49	0.5	5.63	0.77
Min-Ax (mm^2)	11	197.32	45.73	184.89	75.29	-12,43	94.94	0.67

* Note: TV = Total volume; NV = Nasal volume; OV = Oropharyngeal volume; Min-Ax = Minimal axial area; T0 = Before surgery; T1 = After surgery; SD = Standard deviation.

Table 5. Comparison of the preoperative airway parameters of Group 1 and Group 2

	Group 1			Group 2			
Parameters (cm^3)	$\bar{x}$	SD	SE	$\bar{x}$	SD	SE	p
TV	23.78	9.69	2.42	20.61	4.07	1.23	0.25
NV	10.1	3.43	0.86	8.94	3	0.91	0.37
OV	13.68	6.73	1.68	11.67	2.92	0.88	0.3
Min-Ax (mm^2)	239.4	150.36	37.59	197.32	45.73	13.79	0.3

* Note: TV = Total volume; NV = Nasal volume; OV = Oropharyngeal volume; Min-Ax = Minimal axial area; SD = Standard deviation; SE = Standard error.

Table 6. Comparison of the postoperative airway parameters of Group 1 and Group 2

	Group 1			Group 2			
Parameters (cm^3)	$\bar{x}$	SD	SE	$\bar{x}$	SD	SE	p
TV	24.87	8.85	2.21	22.76	8.5	2.56	0.54
NV	10.76	3.85	0.96	10.58	3.8	1.14	0.9
OV	14.11	5.52	1.38	12.17	5.49	1.66	0.37
Min-Ax (mm^2)	251.96	131.69	32.92	184.89	75.29	22.7	0.14

* Note: TV = Total volume; NV = Nasal volume; OV = Oropharyngeal volume; Min-Ax: Minimal axial area; SD = Standard deviation; SE = Standard error.

Discussion

Significant changes that occur in skeletal structures after BMS may affect the PAS. This study aimed to evaluate PAS changes in skeletal Class III patients using CBCT following BMS.

Previous studies (2, 15, 16) evaluated the effects of BMS on PAS between different postoperative intervals, such as 3 months, 6 months, or 1 year, while some of them (17) did not provide any information. Postoperative edema occurring after BMS in the pharyngeal structures may adversely affect the PAS, and it was reported that the measurements obtained 5-8 months after BMS might be more reliable (12). Therefore, patients with T2 data collected at least 5 months after BMS were included in the present study.

Some studies (17, 18) evaluated only the TV, while others (1, 2, 13, 19) divided the PAS into 2 or 3 segments. Moreover, different upper and lower borders have been used in various studies. The important parameters used in PAS evaluations are TV and Min-Ax. (20) Thus, the Min-Ax, TV, OV, and NV parameters were evaluated.

In most studies examining the effect of BMS on PAS, the amount of skeletal movement was reported, but in some, no information was given about the amount of skeletal movement (1, 2, 13, 17). In Group 1, insignificant increases occurred in all PAS parameters following different amounts of surgical movement after MMA. Although there was some decrease in the long term (16, 21), there were significant increases in the airway after MMA, and these increases were maintained in the long term (3, 12, 22-26). It has also been reported that increases in PAS following MMA lead to improved postoperative polysomnography (PSG) recordings in OSA patients (27). There is a consensus in the literature that MMA positively affects PAS, similar to the present study.

Studies by Jakobsone et al. (11), Azevedo et al. (17), Hatap et al. (13), de Souza Pinto et al. (28), and Vaezi et al. (29) reported no significant differences in the PAS parameters after MAMS, similar to the present study. Panou et al.(1) reported no significant difference between the UV and Min-Ax parameters in patients treated by MAMS, while a significant reduction was found in LV and TV in males. The lack of assessment of the relationship between PAS and gender could be considered a weakness of the present study. Similarly, some studies did not evaluate the effect of gender on PAS following MAMS, but others have reported no significant differences (12, 28, 30). Another study (12) reported an average increase in the TV of 6% and a decrease in Min-Ax of approximately 10% due to MAMS. He et al. (31) reported no significant differences in the NV and OV parameters, while significant decreases were found in the TV and LV parameters following MAMS. In the current study, a 10.4% increase in the TV and a 6.2% decrease in the Min-Ax were found following MAMS.

