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Three-dimensional evaluation of superior airway space after orthognathic surgery with counterclockwise rotation and advancement of the maxillomandibular complex in Class II patients

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Objective. The aim of this study was to assess changes in the superior airway space (SAS) in Class II patients undergoing orthognathic surgery with counterclockwise rotation of the maxillomandibular complex (MMC).

Study Design. A total of 23 patients (15 females and 8 males; mean age, 33 years) with symptoms of respiratory disease (mouth breathing) were studied. The patients were subjected to computed tomography analyses at two time intervals: T1 (preoperatively) and T2 (postoperative minimum of 6 months). The computed tomography images were exported to Dolphin Imaging 11.5 software to measure the surface area, minimum axial area, and volume of the SAS.

Results. The surgery (including a median mandibular advancement of 14 mm with an average rotation of 8 degrees) significantly increased the static SAS, with mean postoperative increases of 178 mm^2 in SA, 76.67 mm^2 in minimum axial area, and 10118.5 mm^3 in volume. A significant increase was also observed in the three-dimensional airspace following orthognathic surgery, which provided a greater permeability of the SAS in Class II patients.

Conclusions. This confirmed the efficacy of this technique in the treatment of respiratory disorders. (Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:453-458)

Angle's Class II dentofacial deformity is associated with a steep occlusal plane (OP) and shows mandibular retrognathia, increased anterior facial height, decreased posterior facial height, and a decrease in the pharyngeal airway space.[1]

Several bone structures and soft tissues, such as the soft palate, uvula, arch of the palate, tongue base and all suprahyoid muscles, hyoid bone, and epiglottis, can be directly or indirectly moved via orthognathic surgery.[1,2] Surgery with counterclockwise rotation of the OP is just one example. Anatomically, these structures are closely related to the area of the superior airway; manipulation of these structures may cause changes in this region. We report here the results of our study to better understand the dimensional changes of the superior airway space (SAS) after advancement surgery, as well as the dimensional movement stability following these changes, and devise specific treatment plans for this select group of patients.

In addition to correcting dentofacial deformities in patients with Class II, surgical maxillomandibular advancement (MMA) leads to a significant increase in SAS. The aerial improvement by this surgical technique in the retropalatal and retrolingual regions is secondary to the insertion of the soft palate in the posterior maxilla, together with the insertion of the muscles of the tongue, suprahyoid muscles in the genital tubercle, and the anterior movement inward.[1,3,4]

An additional important parameter regarding an increase in the airway in orthognathic surgery is the counterclockwise OP rotation. This movement causes advancement of the soft palate and leads to projecting of the chin anteriorly.[1,2,5-8]

Several methods or devices, such as the lateral cephalometric two-dimensional (2-D) radiography, computed tomography (CT), and three-dimensional (3-D) analysis software, are used to measure these changes.[2,9]

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Statement of Clinical Relevance

A significant increase has been seen in three-dimensional (3-D) airspace after orthognathic surgery with counterclockwise rotation of the maxillomandibular complex (MMC), which provides greater permeability of the upper airway in Class II patients, confirming the indication of this technique for the treatment of respiratory disorders.

Fig. 1. **A**, Preoperative and postoperative times showing the clinical results of surgery (facial profile). **B**, Preoperative and postoperative times showing the clinical results of surgery (intraoral view).

This study aims to evaluate the changes that occur in the SAS following combined movement, counterclockwise rotation of the ocular plane, and pogonion advancement using 3-D analysis software.

MATERIALS AND METHODS

The research project that led to the present study was submitted to, reviewed, and approved by the Research Ethics Committee of the Federal University of Uberlândia in Minas Gerais, Brazil (Proc. #206780/2013). This study follows all guidelines described by the Declaration of Helsinki.

For this study, 34 records were initially selected from a private maxillofacial surgery service in Salvador, Brazil. Several of the records were incomplete or inadequate. At the end of the selection process, a total of 23 medical records of Class II patients (15 females and 8 males; age range, 16-64 years; mean age, 33 years) who underwent orthognathic surgery with counterclockwise rotation of the maxillomandibular complex (MMC) were retrospectively evaluated. The degree of rotation ranged from 6 to 14 degrees. Patients were operated on by a single oral surgeon and his team between the years 2011 and 2012.

