Pharyngeal Airway Changes in Class III Patients Treated With Double Jaw Orthognathic Surgery—Maxillary Advancement and Mandibular Setback

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Purpose: The pharyngeal airway may change after skeletal movement in patients who have undergone orthognathic surgery. The aim of this study was to evaluate the skeletal and pharyngeal airway changes in subjects with a Class III facial pattern who underwent double-jaw surgery (maxillary advancement and mandibular setback).

Materials and Methods: The present retrospective study assessed preoperative (T0), 2- to 4-month postoperative (T1), and 6- to 12-month postoperative (T2) radiographs of subjects with a Class III facial pattern treated at São Lucas Hospital (Porto Alegre, Brazil) using imaging software (Dolphin Imaging 3D 11.5). Five measurements of the pharyngeal airway space (nasopharynx; upper, middle, and lower oropharynges; hypopharynx) were evaluated and correlated with the skeletal movement of the jaws (lines perpendicular to the Frankfurt horizontal plane passing through the nasion point to points A and B). The Student *t* test for paired samples was used to assess the presence of significant differences between the intervals, and the Spearman correlation coefficient was used to assess the significant correlation existing between the skeletal movement and the pharyngeal airway changes. The results were considered at a maximum level of significance of 5% ($P < .05$).

Results: In the sample of 58 subjects (38 female and 20 male, 18 to 48 years old), measurements of the nasopharynx, upper oropharynx, and middle oropharynx increased, whereas measurements of the lower oropharynx and hypopharynx decreased during these periods (T0 to T1, T0 to T2). Decreases from T1 to T2 in the measurements of the nasopharynx and upper oropharynx were also identified. A correlation between the jaw movements and the change in airway measurement was found between the line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point A and the nasopharynx and between the line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point B and the lower oropharynx for T0 to T1 and T0 to T2.

Conclusions: A correlation between skeletal movements and changes in the measurements of pharyngeal airway was found between maxillary advancement and the nasopharynx, with proportions of 102.8% and 85.5% in the short and medium terms, respectively, and between mandibular setback and the low oropharynx, with proportions of 44.8% and 43.5% in the short and medium terms. A correlation for

Received from the Department of Oral and Maxillofacial Surgery, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil.

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0278-2391/12/7011-0$36.00/0
http://dx.doi.org/10.1016/j.joms.2012.07.052

pharyngeal airway measurements was found between those located anatomically near each other, showing the importance of the pharyngeal muscles in this relation.
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J Oral Maxillofac Surg 70:e639-e647, 2012

Orthosurgical treatment is indicated for correcting facial deformities in patients with a Class III facial pattern. Changing the position of the jaws, particularly the mandible, tongue position, and pharyngeal airway space, also changes the morphology. Previous studies have reported that the narrowing or widening of the pharyngeal airway space is related to mandibular setback or advancement surgery, respectively.[1-3]

Lateral cephalometric radiography remains an important imaging tool in surgical planning. It allows the maxillofacial surgeon to plan the surgery and collect relevant information about the hard and soft tissue structures and the airway space. Although radiographic imaging provides only 2-dimensional images for the evaluation of the pharyngeal airway, it is still used to evaluate sleep disorders and skeletal deformities.[1,2,4] The advantages of cephalometric radiography include its wide availability, simplicity, low expense, and ease of comparison with other studies.[4,5] In addition, significant differences may be found in cephalometric measurements between patients with obstructive sleep apnea syndrome (OSAS) and those without OSAS.[5]

Based on lateral cephalometric analysis, many studies have indicated that the most frequent anatomic alterations associated with OSAS are posterior positioning of the hyoid bone and the base of the tongue, resulting in pharyngeal narrowing. These studies attempted to investigate the effect of orthognathic surgery (OS) on the pharyngeal airway space.[1,2,6] However, most investigated the effects of surgery performed only in the mandible. Maxillomandibular advancement surgery has proved to be an effective option for treating OSAS, because it enlarges the pharyngeal airway space and tightens the upper airway muscles and tendons by advancing the osseous origins. Conversely, the pharyngeal airway space seems to become narrow after mandibular setback, with a risk of developing OSAS. This risk has been confirmed in some patients who underwent OS for mandibular setback, increasing the attention of studies to airway narrowing.[1,2,6]