Studies have also reported a significant increase (18, 25) or decrease (8, 14) in all PAS parameters after MAMS. In Lee et al.'s (14) study, the amount of skeletal movement was not stated, and a significant decrease was reported in the TV and UV parameters following MAMS. Kim et al. (8) reported a significant decrease in the TV and Min-Ax parameters after MAMS (mean maxillary advancement: 0.5 mm, mean MSB: 6 mm) that did not change for up to 6 months postoperatively. However, Kang et al. (2) reported that the OV and TV parameters decreased significantly after MAMS but returned to their original levels within 1 year. The skeletal Class III anomalies were mainly treated by MSB surgery rather than maxillary advancement in these studies (2, 8). Although the opposite has been claimed, (32) most of the studies reported that the treatment of skeletal Class III anomalies with mainly MSB causes a decrease in PAS (2, 13, 33). This narrowing may vary from one individual to another depending on the amount of MSB and the patient's weight (34). Therefore, limited amounts of MSB should be performed in MAMS surgeries. However, due to the limitations in the amount of jaw movement as well as aesthetic and functional considerations, different amounts of MSB are inevitable in BMS. Although different amounts of MSB were performed on the participants in Group 2 of this study, there were no decreases in the TV, UV, and LV parameters. However, a reduction in the Min-Ax parameter may lead to negative results in the long term. One of the biggest worries is the risk of patients developing OSA after BMS, and an association between OSA and the Min-Ax parameter has been reported in that the lower the Min-Ax is, the greater the risk of OSA (27). However, there is disagreement on whether the PAS changes that occur after BMS are maintained in the long term (2, 8, 16). Differences in the methods, the amount of skeletal movement, the patients' weight, and observation periods make it difficult to directly compare studies. Even if compared, it is also difficult to determine whether volumetric increases or decreases that occur in the PAS will affect the patient's quality of life with the use of CBCT (22). Kitagawara et al. (35) evaluated the arterial oxygen saturation (SpO_2) of patients and reported that SpO_2 values, which decreased immediately after the operations, returned to normal levels 1 month after MSB surgery. Most patients may adapt to the new situation; however, OSA might develop as a result of large amount of MSB in obese individuals. The lack of an assessment of the relationship between body mass index (BMI) and changes in PAS can be considered a weakness of the present study. However, BMI information was not available in the patients' records.

There are limited studies (12, 25) comparing the effect of MMA and MAMS on PAS. Bin et al. (25) compared the effects of MAMS and MMA and reported that both methods did not adversely affect the PAS, similar to the present study. However, Brunetto et al. (12) reported that the effects of MAMS on the Min-Ax parameter are not predictable, while the change after MMA can be estimated more reliably. In the present study, the preoperative PAS parameters were slightly larger in Group 2 than Group 1. Additionally, increases in postoperative PAS parameters except the Min-Ax were larger in Group 2 than in Group 1. In a recent long-term study, Trevisiol et al. (21) demonstrated that the increase in PAS after surgery is greater in patients with a small airway. Therefore, preoperative airway records may be useful for providing information about PAS changes after BMS.

Skeletal changes resulting from BMS are associated with varying degrees of increase or reduction in PAS, whether statistically significant or not (1, 11-13). To objectively examine the effect of these volumetric changes on patients' quality of life, long-term studies on patients with similar amounts of skeletal movement using different methods such as the Apnea-Hypopnea index, PSG and Epworth Sleepiness Scale are needed.

Conclusions

Based on the skeletal movement achieved in the present study, no significant differences were found between the PAS parameters of Groups 1 and 2. However, considering the effect on the Min-Ax parameter, the amount of mandibular setback achieved with MAMS needs to be carefully evaluated.

Ethical Approval: Ethics committee approval was received for this study from Scientific Research Ethics Committee of Dicle University Faculty of Dentistry, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2019/9.

Peer-review: Externally peer-reviewed.

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