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Assessment changes on air space of patients pattern II submitted an orthognathic surgery

Evaluación de cambios en el espacio aéreo de pacientes patrón II sometidos a cirugía ortognática

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ABSTRACT: In the orthognathic surgery, depending the technique used, an increase of the upper airway dimensions can be observed. The focus was to evaluate the relationship between airway enlargement after orthognathic surgery in patients with pattern II, based on volumetric, linear and angular measurements of the airway in relation to the occlusal plane. A retrospective observational study was carried out in 10 patients, from the Center for Oral and Maxillofacial Rehabilitation in Piracicaba, São Paulo, which had been submitted to orthognathic surgery for correction of class II dentofacial discrepancy. Cephalometric and soft tissue analysis were performed using Proplan software. Eight linear measures were considered to measure the airway, maxillary and mandibular movements in lateral norm; three three-dimensional volumetric measurements of the airway and five angular measurements to describe the rotation of the occlusal plane. The statistically significant results were saw in VC1 (15.10 [2.78] - 17.29 [3.26]), in VC4 (22.19 [3.71] - 25.84 [3.31]), in coronal plane/Pg (79.70 [7.58] - 87.71 [9.85]), in the LVV-PO angle (79.70 [5.88] - 83.75 [5.86]) representing a large and significant increase after surgery. There was also a strong correlation between the variation in the VC3 measurement and the measurements in the lateral norm, between the variation of the nasopharynx and oropharynx with vertical changes in Pg ($p < 0.05$). According to the results obtained, it can be concluded that the mandibular advancement and chin advancement with counterclockwise rotation had a positive impact on the increase of the airway in the hypopharynx region, being especially favorable in cases of retrognathism and treatment of the syndrome of obstructive sleep apnea.

KEY WORDS: Orthognatic surgery, upper airway, virtual planning.

INTRODUCCIÓN

Orthognathic surgery aims to reestablish the facial pattern that presents maxillomandibular discrepancies through osteotomies and repositioning and, as a result, the surgery causes an alteration of the airways, which can be observed, depending on the technique used, an increase in the size of the airway. Airway dimensions will change depending on the type, direction and magnitude of skeletal movements (Burkhard *et al*., 2014).

Patients with Pattern II, proposed by Capelozza Filho (2004), present sagittal discrepancy between maxilla and mandible, with increased facial convexity as a result of maxillary excess or mandibular deficiency. Normally, a maxilla with good facial expression is observed, while the lower third is deficient and the chin-neck line is shortened. This deformity is an important risk factor for respiratory dysfunction and sleep-related disorders, as structural factors can affect the mechanical function of the upper airways. Patients with Obstructive Sleep Apnea Syndrome (OSAS) usually present mandibular or bimaxillary retrognathism, short mandibular body, inclined mandibular plane and low hyoid bone position (Raffaini & Pisani, 2013).

Bimaxillary orthognathic surgery with counterclockwise rotation of the maxillomandibular complex and mandibular advancement is recommended for the correction of skeletal class II problems and facial pattern II caused by mandibular or bimaxillary retrognathism and significantly increase the upper airspace in the postoperative period and the anatomy velopharyngeal in patients with high occlusal plane (Mehra *et al*., 2001; Parsi *et al*., 2018). When this movement occurs, the genial tubercles advance more than the teeth, consequently advancing the hyoid bone, the base of the tongue and the genioglossus and geniohyoid muscles (Wolford *et al*., 1994; Raffaini & Pisani, 2013; Giralt-Hernando *et al*., 2019).

The oropharyngeal complex is composed of the hyoid bone, the muscles that attach to it, and the pharyngeal airway space. Eggensperger *et al*. (2006) states that there are changes in the position of the hyoid bone and in the size of the pharynx in relation to the mandibular advancement and that, after surgery, anterior displacement of the hyoid bone was observed and it was demonstrated that the pharyngeal airway increases in the postoperative period. Kochel *et al*. (2013) carried out a study with the objective of investigating variations in the volume of the posterior air space (PAS) after mandibular advancement surgery. The results demonstrate that mandibular advancement surgery in class II patients leads to significant increases in EAP volume and significant enlargement of the narrowest sites within the pharynx.

In recent years, airway assessment has become more reliable with the advancement of three-dimensional recording techniques, such as computed tomography (CT), magnetic resonance imaging (MRI) or cone-beam computed tomography (CBCT). Computed tomography quantitatively evaluates airway volume and cross-sectional areas. This three-dimensional imaging technique, along with computer software capable of rendering volumetric data and segmenting different areas of the airways, helps clinicians and researchers to assess changes in the airways that occur in response to orthognathic treatment and the impact on the quality of breathing (Parsi *et al*, 2001; Kachinski *et al*., 2018).

This study aims to evaluate the linear and volumetric changes in the airway space associated with changes in the occlusal plane of pattern II, which patients undergoing orthognathic surgery, through preoperative face tomography and postoperative tomography.

MATERIAL AND METHOD

Study sample

A retrospective observational study was carried out in an initial sample of 23 patients from the Center for Oral and Maxillofacial Rehabilitation who underwent orthognathic surgery, with an aesthetic-functional main complaint, between the years 2020 and 2022, aged between 21 and 41 years. After reviewing the subjects examinations and pertinent medical history, only 10 patients were eligible for inclusion in this study.

For inclusion, patients with class II and pattern II dentoskeletal deformity nedded to had been submitted to bimaxillary orthognathic surgery. All patient surgeries were planned using the same 3D image analysis and planning software (Proplan), with digital intermediate and final guides to guide osteotomies.

Patients excluded from the study included those who had been submitted to a single maxillary surgical procedures; those with a history of tumors, cleft lip or previous orthognathic surgery; and lack of CT scans.

This work is under consideration and awaits approval by the Ethics and Research Committee of the Hospital UNIMED Piracicaba, CAAE 67629423.0.0000.0243. The study was carried out in accordance with the standard ethical principles set out in the 1964 Declaration of Helsinki and its subsequent amendments.

Data collection methods

A surgical team planned all orthognathic surgeries according to the needs of each patient. The facial skeleton and soft tissues were digitally recreated using Digital Imaging and Communications in Medicine (DICOM) from helical computed tomography scans of the face and skull. The scans were acquired with standard configurations (axial, coronal, sagittal and reconstruction sections, with 0.6 mm slices recorded in DICOM format). Preoperative CT was performed before surgery, after teeth were leveled and in bone base from orthodontics. And postoperative CT was performed at least after 3 months.