The benefits produced by OS have been well described for patients with congenital or acquired sleep disorders, but the effect in patients without this condition is a controversial issue not fully described in the literature.[1,7,8] According to Foltán et al,[8] some investigators have affirmed that these alterations are temporary, whereas others have considered them permanent and prone to future worsening owing to mandibular setback surgery associated or not with maxillary advancement. A follow-up period with long-term changes in the upper airway space has been suggested when surgeries involving mandibular setback are performed.[6]

The purpose of this study was to evaluate the changes in the pharyngeal airway after skeletal movements in subjects with a Class III facial pattern who underwent double-jaw surgery (maxillary advancement and mandibular setback) and did not develop sleep disorders. The hypothesis of the present study was that skeletal changes in the maxilla and mandible could affect the measurements of the pharyngeal airway space and that changes at different points of the pharyngeal airway could affect one another. The specific aims of this study were to *1)* evaluate the significant difference between the pre- and postoperative periods and between 2 postoperative periods for each measurement analyzed; *2)* evaluate the significant correlation and proportion between the jaw movement and the measurements of the pharyngeal airway space in the short and medium terms; and *3)* evaluate the significant correlation and proportion only between the measurements of the pharyngeal airway space in the short and medium terms.

Materials and Methods

STUDY DESIGN/SAMPLE

To address the research purpose, the authors conducted a retrospective study evaluating the measurements on lateral cephalometric radiographs of subjects with a Class III facial pattern who underwent double-jaw OS. Radiographs taken 1 week before surgery (T0), 2 to 4 months after surgery (T1), and 6 to 12 months after surgery (T2) were measured and compared. In the study population, all patients underwent maxillary advancement and mandibular setback in horizontal movements, with vertical movement being smaller than 3 mm in all cases. Surgeries were performed under general anesthesia with rigid internal fixation using titanium plates and screws. All patients received the same treatment with regard to the surgical technique: Le Fort I osteotomy to allow maxillary movement, bilateral sagittal osteotomy of the mandibular ramus to allow mandibular movement, fixation with 4 “L” miniplates in the maxilla, 1 miniplate, and 1 bicortical screw on each side of the

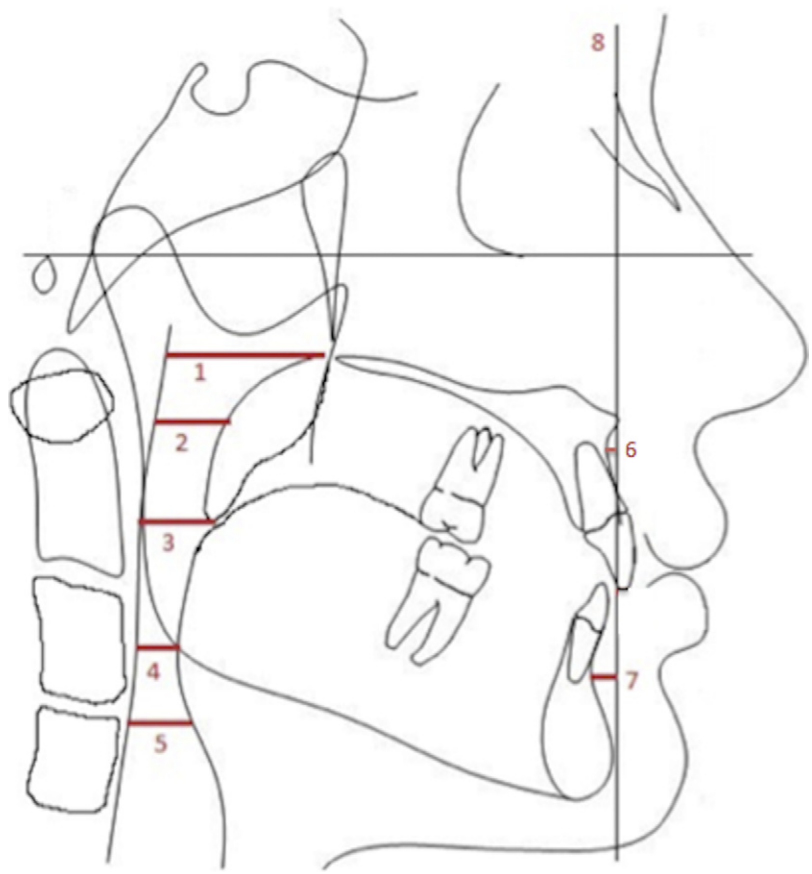

FIGURE 1. Measurements of the pharyngeal airway space and hard tissue points related to the line perpendicular to the Frankfurt horizontal plane passing through the nasion point. *1,* nasopharynx; *2,* upper oropharynx; *3,* middle oropharynx; *4,* lower oropharynx; *5,* hypopharynx; *6,* line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point A; *7,* line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point B; *8,* line perpendicular to the Frankfurt horizontal plane passing through the nasion point.