The inclusion criteria for the study were as follows: adult patients with respiratory disorders (mouth breathing), bearers of Angle's dentofacial Class II occlusion, orthognathic surgery with counterclockwise rotation of the MMC, patients whose medical records contained cone beam computed tomography (CBCT) at both

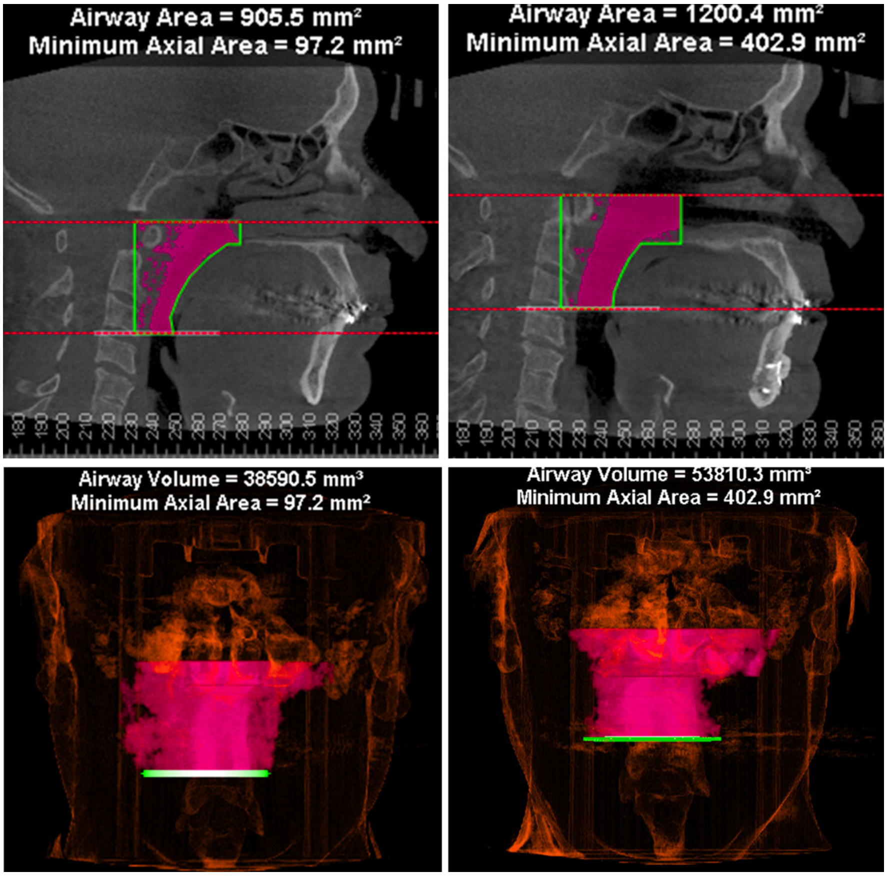

Fig. 2. Anatomic limits used in this analysis to determine volume (VOL), surface area (SA), and minimum axial area (MAA) (preoperative and postoperative).

preoperative and postoperative periods (minimum of 6 months from T1 to T2), bimaxillary advances from performing Le Fort I osteotomy in 1 or 3 segments, and bilateral sagittal osteotomy of the mandibular ramous with advancement of pogonion and counterclockwise rotation of the occlusal plane associated with genioplasty surgery (Figures 1A and 1B). All of the osteotomies were fixed by rigid internal fixation with titanium plates and screws. Patients who did not fit the above inclusion criteria, had craniofacial syndromes, experienced a Class I or III occlusion, or were subjected to previous orthognathic surgeries were excluded from this study.

Preoperative and postoperative CBCT scans were performed on a single machine, Kodak 9500 3-D cone beam radiography system (Carestream Health, Rochester, NY); there was a minimum of 6 months in the postsurgery CBCT group. The parameters of the CBCT were as follows: The patients were standing in a centric fashion with the Frankfurt plane parallel to both the horizontal plane and the floor; the procedure was standardized and supervised by a single technician (surgeon); the patient was in the supine position and was instructed to remain still, not to swallow and to hold the breath at the end of exhalation. An extended field of view (EFOV) with defined voxels from 0.25 to 0.30 mm and an exposure time of 9 seconds was used.