Orthognathic surgery was planned using 3D cephalometric measurements and facial analysis. Through the software, composite skulls were obtained. Le Fort I osteotomies, sagittal osteotomies of the mandibular rami and osteotomy for genioplasty were simulated. When necessary, osteotomies for maxillary segmentation were also performed. The maxillary and mandibular segments were moved to the desired positions in order to create 3D facial harmony in all three dimensions. The results obtained were then transferred to the patient at the time of surgery, using intermediate and final surgical guides printed through the Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) system, by the Moonray printer, with photopolymerizable resins.

The same surgical team that carried out the planning performed all surgical procedures, according to the standard osteotomy protocol by the authors René Le Fort (1901) and Bruce N. Epker (1977) (Le Fort I osteotomy and Sagittal Branch Osteotomy Epker's mandibles). The surgeries took place in a hospital environment, under general anesthesia. All occurred without intercurrences. In all patients, advancement genioplasty between 4mm and 7mm was performed; in 7 patients there was maxillary advancement and in 9 patients counterclockwise rotation of the occlusal plane was performed, varying from 2.86º to 6º.

Assessment of the airway and occlusal plane

Airway assessment was compared from preoperative tomography and postoperative tomography (between 03 and 24 months) and cephalometric analysis was performed using Proplan software (Materialise Proplan CMF, Leuven, Belgium).

For airway segmentation, a Hounsfield scale pattern was used (from -1024 to -950) and separated into the nasopharynx (between the posterior nasal spine and VC1 - the most anterior lower point of the first cervical vertebra parallel to the Frankfurt plane) , oropharynx (between VC1 and VC3 - lower most anterior point of the body of the third cervical vertebra parallel to the Frankfurt plane) and hypopharynx (between VC3 and VC4 - lower most anterior point of the body of the fourth cervical vertebra parallel to the Frankfurt plane).

The linear measurements of each region were evaluated together with the position of the hyoid bone (most anterior point of the hyoid passing horizontally at the most inferior point of the 2nd cervical vertebra). Volumetric measurements were performed using the Proplan software, specified in table I and figure 1 (Abramson *et al*., 2011; Burkhard *et al*., 2014; Marcussen *et al*., 2017; Elshebiny *et al*., 2020; Pellby & Bengtsson, 2021; Steegman *et al*., 2023).

To evaluate changes in the occlusal plane related to clockwise or counterclockwise rotations, two angles of the occlusal plane parallel to the Frankfurt plane were evaluated: FH-OcPL and FH-OcPR (Angle formed between the occlusal plane of the maxilla passing through the incisal of the incisor and occlusal of the first molar and the Frankfurt horizontal plane (formed by the points Porio and Orbitale) left and right side), given by the Proplan software; LVV/PO (true vertical line in relation to the occlusal plane) according to Arnett & McLaughlin (2004);

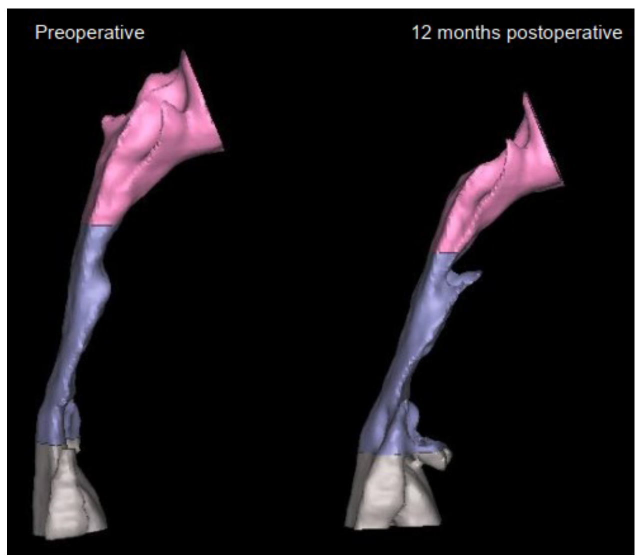

Fig. 1. Illustration of 3D volumetric measurements of the airway preoperative and 12 months postoperative.

Table I. Table of volumetric measurements, in 3 dimensions, analyzed and definition of each measurement.

VOLUME (mm^3)	DEFINITION
Nasopharynx	Superior limit: base of the sphenoid sinus.
	Inferior limit: inferior arch of the body of the first cervical vertebra.
	Anterior limit: perpendicular line passing through posterior nasal spine.
Oropharynx	Superior limit: inferior arch of the body of the first cervical vertebra.
	Inferior limit: inferior arch of body of third cervical vertebra.
Hypopharynx	Superior limit: inferior arch of the third cervical vertebra.
	Inferior limit: anterior inferior arch of the body of the fourth cervical vertebra.

Coronal/point A (horizontal distance from the coronal plane to the point in the largest concavity of the anterior portion of the maxilla); Coronal/Pg (horizontal distance from the coronal plane to the pogonion); PHF/A (vertical distance from the reference line to point A); PHF/Pg (vertical distance from the Frankfurt horizontal plane to the pogonion); andcephalometric evaluation of the mandibular and Frankfurt horizontal plane: GoLMe/FH and GoRMe/FH (angles formed between the Frankfurt horizontal plane and the Mandibular plane [Go-Me] on the right and left sides), also given by the software.

Data analysis

Initially, descriptive and exploratory analyzes of all data were performed. For quantitative variables, means, standard deviations, medians, minimum and maximum values were used, and for categorical variables, absolute and relative frequencies were used. Next, the paired t-test was used to compare the measurements taken pre- and postoperatively. The surgery effect sizes were also calculated on these measures according to Cohen (1988). The t-test for an average was used to compare the average variations with the reference values, since differences between the preoperative and postoperative periods smaller than 2 mm for linear measurements and smaller than 4º for angular measurements are not considered to be clinically significant (Tng *et al*., 1994; Donatsky *et al*., 1997; Padwa *et al*., 1997; Hsu *et al*., 2013; Zhang *et al*., 2016). For these comparisons, the absolute values of the variations were considered, comparing how much they varied (for more or for less) with the reference values. Pearson's correlation analyzes of variations in volumes and linear measurements with variations in occlusal plane measurements were also performed. All analyzes were performed using the R program, with a significance level of 5 %.