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mandible with a 2.0 Neoface System miniplate (NeoOrtho, Curitiba, Paraná, Brazil). All patients received the same pre- and postoperative care.

To be included in the study sample, the patients had to fulfill the following criteria: *1)* have a Class III facial pattern before surgery; *2)* have undergone double-jaw surgery (maxilla advancement and mandibular setback); and *3)* have received the surgical and fixation technique described earlier. Patients were excluded as study subjects if they *1)* underwent OS or had facial trauma before the double-jaw OS surgery was evaluated; *2)* underwent 1-jaw OS; *3)* had vertical movement greater than 3 mm; and *4)* had congenital or acquired sleep disorders or other systemic diseases or syndromes.

VARIABLES

To conduct the study, the T0, T1, and T2 intervals were evaluated.

Several published articles have characterized the airway division in different ways. There is no consensus in the literature for an established standard pattern of airway division. Thus, the authors of the present study assessed 5 airway measurements for each interval: the nasopharynx; the upper, middle, and lower oropharynges; and the hypopharynx. To correlate these measurements to the skeletal movement performed, the distances from the lines perpendicular to the Frankfurt horizontal plane passing through the nasion point (n-perp) to points A (A-n-perp) and B (B-n-perp) were also measured (Fig 1, Table 1).

DATA COLLECTION METHODS

The radiographs of all patients were obtained at the radiology service of the School of Dentistry, Pontifical Catholic University of Rio Grande do Sul using a PM 2002 CC proline panoramic imaging unit (Planmeca, Helsinki, Finland).

Radiographs were digitized using an HP Scanjet G4050 scanner (Hewlett-Packard Company, Palo Alto, CA) and then imported into Dolphin Imaging 3D 11.5 (Dolphin Imaging Software, Canoga Park, CA) to perform the cephalometric tracing and mea-

Table 1. AIRWAY MEASUREMENTS AND DISTANCES OF THE MAXILLA AND MANDIBLE TO THE LINE PERPENDICULAR TO THE FRANKFURT PLANE PASSING THROUGH THE NASION POINT

Measurement	Description
Nasopharynx	Distance from the posterior nasal spine to the nearest point in a straight line on the posterior wall of the nasopharynx
Upper oropharynx	Distance from the midpoint of the image of the posterior wall of the soft palate to the nearest point in a straight line into the posterior oropharynx
Middle oropharynx	Distance from the lowest point of the image of the soft palate to the nearest point in a straight line into the posterior oropharynx
Lower oropharynx	Distance from the anterior wall of the oropharynx at the time of its radiographic image crosses the mandibular angle to the nearest point in a straight line into the posterior oropharynx
Hypopharynx	Distance from the anterior and posterior wall of the hypopharynx in a straight line at the same level of the most superior to anterior point of the fourth cervical vertebra (C4)
A-n-perp	Hard tissue A point to n-perp—to measure the forward movement of the maxilla
B-n-perp	Hard tissue B point to n-perp—to measure the setback of the jaw

Abbreviation: n-perp, line perpendicular to the Frankfurt horizontal plane passing through the nasion point.

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sure the distances between the specific cephalometric points.

All radiographs were taken with a standard length marker of 50.0 mm. The lateral cephalometric analyses were performed with images totally calibrated by Dolphin Imaging 3D 11.5. In the digitalizing setup of Dolphin Imaging 3D, the ruler length was 50.0 mm. This ruler length was set because the head-holder nosepiece of the imaging system is set at 50.0 mm. In the digitalization menu of Dolphin, the first option is to mark ruler point 1. At this time, the topmost graduation was marked in the head-holder nosepiece ruler and the same was performed to ruler point 2 at the bottommost graduation.

The software provides a sequence for locating the main cephalometric points, magnifying the image to define the positions. After the indication of the determined points, the software connects the points to form a recognizable image of the tracing, which may be adjusted manually, if necessary. Selection analysis was then chosen.

This software allows the customization of a new analysis from measurements of existing analyses or the creation of new measurements according to the professional's need. For the present research (Fig 1), a customized cephalometric analysis was created (based on airway studies by Marşan et al[1] and Sears et al[2]) and then selected in the software for the evaluation of the desired measurements.