The CT images were converted into a DICOM file and exported to Dolphin Imaging 11.5 software (Dolphin Imaging and Management Solutions, Chatsworth, CA) to measure changes in the SAS. Using the 3-D features of the software, the orientations of the sagittal and axial planes were examined. The orbits were subsequently examined; the alignment was standardized and consisted of a head position in which the Frankfurt plane was parallel to the floor.

The software airway analysis tool was used to determine volume (VOL), surface area, and minimum axial area (MAA). Structures and landmarks were taken as reference to establish the limits of the oropharynx.

The anatomic limits used in this analysis were as follows:

- Upper boundary – parallel line to Frankfurt, located between the tooth of the axis, which corresponds to the line perpendicular to the Frankfurt plane and the tangent to the basion perpendicular to the tangent to the posterior border of the posterior nasal spine (PNS)[10]

Table I. Preoperative and postoperative results

Patient	Preoperative			Postoperative		
	Area mm^2	MAA mm^2	Volume mm^3	Area mm^2	MAA mm^2	Volume mm^3
1	740.1	97.0	15695.7	699.1	108.5	25160.9
2	692.4	87.8	21903.2	972.6	168.9	35283.9
3	570.8	58.8	16247.3	598.1	107.4	17997.2
4	635.7	94.0	21813.3	674.9	129.1	24944.2
5	619.3	191.2	18286.0	1291.4	126.8	46969.3
6	429.5	69.5	15090.7	998.4	97.2	35808.3
7	382.2	83.4	10721.0	771.1	138.4	17432.1
8	723.7	113.2	21207.6	742.9	249.8	35601.3
9	698.9	272.6	24068.5	947.3	376.6	33707.9
10	755.1	45.2	20130.0	763.4	109.8	23236.6
11	578.2	38.3	19850.9	530.4	63.6	20472.2
12	694.0	31.8	24461.9	897.0	147.7	40736.0
13	440.2	47.9	8857.3	658.6	115.0	19814.7
14	425.4	72.6	11246.9	744.5	144.4	30237.9
15	770.0	29.9	14297.1	1048.2	349.3	36451.1
16	631.5	113.8	22108.5	650.1	163.1	21444.9
17	552.0	162.1	21536.4	852.9	290.2	37103.3
18	925.3	154.0	25945.8	1008.5	393.5	37163.5
19	1111.1	410.6	40779.5	956.5	250.5	32322.3
20	587.1	41.9	18609.6	820.9	127.2	26854.1
21	623.9	110.4	21940.2	862.8	130.5	33898.1
22	905.5	97.2	38590.5	1201.7	402.9	53810.3
23	517.5	60.1	17576.2	412.1	54.8	17242.7
MEAN	652.58	107.9	20476.7	830.58	184.57	30595.2

MAA, Minimum axial area.

- Lower boundary – parallel line to Frankfurt, located between the lower limit of the third vertebra up to the anterior wall of the oropharynx
- Posterior boundary – line perpendicular to Frankfurt, extending from the end of the tooth Axis to the lower boundary of the third vertebra
- Anterior boundary – the anterior wall of the oropharynx (Figure 2)

An examiner and two reviewers were used to evaluate the reliability of our methods. The data were organized into a table to analyze the results.

The following measurements were estimated for a descriptive analysis of the data: mean, median, and standard deviation. We used Student's *t* test (for paired samples with normal distribution) or the Wilcoxon's test (for paired samples with nonparametric distribution) to compare samples in the preoperative and postoperative stages. For all analyses, $P < .05$ was considered statistically significant, with 95% confidence intervals.

RESULTS

The results showed that patients undergoing orthognathic surgery after a median mandibular advancement of 14 mm with an average counterclockwise rotation of 8 degrees of the MMC had a significant increase in the SAS ($P < .05$; Table I).

The surface area had a mean postoperative increase of 178 mm^2. The student's *t* test was normally distributed and demonstrated a *P* value of .00045.

The MAA had an average increase of 76.67 mm^2. The Wilcoxon's test for nonparametric paired samples demonstrated a significant difference in the median values between the preoperative and postoperative phases ($P = .00055$); the median value increased from 87.80 at the preoperative stage to 138.40 at the postoperative stage, demonstrating a significant difference of 50.6.