Table II. Table of descriptive analysis of the characteristics of the sample of patients with class II discrepancy undergoing orthognathic surgery.

Variable	Category	Frequency (%)
Sex	Female	8 (80 %)
	Male	2 (20 %)
Rotation	Counter-clockwise	9 (90 %)
	Clock	1 (10 %)
Maxilla - Advancement	No	3 (30 %)
	Yes	7 (70 %)
Maxilla – Impaction	No	3 (30 %)
	Yes	7 (70 %)
Maxilla – Segmentation	No	7 (70 %)
	Yes	3 (30 %)
Jaw – Advancement	No	1 (10 %)
	Yes	9 (90 %)
Ment – Advancement	No	0 (0%)
	Yes	10 (100 %)
Ment – Impaction	No	9 (90 %)
	Yes	1 (10 %)
Ment – Repositioning	No	5 (50 %)
	Less	4 (40 %)
	Upper	1 (10 %)
Variable	**Mean (SD)**	**Median (min - max)**
Age (years), n=10	29 (6.5)	27 (21 - 41,0)
Counterclockwise rotation (degrees), n=9	4.5 (1.9)	4 (2.7 - 8.2)
Clock rotation (degrees), n=1	3 (-)	3 (3 - 3)
Maxilla advancement (mm), n=7	4.4 (2.1)	5 (0 - 7)
Maxilla impaction (mm), n=7	4.4 (2.4)	4 (2 - 8)
Advancement in ment (mm), n=10	4.8 (1.2)	4.5 (3 - 7)
Superior repositioning of the ment (mm), n=1	6 (-)	6 (6 - 6)
Inferior repositioning of the ment (mm), n=4	4.1 (1.4)	4 (2.5 - 6)

RESULTS

Data from 10 patients with class II discrepancy who underwent orthognathic surgery, 80 % female and 20 % male, were analyzed. The average age of the patients is 29 years, ranging from 21 to 41 years. It is observed that 90 % of the patients presented counterclockwise rotation and one patient presented clockwise rotation. In addition, 70 % had advancement in the maxilla, 90 % advancement in the mandible and all (100 %) had advancement in the chin, shown in Table II.

In Table III, it is observed that there was a statistically significant increase in the linear measurements of VC1 (the most anterior inferior point of the first cervical vertebra parallel to the Frankfurt plane) and VC4 (the most anterior inferior point of the body of the fourth cervical vertebra parallel to the Frankfurt plane), $p < 0.05$, with a large effect size, figures 2 and 3. In other words, orthognathic surgery

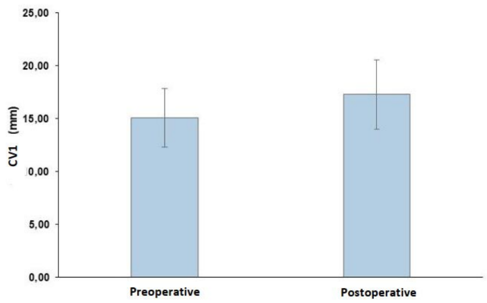

Fig. 2. Mean and standard deviation of the linear measurement in CV1 (the lowest most anterior point of the first cervical vertebra parallel to the Frankfurt plane, in mm) in the pre and postoperative period of patients with class II discrepancy undergoing orthognathic surgery.

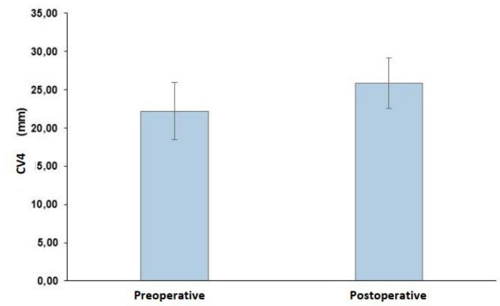

Fig. 3. Mean and standard deviation of the linear measurement at CV4 (the lowest most anterior point on the body of the fourth cervical vertebra parallel to the Frankfurt plane, in mm) in the pre and postoperative period of patients with class II discrepancy undergoing orthognathic surgery.

Table III. Table of mean (standard deviation), median (minimum and maximum value) of measurements taken pre and postoperative in patients with class II discrepancy undergoing orthognathic surgery.

Variable	Preoperative		Postoperative		p-value
	Mean (SD)	Median (min; max)	Mean (SD)	Median (min, max)	
Volumetric measurements					
Nasopharyngeal volume (mm^3)	6,744.19 (2.388,45)	6,525.47 (1,574.59; 9,699.63)	7,414.60 (1,278.84)	7,710.78 (4,507.97; 8,598.22)	0.4463
Oropharyngeal volume (mm^3)	6,738.91 (3.158,03)	7,099.43 (2,520.12; 11,245.54)	8,473.65 (2,692.88)	8,824.44 (4,789.20; 13,177.60)	0.0692
Hypopharyngeal volume (mm^3)	3,707.02 (1.285,02)	3,515.40 (2,003.33; 5,533.62)	4,274.35 (1,918.04)	3,724.41 (2,536.32; 8,264.11)	0.2868
Linear measurements					
CV1 (mm)	15.10 (2.78)	14.15 (12.40; 20.30)	17.29 (3.26)	17.85 (12.70; 21.70)	0.0046
CV3 (mm)	14.54 (4.67)	13.90 (5.70; 20.30)	17.46 (3.03)	16.75 (13.80; 22.40)	0.0717
CV4 (mm)	22.19 (3.71)	22.05 (14.80; 28.30)	25.84 (3.31)	25.75 (21.70; 32.10)	0.0082
Position of the hyoid bone (mm)	35.74 (4.57)	34.40 (30.30; 44.70)	36.52 (3.34)	35.70 (33.00; 43.80)	0.2330
Angle of the occlusal plane					
FH-OcPL (degree)	16.44 (4.67)	19.20 (9.00; 20.80)	15.04 (4.80)	14.30 (7.20; 24.50)	0.5123
FH-OcPR (degree)	18.25 (4.71)	19.90 (8.30; 24.40)	14.29 (3.87)	13.50 (7.30; 20.30)	0.0430
TVL – OP (degree)	79.70 (5.88)	80.55 (71.20; 88.80)	83.75 (5.86)	84.60 (70.60; 90.60)	0.0399
Coronal plane – PG (mm)	79.70 (7.58)	76.25 (71.20; 94.30)	87.71 (9.85)	88.00 (68.20; 100.40)	0.0494
coronal plane – PA (mm)	89.26 (8.50)	89.75 (70.00; 103.30)	93.56 (7.31)	91.50 (85.10; 105.40)	0.1299
FHP – A (mm)	34.86 (4.69)	35.25 (26.40; 40.70)	35.07 (5.79)	34.05 (28.10; 48.30)	0.8985
FHP – PG (mm)	82.62 (11.01)	81.90 (64.30; 102.30)	85.59 (7.96)	84.65 (73.60; 98.00)	0.1926
GoRMe-FH (degree)	30.80 (6.74)	31.90 (18.30; 39.10)	29.04 (3.42)	27.80 (25.80; 34.10)	0.2986
GoLMe-FH (degree)	31.26 (5.70)	31.50 (21.40; 39.50)	28.60 (2.68)	28.10 (25.30; 33.30)	0.1201