DATA ANALYSIS

One examiner performed all the tracings, and 10% of the tracings were repeated after 2 months by the same examiner and by a more experienced examiner (gold standard). To evaluate the intra- and extra-examiner agreements, the intraclass correlation coefficient was used. To assess the normality of the data, the nonparametric Kolmogorov-Smirnov test was used.

For every measurement, the Student *t* test for paired samples was used to assess the presence of significant differences between the pre- and postoperative periods (T0 vs T1 and T0 vs T2) and between the 2 postoperative periods (T1 vs T2) to evaluate any relapse.

To assess an existing significant correlation between the skeletal movement and the pharyngeal airway measurements observed between the pre- and postoperative intervals (T1 vs T0 and T2 vs T0) and between the 2 postoperative intervals (T2 vs T1 in relapse), the Spearman correlation coefficient was used, because normality in the data representing movement among the intervals assessed was not observed (T1 vs T0, T2 vs T0, and T2 vs T1).

The results were considered at a maximum level of significance of 5%, at which the values found for a *P* value lower than .05 reject the null hypothesis that there is no significant difference between the pre- and postoperative periods and between the 2 postoperative periods for each measurement analyzed. No significant correlation of proportion was found between the skeletal changes in the maxilla and mandible and the pharyngeal airway measurements among the intervals evaluated. For the processing and analysis of the data, SPSS 18.0 for Windows (SPSS, Inc, Chicago, IL) was used.

This research was approved by the local institutional review board of the Pontifical Catholic University of Rio Grande do Sul.

Results

The lateral cephalometric radiographs of 58 patients with a Class III facial pattern (38 women and 20

Table 2. DESCRIPTIVE STATISTICS OF MEASUREMENTS EVALUATED AT T0, T1, AND T2 AND CHANGES (MILLIMETERS) DURING MOVEMENT FROM T0 TO T1, T0 TO T2, AND T1 TO T2

	T0		T1		T2	
	Mean (SD)	Max/Min	Mean (SD)	Max/Min	Mean (SD)	Max/Min
A-n-perp	−1.09 (3.95)	−10.4/7.4	2.75 (4.47)	−9.2/13.8	2.77 (4.47)	−9.2/13.1
Nasopharynx	25.23 (4.42)	12.8/35.7	29.19 (4.46)	17.7/40.0	28.55 (4.17)	17.6/38.3
Upper oropharynx	14.93 (3.39)	9.1/24.9	17.45 (3.93)	10.9/26.3	16.82 (3.48)	10.8/26.4
Middle oropharynx	12.08 (3.43)	6.1/22.4	13.64 (3.61)	6.2/23.8	13.42 (3.29)	6.7/24.8
B-n-perp	5.02 (8.49)	−15.0/31.8	−0.15 (7.77)	−20.9/19.8	−0.06 (7.73)	−20.4/19.1
Lower oropharynx	14.53 (4.02)	7.2/26.7	12.21 (3.89)	4.7/23.5	12.32 (3.85)	4.5/23.4
Hypopharynx	12.34 (3.57)	7.0/22.1	10.10 (3.15)	5.2/20.8	10.26 (3.03)	5.6/20.8
	T0 to T1		**T0 to T2**		**T1 to T2**	
	Mean (SD)	Max/Min	Mean (SD)	Max/Min	Mean (SD)	Max/Min
A-n-perp	3.85‡ (2.00)	0.1/8.0	3.87‡ (1.97)	0.2/8.2	−0.01§ (0.36)	−0.7/0.8
Nasopharynx	3.96‡ (3.22)	0.0/12.9	3.31‡ (2.56)	−0.3/9.4	−0.64† (1.74)	−4.5/3.0
Upper oropharynx	2.51‡ (2.0.5)	−0.6/7.5	1.89‡ (1.42)	0.0/5.9	−0.62† (1.52)	−4.6/2.0
Middle oropharynx	1.55‡ (1.47)	−0.5/7.1	1.33‡ (1.42)	−1.0/6.5	−0.21§ (1.43)	−3.6/2.9
B-n-perp	−5.17‡ (3.09)	−12.9/−0.2	−5.08‡ (2.90)	−13.2/−0.9	0.08§ (0.49)	−0.8/1.1
Lower oropharynx	−2.32‡ (1.73)	−6.9/−0.2	−2.21‡ (1.43)	−5.8/−0.1	0.11§ (1.27)	−2.1/5.4
Hypopharynx	−2.24‡ (2.10)	−8.6/0.1	−2.08‡ (1.91)	−7.8/0.5	0.16§ (1.42)	−3.2/4.4

Abbreviations: A-n-perp, line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point A; B-n-perp, line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point B; Max, maximum; Min, minimum; SD, standard deviation; T0, preoperative; T1, 2 to 4 months postoperative; T2, 6 to 12 months postoperative.
†$P < .01$, ‡$P < .001$, significant differences.
§Not significant.