The VOL demonstrated an increase of 10.118.5 mm^3. The mean average VOL at the preoperative stage was significantly different from the average VOL of the postoperative phase (Student's *t* test, $P = .00001$).

DISCUSSION

Most patients who present with common clinical findings, such as mouth breathing, fatigue, and sleepiness, also have associated radiographic characteristics, such as mandibular and maxillary retrognathia, posterior vertical maxillary deficiency, retropositioned tongue, angled and high occlusal mandibular plane, short head and neck line, decreased upper airway, poor definition of gonion angles, Class II facial deformity, nasal obstruction, oropharyngeal abnormality (e.g., hyperplasic tonsils), enlargement of adenoids, and macroglossia.[2,6,8,9,11,12]

Studies have shown that the dimensions of the oropharyngeal airways do not show dimorphism in relation to gender, which we confirmed in the present study. The difference between the two genders was not statistically significant following bimaxillary surgery ($P > .05$).[13,14] There were no significant differences between genders in the airway alterations and sleep disorders reported by the patients in our study. For all patients, clinical improvements were seen in both genders and different age groups.

In the systematic review and meta-analysis by Holty and Guilleminault,[7] the authors reported on 22 studies on MMA describing 627 adults with OSAS, with the following four findings: (1) MMA is the most efficacious treatment for OSAS. The apnea−hypopnea index (AHI) decreased from 66.9/hr to 9.5/hr ($P < .001$), with an 86% rate of surgical success. Of these, 43.2% were cured (AHI <5/hr), with increased cure rate of 66.7% for those who had preoperative AHI <30/hr. The outcome of surgical success exceeded beyond 44 months. (2) The degree of mandibular advancement was not a predictor of surgical success in any of the analyses. (3) The MMA has a major complication rate of 1% and minor complication rate of 3.1%; there were no reported deaths.

According to our results, combined advancement surgery for the maxilla and the mandible results in improvements in the airspace compared with isolated advancement of the mandible. Without exception, all patients reported improvements in respiratory symptoms (a decrease in mouth breathing, fatigue, and daytime sleepiness) and a decrease in the frequency of use of continuous positive airway pressure (CPAP).

These findings indicate that there may have been alterations related to possible edema or physiologic deformation in patients who did not have a significant increase in surface area, MAA, or VOL. Patients also demonstrated overall satisfaction with the results, citing the respiratory benefits obtained through surgery. A satisfactory level of nasopharyngeal improvement was achieved with procedures such as septoplasty and turbinectomy but not measured.

In our study, all of the 23 patients had respiratory disorders (e.g., mouth breathing), fatigue, and daytime sleepiness. Four of them required daily use of CPAP and were able to discontinue the use of CPAP following surgery. Surgery resulted in improvements in chewing with occlusal stability; additionally, patients had improved periodontal health and maintenance over the course of the study.

Five different measurements of the anteroposterior airway were taken: the PNS to pharyngeal wall, soft palate to the pharynx, tongue base to pharyngeal wall, vallecula epiglottis to the pharyngeal wall, and minimal pharyngeal airspace.[15] Because various bone structures and soft tissues, such as the soft palate, uvula, palatoglossal arch, tongue and all suprahyoid muscles, hyoid bone, and epiglottis, can directly or indirectly move using orthognathic surgery,[1] we chose to use a methodology with more stable structures following MMA with counterclockwise rotation of the MMC. We therefore chose reference structures, such as the basion, third cervical vertebra, and the PNS.

The present study confirms the relationship between MMA with counterclockwise rotation of the occlusal plane of the MMC and an increase in the superior airway VOL area. To confirm increases in stability, function, and maintenance of periodontal health over the course of the year, it is recommended that these 23 patients be followed-up at a later date. Care must be taken in the surgical planning with a goal of prioritizing esthetics.

CONCLUSIONS

The results of this investigation showed a significant increase in the 3-D airspace after orthognathic surgery with counterclockwise rotation of the MMC. A significant increase was seen in the 3-D airspace following orthognathic surgery, which provided a greater permeability of the SAS in Class II patients and thus confirmed the efficacy of this technique in the treatment of respiratory disorders.

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