1dz=0.20 (small effect); dz=0.50 (medium effect); dz=0.80 (big effect) according to Cohen (1988 e 1992).

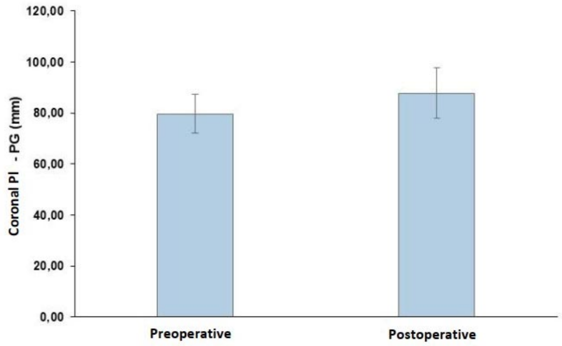

Fig. 4. Mean and standard deviation of the linear measurement of the coronal plane – PG (mm) in the pre- and postoperative period of patients with class II discrepancy undergoing orthognathic surgery.

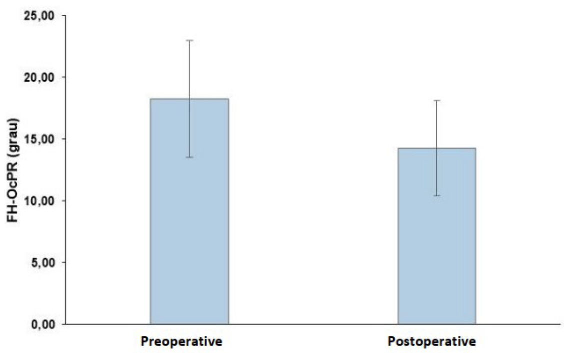

Fig. 5. Mean and standard deviation of the angular measurement FH-OcPR (angle formed between the occlusal plane of the maxilla passing through the incisor of the incisor and the occlusal of the first molar and Franktut's horizontal plane, right side, in degrees) in the pre and postoperative period of patients with class II discrepancy undergoing orthognathic surgery.

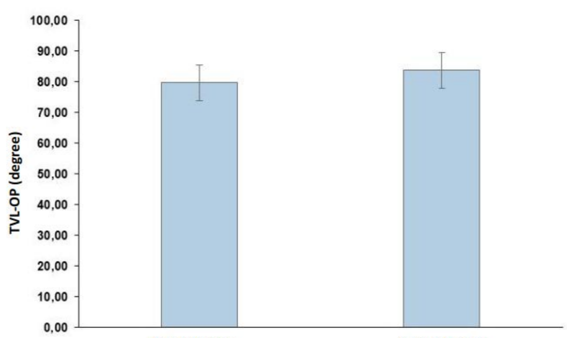

Fig. 6. Mean and standard deviation of TVL-OP angular measurement (angle between the maxillary occlusal plane and the true vertical line, in degrees) pre- and postoperatively in patients with class II discrepancy undergoing orthognathic surgery.

resulted in a large and significant increase in these two measures. Regarding the linear measures in lateral norm, there was a statistically significant increase in the measurement of the coronal plane PG (mm), with an effect size between medium and large, figure 4. In addition, there was a statistically significant decrease in the FH-OcPR angle (angle between the occlusal plane of the maxilla passing through the incisor of the incisor and the occlusal of the first molar and Franktut's horizontal plane, right side) and increase in the LVV – PO angle (angle between the maxillary occlusal plane and the true vertical line), $p<0 .05$, also with size effects between medium and large, figures 5 and 6.

In table IV presents the descriptive analysis of variations in measurements after surgery for all variables, as well as the results of comparison analyzes with reference values for linear and angular measurements. Clinically significant variations were observed in the measurement of VC3 (the most anterior inferior point on the body of the third cervical vertebra parallel to the Frankfurt plane), with 70% of the sample having variations above 2 mm ($p < 0.05$). Still regarding the linear measurements, there was a clinically significant variation in the measurements of the coronal plane – PG and PHF – A ($p < 0.05$), and all patients had variations greater than 2 mm in the coronal plane – PG and 90 % and had variations of more than 2 mm in the PHF - A. With regard to angular measurements, there was a clinically significant variation in the FH-OcPR angle (angle formed between the occlusal plane of the maxilla passing through the incisor of the incisor and the occlusal plane of the first molar and Franktut's horizontal plane, right side), and 70 % of the sample presented variation above 4º after surgery. In addition, there was also a clinically significant variation ($p < 0.05$) in the GoLMe-FH angle (Angle formed between the Frankfurt horizontal plane and the mandibular plane, right side), with 90 % of the patients having a variation above 4º in this angle.

Table V shows the results of the correlation analyzes between changes in measurements after surgery. There is a strong negative significant correlation between the variation in the measurement of VC1 (Lower most anterior point of the first cervical vertebra parallel to the Frankfurt plane) and the variation in the LVV-PO angle (Angle between the maxillary occlusal plane and the true vertical line), $p<0 .05$, figure 7. That is, when the variation in the VC1 measurement increases, the variation in this angle decreases. A moderately significant positive correlation was also observed between

Table IV. Table of mean (standard deviation), median (minimum and maximum value) of variations in measurements between the pre and postoperative period of patients with class II discrepancy undergoing orthognathic surgery.