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men; 18 to 48 years old; mean, 27.3 years old) who underwent double-jaw OS were evaluated at T0, T1 (mean, 2.8 mo), and T2 (mean, 9.3 mo).

A strong agreement between intra- and inter-examiners was observed (intraclass correlation coefficient 0.900 for both situations for all points evaluated). Table 2 lists the values obtained for each measurement evaluated at T0, T1, and T2, the changes found for each of these measurements during movement from T0 to T1, T0 to T2, and T1 to T2, and results of the Student *t* test for paired samples. Positive values indicate an increase in measurements and negative values indicate a decrease. Significant alterations ($P <$ .001) between the preoperative period and the 2 postoperative periods (T0 to T1 and T0 to T2) were identified for each measurement analyzed. Significant changes were also seen between the 2 postoperative intervals (T1 to T2) in the nasopharynx and upper oropharynx ($P < .01$).

The existing correlation, observed with the Spearman correlation coefficient, between airway measurements and measurements related to the n-perp during movement found from T0 to T1, T0 to T2, and T1 to T2 are presented in Table 3. The proportion of airway movement related to the points associated with the n-perp was also recorded.

During the movement from T0 to T1, a significant correlation between the lower oropharynx and B-n-perp ($P < .05$) and between the nasopharynx and A-n-perp ($P < .001$) was identified. The movement proportions were 102.8% and 44.8% between the nasopharynx and A-n-perp and between B-n-perp and the lower oropharynx, respectively.

Similarly, a significant correlation was observed from T0 to T2 between the lower oropharynx and B-n-perp ($P < .05$) and between the nasopharynx and A-n-perp ($P < .01$). The movement proportions were 85.5% between the nasopharynx and A-n-perp and 43.5% between the lower oropharynx and B-n-perp. In contrast, no significant correlations between the measurements were observed from T1 to T2.

A certain correlation was observed only between airway measurements during movement found from T0 to T1, T0 to T2, and T1 to T2. These correlations are listed in Table 4. From T0 to T1, a correlation was found between the lower oropharynx and the hypopharynx ($P < .05$) and between the upper oropharynx and the nasopharynx; from T0 to T2, a correlation was found between the upper oropharynx and the middle oropharynx, between the upper oropharynx and the lower oropharynx ($P < .05$), and between the upper oropharynx and the nasopharynx. From T1 to T2, no correlation was identified. When analyzing only the airway measurements, a strong correlation was found between the upper oropharynx and the nasopharynx from T0 to T1 (63.3%) and from T0 to T2

Table 3. PROPORTION AND CORRELATION BETWEEN PHARYNGEAL AIRWAY MEASUREMENTS AND MEASUREMENTS RELATED TO SKELETAL MOVEMENT DURING MOVEMENT FROM T0 TO T1, T0 TO T2, AND T1 TO T2

	T0 to T1		T0 to T2		T1 to T2	
	A-n-perp	B-n-perp	A-n-perp	B-n-perp	A-n-perp	B-n-perp
Nasopharynx	102.8%‡	—§	85.5%†	—§	6,400.0%§	—§
Upper oropharynx	65.1%§	—§	48.8%§	—§	6,200.0%§	—§
Middle oropharynx	40.2%§	—§	34.3%§	—§	2,100.0%§	—§
Lower oropharynx	—§	44.8%*	—§	43.5%*	—§	137.5%§
Hypopharynx	—§	43.3%§	—§	40.9%§	—§	200.0%§

Abbreviations: —, opposite movements (without cause-effect relation); A-n-perp, line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point A; B-n-perp, line perpendicular to the Frankfurt horizontal plane passing through the nasion point to point B; T0, preoperative; T1, 2 to 4 months postoperative; T2, 6 to 12 months postoperative.

*$P < .05$, †$P < .01$, ‡$P < .001$, significant differences (Spearman correlation).

§Not significant (Spearman correlation).

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(57.0%). From T0 to T1, a proportion of 103.5% was observed between the lower oropharynx and the hypopharynx; from T0 to T2, a proportion of 142.1% was observed between the upper oropharynx and the middle oropharynx and a proportion of 85.5% was observed between the upper oropharynx and the lower oropharynx.