Variable	**Variation after surgery**		**Reference value**	**[1]p-value**	**Frequency (%) of cases with variation above the reference value**
	Mean (SD)	Median (min; max)			
Volumetric measurements					
Nasopharyngeal volume(mm^3)	670.41 (2,662.31)	462.90 (-2,903.14; 6,809.12)	-	-	-
Oropharyngeal volume (mm^3)	1,734.74 (2,659.19)	1,705.82 (-2,547.87; 7,577.63)	-	-	-
Hypopharyngeal volume(mm^3)	567.33 (1,584.48)	770.92 (-2,689.72; 3,072.19)	-	-	-
Linear measurements					
CV1 (mm)	2.19 (1.85)	1.64 (0.10; 5.60)	2 mm	0.7549	3 (30 %)
CV3 (mm)	2.92 (4.52)	2.75 (-4.60; 13.00)	2 mm	0.1485	7 (70 %)
CV4 (mm)	3.65 (3.42)	4.60 (-1.90; 7.80)	2 mm	0.0129	7 (70 %)
Position of the hyoid bone (mm)	0.78 (1.93)	0.80 (-2.90; 3.60)	2 mm	0.3366	4 (40 %)
Angle of the occlusal plane					
FH-OcPL (degree)	-1.40 (6.49)	-1.70 (-12.80; 9.80)	4º	0.4832	5 (50 %)
FH-OcPR (degree)	-3.96 (5.32)	-4.95 (-8.00; 10.30)	4º	0.0231	7 (70 %)
TVL – OP (degree)	4.05 (5.34)	2.50 (-2.10; 12.60)	4º	0.5351	4 (40 %)
Coronal plane - PG (mm)	8.01 (11.16)	8.25 (-17.60; 24.50)	2 mm	0.0019	10 (100 %)
Coronal plane – PA (mm)	4.30 (8.16)	2.30 (-4.30; 21.70)	2 mm	0.1076	7 (70 %)
FHP – A (mm)	0.21 (5.06)	-1.60 (-5.60; 7.70)	2 mm	0.0097	9 (90 %)
FHP – PG (mm)	2.97 (6.67)	0.55 (-4.30; 15.80)	2 mm	0.1270	6 (60 %)
GoRMe-FH (degree)	-1.76 (5.05)	-4.05 (-6.30; 7.50)	4º	0.0882	7 (70 %)
GoLMe-FH (degree)	-2.66 (4.90)	-4.95 (-7.00; 5.20)	4º	0.0045	9 (90 %)

Table V. Table of correlation analyzes of variations in volume and angular measurements with variations in the occlusal plane in patients with class II discrepancy undergoing orthognathic surgery.

Vol./linear measurement	**Occlusal Plane Angle r (p-value)**							
	FH-OcPL	**FH-OcPR**	**TVL - OP**	**Coronal pl - PG**	**Coronal pl – PA**	**FHP- A**	**FHP – PG**	**GoRMe-FH**
Nasopharyngeal vol.	-0.04 (0.9093)	-0.16 (0.6644)	-0.38 (0.2737)	0.15 (0.6890)	0.66 (0.0360)	0.34 (0.3397)	0.71 (0.0203)	0.52 (0.1259)
Oropharyngeal vol.	0.34 (0.3355)	-0.16 (0.6625)	-0.26 (0.4641)	0.19 (0.6022)	0.66 (0.0377)	0.05 (0.8994)	0.86 (0.0014)	0.58 (0.0786)
Hypopharyngeal vol.	-0.60 (0.0681)	-0.42 (0.2241)	0.30 (0.4051)	-0.46 (0.1850)	-0.49 (0.1544)	0.05 (0.8925)	-0.38 (0.2825)	-0.61 (0.0594)
CV1	0.27 (0.4471)	-0.09 (0.8140)	-0.70 (0.0249)	-0.37 (0.2860)	0.53 (0.1180)	0.25 (0.4882)	0.62 (0.0543)	0.43 (0.2156)
CV3	0.33 (0.3479)	0.24 (0.4965)	0.00 (0.9906)	0.43 (0.2113)	0.73 (0.0165)	0.15 (0.6718)	0.58 (0.0781)	0.65 (0.0438)
CV4	-0.51 (0.1329)	-0.51 (0.1335)	0.47 (0.1727)	0.68 (0.0315)	0.04 (0.9223)	0.04 (0.9211)	-0.17 (0.6317)	-0.35 (0.3249)
Hyoid position	0.40 (0.2477)	0.42 (0.2320)	0.08 (0.8213)	-0.20 (0.5776)	0.01 (0.9731)	0.12 (0.7508)	0.22 (0.5366)	0.33 (0.3499)

the variation in the VC4 measurement (the lowest, most anterior point on the body of the fourth cervical vertebra parallel to the Frankfurt plane) and the variation in the measurement of the coronal PG plane ($p < 0.05$). Also, the variation in the measurement of the coronal/A plane, presented a moderately significant positive correlation with the variations in the nasopharynx and oropharynx volume ($p < 0.05$). The variation in the measurement of the coronal/A plane also showed a strong significant positive correlation with the variation in the measurement of VC3 (the lowest most anterior point of the body of the third cervical vertebra parallel to the Frankfurt plane), figure 8. Also, a positively strong disparity between the variation in the measurement of the horizontal plane of Frankfurt A and PG, and the variations in the nasopharynx and oropharynx volumes ($p < 0.05$) can be observed. In addition, there was a positive and significantly moderate correlation between the variation in the GoRMe-FH angle (angle formed between the Frankfurt horizontal plane and the mandibular plane, right side) and the variation in the measurement of VC3 (the lower most anterior point of the body of the third cervical vertebra parallel to the Frankfurt plane), $p < 0.05$.

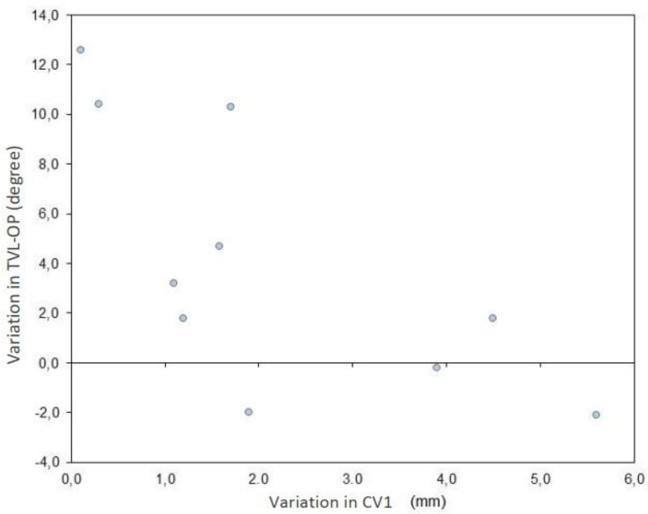

Fig. 7. Scatter plot between the variations in the linear measurement in CV1 (the lowest, most anterior point of the first cervical vertebra parallel to the Frankfurt plane, in mm) and in the measurement of the TVL-OP angle (angle between the maxillary occlusal plane and the true vertical line), r = -0.70, p = 0.0249

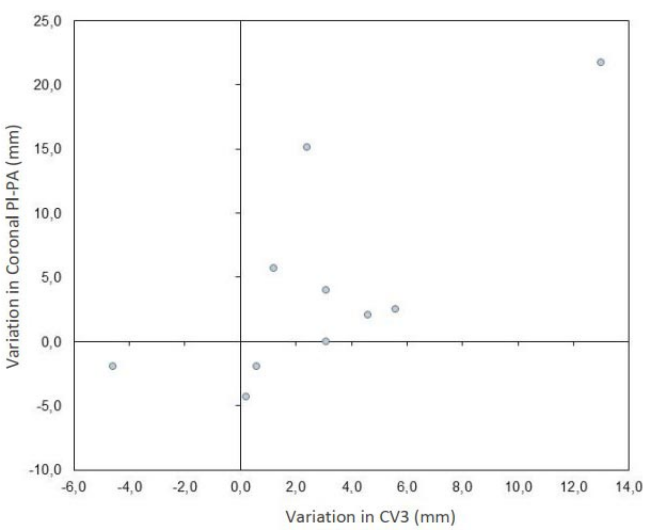

Fig. 8. Scatter plot between variations in the linear measurement in C3 (the lowest most anterior point on the body of the third cervical vertebra parallel to the Frankfurt plane, in mm) and in the linear measurement in the PA coronal plane (mm), r = 0, 73, p = 0.0165.

DISCUSSION

It is well known that the oropharyngeal and craniofacial structures, including retrognathia, reduced mandibular length and low hyoid position, present in patients with profile II and class II malocclusion, are associated with a narrow posterior airway and, consequently, a greater risk of developing OSAS (Wiedemeyer *et al*., 2019).

Traditionally, the posterior airspace has been assessed using lateral cephalometric radiographs, which allow measurements in the sagittal plane and have the advantage of low cost and minimal exposure to radiation. But this method results in superimposition of all structures of the craniofacial complex and provides a two-dimensional view. Furthermore, the axial plane cannot be examined (Abramson *et al*., 2011). Conventional CT, MRI, or cone-beam CT have become more reliable due to spatial resolution, three-axis rotating images, and selective visualization of certain anatomical structures.

To assess anatomical structures such as the EAP, various software designed to manage and analyze digital image communications in medicine (DICOM) are used (Kochel *et al*., 2013; Burkhard *et al*., 2014; Marcussen *et al*., 2017). Few studies report the accuracy of 3D virtual planning using various populations, skeletal movements and various methods to quantify the accuracy of software programs (Elshebiny *et al*., 2020). In this study, the software used was Proplan (Materialise Proplan CMF, Leuven, Belgium) with tools to segment and measure the linear and volumetric airway, as well as the movements planned by the surgical team for orthognathic surgery.

Orthognathic surgery may represent an alternative for the treatment of OSAS in patients with class II malocclusion, who usually have reduced posterior air space (Kachinski *et al*., 2018). Raffaini & Pasani (2013) evaluated patients with class II malocclusion, and it was observed that, after maxillomandibular advancement surgery, there was a significant increase in posterior air space, accompanied by patients' perception of improved respiratory function. Similar results were observed by Fairburn *et al*. (2007), who used conventional CT to assess the morphological changes in the airway produced by maxillomandibular advancement surgery. The results showed that there was a significant increase in the anteroposterior and lateral dimensions of the pharynx after surgery, showing that maxillomandibular advancement surgery promotes changes in the shape of the airway that make it less prone to collapse.

Brevi *et al*. (2011) andMarcussen *et al*. (2017) state that counterclockwise rotation does not directly influence the airways in a positive way, but allows for greater mandibular advancement with an acceptable aesthetic result. Which means that counterclockwise rotation of the maxillomandibular complex influences the oropharynx, indirectly through mandibular advancement. In the present study, there is a strong correlation between the variation in nasopharynx and oropharynx volume, and the variation in PHF/Pg ($p < 0.05$), which corroborates the study by Wolford, *et al*. (1994) where he demonstrates that counterclockwise rotation of the occlusal plane can increase the posterior airway by advancing the mandibular symphysis, bringing with it the genioglossus and geniohyoid muscles and, posteriorly, the base of the tongue. Not only that, counterclockwise rotation of the hard palate also affects the soft palate, accompanied by an increase in the retropalatal space.

The angle between the true vertical line and the occlusal plane (LVV-PO) increased after surgery and rotation of the maxillomandibular complex, getting close to the reference value of 93º to 97º considered as standard by Arnett and Mclaughlin (2004). There was also a decrease in the FH-OcPR and GoLMe-FH angle compatible with the movements performed in the maxillomandibular complex. As for changes in the maxilla, there was variation between the volume of the nasopharynx and oropharynx and in the VC3 measure, and variation in the PHF/A; however, it was not possible to define which maxillary movement allowed this increase in the oropharynx, due to the heterogeneity of the sample (70 % had maxillary impaction, 70 % maxillary advancement, 30 % maxillary segmentation, 10 % inferior repositioning).