Table 4. PROPORTION (FIRST VERSUS SECOND MEASUREMENT) AND CORRELATION BETWEEN ONLY AIRWAY MEASUREMENTS DURING THE MOVEMENT OBSERVED FROM T0 TO T1, T0 TO T2, AND T1 TO T2

Correlation of Airway Measurements	T0 to T1	T0 to T2	T1 to T2
Upper oropharynx and nasopharynx	63.3%‡	57.0%†	96.8%§
Upper oropharynx and middle oropharynx	161.9%§	142.1%*	295.2%§
Upper oropharynx and lower oropharynx	−108.1%§	−85.5%*	−563.6%§
Upper oropharynx and hypopharynx	−112.0%§	−90.8%§	−387.5%§
Nasopharynx and middle oropharynx	255.4%§	248.8%§	304.7%§
Nasopharynx and lower oropharynx	−170.6%§	−149.7%§	−581.8%§
Nasopharynx and hypopharynx	−176.7%§	−159.1%§	−400.0%§
Middle oropharynx and lower oropharynx	−66.8%§	−60.1%§	−190.9%§
Middle oropharynx and hypopharynx	−69.1%§	−63.9%§	−131.2%§
Lower oropharynx and hypopharynx	103.5%*	106.2%§	68.7%§

Note: A negative value indicates movement in the opposite direction.

Abbreviations: T0, preoperative; T1, 2 to 4 months postoperative; T2, 6 to 12 months postoperative.

*$P < .05$, †$P < .01$, ‡$P < .001$, significant differences (Spearman correlation).

§Not significant (Spearman correlation).

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Discussion

Skeletal changes caused by double-jaw OS may affect measurements of the pharyngeal airway. This study assessed the changes in the pharyngeal airway after skeletal movement observed in subjects with a Class III facial pattern who had undergone double-jaw surgery (maxillary advancement and mandibular setback). The aim of this study was to identify the correlations between certain airway measurements, in addition to the alterations and proportions of the changes and particular jaw movements in the short and medium terms. Degrees of relapse were found in the nasopharyngeal and upper oropharyngeal measurements. Correlations were found between the increase in the nasopharynx after maxillary advancement and the decrease in the lower oropharynx after mandibular setback in the short and medium terms. The correlation between different airway measurements, an aspect practically absent in other studies, was identified between measurements of the airway that are anatomically near one another.

In their meta-analysis, Mattos et al[9] commented that the alterations caused by mandibular advancement surgery may result in an increased airway space, as occurs in bimaxillary advancement. In contrast, a decrease in the airway dimensions associated with mandibular setback surgeries[10] has been reported, as shown by Athanasiou et al[11] and Gu et al.[12] However, currently, there is only moderate evidence to prove these assertions, because some investigators did not find alterations in the airway space after orthognathic surgery to correct an anteroposterior skeletal discrepancy.[9] In addition, the effects of bimaxillary surgery have not been fully described.[4] Some investigators have affirmed that bimaxillary surgery to correct a Class III skeletal deformity (maxillary advancement and mandibular setback) may have a lesser effect in decreasing the airway space than 1-jaw surgery (only mandibular setback).[9]

Eggensperger et al[13] evaluated the lateral radiographs of 32 patients who underwent mandibular setback surgery that were taken 1 week and 6 and 12 months postoperatively and observed a continuous decrease in the nasopharynx and oropharynx space; the hypopharynx remained virtually unaltered. Marşan et al,[3] Hochban et al,[14] Saitoh,[15] and Tselnik and Pogrel[16] have also reported decreases in the pharyngeal airway space after mandibular setback surgeries.

Chen et al[17] compared patients with a Class III facial pattern who underwent only mandibular setback with similar patients who underwent maxillary advancement associated with mandibular setback. In the first group, they found a significant decrease in the pharyngeal airway space in the oropharynx and hypopharynx 6 and 24 months after surgery; in the second group, an increase in the nasopharynx and oropharynx and a decrease in the hypopharynx were found after 6 months, but no significant alterations were found after 24 months. This shows that bimaxillary surgery has little effect on the pharyngeal airway space when compared with single mandibular setback. This is probably caused by the advancement of the velopharyngeal musculature, which might decrease constriction of the airway after mandibular setback. Demetriades et al[5] found similar results between these 2 groups and noted the 5-mm setback as being potentially critical for the development of OSA.

Marşan et al[1] found an increase in the nasopharynx and no alteration in the hypopharynx in patients with a Class III facial pattern who underwent bimaxillary surgery. Hasebe et al[10] did not find any differences in the pharyngeal airway space between these groups.