According to Giralt-Hernando *et al*. (2021) the concomitant advancement of the chin during mandibular advancement significantly improves the airway at the level of the oropharynx. Advancement of the mentum involves anterior movement of the genial tubercles, which together with movements of the hyoid bone, lead to increased flow in the airways. In addition, a meta-analysis (Giralt-Hernando *et al*., 2019) showed that rotation of the maxillomandibular complex together with genioplasty significantly increases the posterior airway ($p < 0.001$). In this present study, the advancement of the pogonion (coronal plane linear measure/Pg) had a statistically significant increase greater than 2 mm ($p < 0.05$), and a moderate correlation between the variation in the measurement of CV4 (hypopharyngeal region) and the variation in the coronal plane measurement.

Another aspect covered in the present study was the position of the hyoid bone, whose result was not statistically significant. According to studies published by Burkhard *et al*. (2014) the hyoid bone presents temporary stability. After a certain period of surgery, the hyoid bone tends to return to its originais position. This recurrence can be caused by adjustments in the location of attachment to the bone of tendons and muscles, as well as alterations in the tendon-bone interface.

Regarding airway volume, this study showed an increase in nasopharynx, oropharynx and hypopharynx volumes between pre and post orthognathic surgery, but with statistical insignificance (effect size, respectively, 0.25 dz; 0.65 dz and 0.36 dz). Christino *et al*. (2021) reports in their work a hypothesis regarding the decrease in the height of the upper airways, which influences the calculation of the volume. The authors show in their work that between the group with counterclockwise rotation of the occlusal plane (R) and the group without counterclockwise rotation of the occlusal plane (NR), both present a reduction in the height of the upper airways, greater in the R group (5.9%) than in the NR group (2.6 %). And although reducing the height of the upper airways interferes with its volume, according to Bernoulli's principle (1738), this reduction makes the structure more resistant to collapse, which is excellent for the treatment of obstructive sleep apnea syndrome.

With regard to the follow-up time, in this study the follow-up time was 03 to 24 months, which eliminates the short-term concern about edema. Long-term changes in the airways can also be caused by aging, weight gain and increased fat in the pharyngeal region (Riepponen *et al*., 2016).

CONCLUSION

Based on the results obtained, it can be concluded that the mandibular advancement and chin advancement with counterclockwise rotation had a positive effect on the increase of the airway in the hypopharyngeal region. The study also revealed a significant increase in the VC4 sagittal measurement, being especially favorable in cases of retrognathism and for the treatment of obstructive sleep apnea syndrome.

Some measurements (oropharyngeal volume, VC3 measurement, coronal plane/A measurement, GoLMe-FH angle) had variations with moderate, clinically significant effect sizes. Therefore, it is important that further studies be carried out.

CONFLICT OF INTEREST: The authors declare that they have no conflicts of interest.

DA COSTA MS, CORAL AJ, CAVALIERI PEREIRA L. Evaluación de cambios en el espacio aéreo de pacientes patrón II sometidos a cirugía ortognática. *Craniofac Res.* 2024; 3(1):27-37.

RESUMEN: En la cirugía ortognática, se puede observar un aumento de las dimensiones de la vía aérea superior. El objetivo es evaluar la relación entre el aumento de la vía aérea después de la cirugía ortognática en pacientes clase II, basándose en mediciones volumétricas, lineares y angulares de la vía aérea en relación con el plano oclusal. Se realizó un estudio observacional retrospectivo en 10 pacientes, del Centro de Rehabilitación Oral y Maxilofacial de Piracicaba, São Paulo, que habían sido sometidos a cirugía ortognática para corrección de discrepancia dentofacial clase II. Los análisis cefalométricos y de tejidos blandos se realizaron utilizando el software Proplan. Se consideraron ocho medidas lineares para calcular los movimientos de la vía aérea, maxila y mandibula en norma lateral; tres mediciones volumétricas tridimensionales de la vía aérea y cinco mediciones angulares para describir la rotación del plano oclusal. Los resultados estadísticamente significativos se observaron en VC1, en VC4 en plano coronal/Pg, en el ángulo LVV-PO lo que representa un aumento grande y significativo después de la cirugía. También hubo una fuerte correlación entre la variación en la medición de VC3 y las mediciones en la norma lateral, entre la variación de la nasofaringe y la orofaringe con cambios verticales en Pg ($p < 0,05$). De acuerdo a los resultados se puede concluir que el avance mandibular y el avance del mentón con rotación antihoraria tuvieron un impacto positivo en el aumento de la vía aérea en la región de la hipofaringe, siendo favorable en casos de retrognatismo y tratamiento del síndrome de apnea obstructiva del sueño.

PALABRA CLAVE: Cirugía ortognática, vía aérea superior, planeación virtual.

REFERENCES

Abramson Z, Susarla SM, Lawler M, Bouchard C, Troulis M, Kaban LB. Three-dimensional computed tomographic airway analysis of patients with obstructive sleep apnea treated by maxillomandibular advancement. *J Oral Maxillofac Surg*. 2011; 69(3):677-86. http://dx.doi.org/10.1016/j.joms.2010.11.037

Arnett GW, McLaughlin RP. *Planejamento Facial e Dentário para Ortodontistas e Cirurgiões Bucomaxilofaciais*. São Paulo: Artes Medicas. 2004. p 24.

Brevi BC, Toma L, Pau M, Sesenna E. Counterclockwise rotation of the occlusal plane in the treatment of obstructive sleep apnea syndrome. *J Oral Maxillofac Surg*. 2011; 69:917-23. http://dx.doi.org/10.1016/j.joms.2010.06.189

Burkhard JP, Dietrich AD, Jacobsen C, Roos M, Lübbers HT, Obwegeser JA. Cephalometric and three-dimensional assessment of the posterior airway space and imaging software reliability analysis before and after orthognathic surgery. *J Craniomaxillofac Surg.* 2014; 42(7):1428-36. http://dx.doi.org/10.1016/j.jcms.2014.04.005

Capelozza Filho L. *Diagnóstico em Ortodontia.* Maringá: Dental Press Editora. 2004. Avalible online: https://repositorio.usp.br/item/001492764

Christino M, Vinha PP, Faria AC, Garcia DM, de Mello-Filho FV. Impact of counterclockwise rotation of the occlusal plane on the mandibular advancement, pharynx morphology, and polysomnography results in maxillomandibular advancement surgery for the treatment of obstructive sleep apnea patients. *Sleep Breath.* 2021; 25(4):2307-13. http://dx.doi.org/10.1007/s11325-020-02279-8

Cohen, J. *Statistical power analysis for the behavioral sciences*. Hillsdale, NewJersey: Lawrence Erlbaum Associates. 1988.