Pereira-Filho et al[4] found an increase in the nasopharyngeal space with long-term maintenance, an increase in the oropharynx with relapse in the long term, and a decrease in the hypopharynx with long-term maintenance for bimaxillary surgery in patients with a Class III pattern. These investigators did not report any significant alteration in the nasopharynx and oropharynx, and only a small decrease in the hypopharynx occurred after single mandibular setback; in contrast, an increase in the nasopharynx and oropharynx with no alteration in the hypopharynx occurred for single maxillary advancement, with great stability in the long term, probably because of the pharyngeal muscles. Samman et al[18] and Greco et al[19] presented similar findings for maxillary advancement. Degerliyurt et al[20] also compared the tomograms of patients with a Class III pattern treated only with mandibular setback with similar patients treated with bimaxillary surgery and found a decrease in the nasopharynx and oropharynx in the 2 groups, with a smaller decrease for the bimaxillary group.

The findings of this study indicate, in the short (T0 to T1) and medium (T0 to T2) terms, an increase in the nasopharynx, upper oropharynx, and middle oropharynx and a decrease in the lower oropharynx and hypopharynx. A decrease was also found in the nasopharynx and upper oropharynx from T1 to T2. The results are close to those found in the literature for this group of patients (Class III pattern undergoing bimaxillary surgery), with small variations.

However, a more thorough analysis of the correlation between the movements of the jaws and the pharyngeal airway in the short term (T0 to T1) showed a proportion of movement of 102.8% between the nasopharynx and A-n-perp (maxillary advancement) for patients with a Class III pattern who underwent double-jaw OS, which indicated a response higher than 100% for the pharyngeal airway space at this level in relation to the maxillary movement. Between the lower oropharynx and B-n-perp (mandibular setback), the proportion was 44.8%, indicating a decrease in airway space in the region of the lower oropharynx, but in a different proportion to the decrease for mandibular setback.

In the medium term (T0 to T2), the proportion of movement between the nasopharynx and A-n-perp (maxillary advancement) was 85.5%; although lower than from T0 to T1, this proportion still reflects almost entire maxillary advancement. Between the lower oropharynx and B-n-perp (mandibular setback), the proportion was 43.5%, practically the same as from T0 to T1.

A certain correlation was also identified in relation to the movement between airway measurements from T0 to T1 and from T0 to T2. For these periods, a strong correlation was found between the upper oropharynx and the nasopharynx from T0 to T1 (proportion, 63.3%) and from T0 to T2 (proportion, 57.0%). This could be explained by the traction exerted through the velopharyngeal musculature caused by maxillary advancement. Nearby points tended to exhibit correlated movements. From T0 to T1, this was observed between the lower oropharynx and the hypopharynx (proportion, 103.5%) and from T0 to T2 between the upper oropharynx and the middle oropharynx (proportion, 42.1%) and between the upper oropharynx and the lower oropharynx (proportion, 85.5%); the latter 2, even if in opposite directions (owing to opposite movements of the jaws), are relatively nearby structures that may present clinical correlations through the pharyngeal musculature.

Studies comparing the evaluation of airway space between radiographs and tomograms have differed in their conclusions. Although Sears et al[2] found a small correlation between these 2 imaging techniques in the region of the nasopharynx and hypopharynx (but a strong correlation in the oropharynx), Abramson et al[21] and Marşan et al[1] found a strong correlation between linear measurements evaluated on radiographs and the volume of airway space on tomograms, even if at different levels.

Riley and Powell[22] reported a significant correlation between the pharyngeal airway space measured on cephalometric radiographs and oropharynx airway measurements. Park et al[23] found a significant linear decrease in the area or volume in the measurements of the soft palate and the base of the tongue, whereas Jakobsone et al[24] observed a substantial increase in the volume of the oropharynx in patients with a Class III facial pattern who underwent bimaxillary surgery. For Pereira-Filho et al,[4] these results indicated that a study based on lateral radiographs is still a proper method to evaluate the pharyngeal airway space, although tomograms show more details.

A relapse occurs in the airway region, but never to the level that was present in the preoperative period. This suggests that the anatomic and physiologic expansion of the airway space is limited after jaw advancement and the surgeon should compensate in surgical movements for the long-term results of the airway space if the aim of the surgery is to treat OSAS.[2] In this study, significant changes in the nasopharynx and upper oropharynx from T1 to T2 were identified. However, no significant correlations were observed from T1 to T2 between the airway measurements and the skeletal movement, probably because changes in the airway space and skeletal measurements in relation to the n-perp were so small (mean, <1 mm) that it hindered the establishment of correlations. Radiographs at T1 were taken 2 to 4 months after surgery. A significant relapse may have occurred in these first 2 to 4 months after surgery that was eliminated from the study. Unfortunately, this fact complicates the evaluation of stability and relapse. It is important to state that there were probably no noticeable clinical effects even for the measurements that showed a statistically significant degree of accommodation.

The hypothesis that bimaxillary surgery to correct Class III deformities could have a lesser effect on the decrease in the oropharynx than only mandibular setback surgery has yet to be proved.[9] According to Foltán et al[8] and Demetriades et al,[5] this type of surgery increases the resistance against the passage of air in the posterior airway space, probably because of the more dorsal position of the base of the tongue, and in some cases may lead to the development of OSAS.

The existing literature about the effects of OS on OSAS is still controversial.[5] The possible effect of OS on respiratory function during sleep was first mentioned by Guilleminault et al.[25] OSAS has been the object of many studies because it can be treated after bimaxillary advancement, it may be attenuated by mandibular advancement, and it can be aggravated or the patient can develop it after mandibular setback surgery.[9]

Many studies have shown the effectiveness of double-jaw advancement for patients with OSAS.[2,10] OS has shown a higher success rate than other frequently used procedures to treat OSAS, such as uvulopalatopharyngoplasty, hyaloid suspension, and genioglossus advancement. Patients commonly report subjective improvements greater than those evidenced in objective tests, such as the increase in the posterior airway space seen on the lateral radiograph.[2]

The potential impact of OS on the upper airways should be incorporated into the treatment plan. Although the number of confirmed cases of the development of OSAS in patients who underwent mandibular setback and did not show previous symptoms is small compared with the number of surgeries performed worldwide, the risk factors for OSAS, such as an unfavorable anatomy, smoking, age, and obesity, in patients with a Class III deformity should be observed.[5,7] In these situations, maxillary advancement surgeries or double-jaw surgeries (maxillary advancement and mandibular setback) are preferred instead of only mandibular setback. Some patients with a Class III pattern present an augmented pharyngeal airway space before surgery, so a small setback may have no clinical repercussion; however, patients with a previously normal airway space should receive an even smaller setback. Mentum advancements may be an alternative in these cases.[4] In this study, none of the patients presented previous signs or symptoms of OSAS or developed them in the postoperative period up to the present, even in great mandibular setback movements (the greatest was 12.9 mm), showing the adaptive capacity of the pharyngeal musculature in patients with no predisposition to OSAS.

According to Hellsing,[26] a change in the natural head position with an extension of 20° can result in increased airway dimensions. The head position in this study could be controlled once all radiographs were taken at the same service using the same device. The position of the tongue during image acquisition is another issue that may affect the results[9] and may cause biased results. In the literature, the great variability used to characterize the airway division can be a factor that complicates the comparison of results among several published articles. The effects of the jaw movement over the pharyngeal airway space also varies with the extent of this movement; however, the division of a sample into smaller groups according to the degree of movement could lead to a very small number of individuals in each group with a large difference in the size of the sample between the groups, which could hinder statistical analysis. The same applies to the division of the sample using gender. However, the use of a consistent and controlled study design, the method of data acquisition and statistical analyses, reliable computer programs, and a sample that followed specific inclusion and exclusion criteria made the results reliable to apply in clinical routine.

In the present study, significant changes were observed in every measurement of the pharyngeal airways and skeletal movement from the preoperative period to the postoperative periods in the short and medium terms. Between the 2 postoperative periods, significant changes were found in the nasopharyngeal and upper oropharyngeal measurements (mean values, 0.64 and 0.62 mm). The results are in agreement with those described in the literature, with some variations. Correlations were found between the airway measurements and skeletal movement by the increase in the nasopharynx with maxillary advancement (102.8% and 85.5%) and the decrease in the lower oropharynx with mandibular setback (44.8% and 43.5%) in the short and medium terms, respectively. Correlations were found between airway measurements located anatomically near each other, showing the importance of the pharyngeal musculature in this relation, an aspect that has not been sufficiently discussed in published articles. There was no correlation between the changes in any measurements during the 2 postoperative periods. Further research on the changes in the pharyngeal airway space associated with OS are needed and will benefit from the constant technologic developments, such as computed tomographic scans and computer programs.

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