Donatsky O, Bjørn-Jørgensen J, Holmqvist-Larsen M, Hillerup S. Computerized cephalometric evaluation of orthognathic surgical precision and stability inrelation to maxillary superior repositioning combined with mandibular advancement or setback. J *Oral Maxillofac Surg.* 1997; 55(10):1071-80. https://doi.org/10.1016/s0278-2391(97)90282-2

Eggensperger N, Smolka K, Luder J, Iizuka T. Short- and long-term skeletal relapse after mandibular advancement surgery. *Int J Oral Maxillofac Surg*. 2006; 35(1):36-42. http://dx.doi.org/10.1016/j.ijom.2005.04.008

Elshebiny T, Bous R, Withana T, Morcos S, Valiathan M. Accuracy of Three-Dimensional Upper Airway Prediction in Orthognathic Patients Using Dolphin Three-Dimensional Software. *J Craniofac Surg*. 2020 31(4):1098-1100. http://dx.doi.org/10.1097/SCS.0000000000006566

Fairburn SC, Waite PD, Vilos G, Harding SM, Bernreuter W, Cure J, Cherala S. Three-dimensional changes in upper airways of patients with obstructive sleep apnea following maxillomandibular advancement. *J Oral Maxillofac Surg.* 2007; 65(1):6-12. http://dx.doi.org/10.1016/j.joms.2005.11.119

Giralt-Hernando M, Valls-Ontañón A, Guijarro-Martínez R, Masià-Gridilla J, Hernández-Alfaro F. Impact of surgical maxillomandibular advancement upon pharyngeal airway volume and the apnoea-hypopnoea index in the treatment of obstructive sleep apnoea: systematic review and meta-analysis. *BMJ Open Respir Res.* 2019; 6(1):e000402. http://dx.doi.org/10.1136/bmjresp-2019-000402

Giralt-Hernando M, Valls-Ontañón A, Haas Junior OL, Masià-Gridilla J, Hernández-Alfaro F. What are the Surgical Movements in Orthognathic Surgery That Most Affect the Upper Airways? A Three-Dimensional Analysis. *J Oral Maxillofac Surg.* 2021; 79(2):450-62. http://dx.doi.org/10.1016/j.joms.2020.10.017. Epub 2020 Oct 15. PMID: 33171114

Hsu SS, Gateno J, Bell RB, Hirsch DL, Markiewicz MR, Teichgraeber JF, Zhou X, Xia JJ. Accuracy of a computer-aided surgical simulation protocol for orthognathic surgery: a prospective multicenter study. *J Oral Maxillofac Surg.* 2013; 71(1):128-42. http://dx.doi.org/10.1016/j.joms.2012.03.027

Kachinski A, Azanha JM, Campos PD, Corrêa CC, Campos LD. Avaliação das vias aéreas superiores por meio de tomografia computadorizada de feixe cônico em indivíduos submetidos à cirurgia ortognática: revisão de literatura. *Salusvita, Bauru*. 2018; .37(2):405-19.

Kochel J, Meyer-Marcotty P, Sickel F, Lindorf H, Stellzig-Eisenhauer A. Short-term pharyngeal airway changes after mandibular advancement surgery in adult Class II-Patients--a three-dimensional retrospective study. *J Orofac Orthop*. 2013; 74(2):137-52. http://dx.doi.org/10.1007/s00056-012-0132-x

Marcussen L, Stokbro K, Aagaard E, Torkov P, Thygesen T. Changes in Upper Airway Volume Following Orthognathic Surgery. *J Craniofac Surg.* 2017; 28(1):66-70. http://dx.doi.org/10.1097/SCS.0000000000003206

Mehra P, Downie M, Pita MC, Wolford LM. Pharyngeal airway space changes after counterclockwise rotation of the maxillomandibular complex. *Am J Orthod Dentofacial Orthop.* 2001; 120(2):154-9. http://dx.doi.org/10.1067/mod.2001.114647

Padwa BL, Kaiser MO, Kaban LB. Occlusal cant in the frontal plane as a reflection of facial asymmetry. *J Oral Maxillofac Surg.* 1997; 55(8):811-6. http://dx.doi.org/10.1016/s0278-2391(97)90338-4

Parsi GK, Alsulaiman AA, Kotak B, Mehra P, Will LA, Motro M. Volumetric changes of the upper airway following maxillary and mandibular advancement using cone beam computed tomography. *Int J Oral Maxillofac Surg*. 2019; 48(2):203-10. http://dx.doi.org/10.1016/j.ijom.2018.08.004

Pellby D, Bengtsson M. Changes in the upper airway volume after orthognathic surgery: three-dimensional measurements in a supine body position. *Int J Oral Maxillofac Surg*. 2023; 52(9):948-55. http://dx.doi.org/10.1016/j.ijom.2022.11.012

Raffaini M, Pisani C. Clinical and cone-beam computed tomography evaluation of the three-dimensional increase in pharyngeal airway space following maxillo-mandibular rotation-advancement for Class II-correction in patients without sleep apnoea (OSA). J *Craniomaxillofac Surg*. 2013; 41(7):552-7. http://dx.doi.org/10.1016/j.jcms.2012.11.022

Riepponen A, Myllykangas R, Savolainen J, Kilpeläinen P, Kellokoski J, Pahkala R. Changes in posterior airway space and hyoid bone position after surgical mandibular advancement. *Acta Odontol Scand.* 2017; 75(1):73-8. http://dx.doi.org/10.1080/00016357.2016.1252851

Steegman R, Hogeveen F, Schoeman A, Ren Y. Cone beam computed tomography volumetric airway changes after orthognathic surgery: a systematic review. *Int J Oral Maxillofac Surg*. 2023; 52(1):60-71. http://dx.doi.org/10.1016/j.ijom.2022.05.013

Tng TT, Chan TC, Hägg U, Cooke MS. Validity of cephalometric landmarks. An experimental study on human skulls. *Eur J Orthod*. 1994; 16(2):110-20. http://dx.doi.org/10.1093/ejo/16.2.110

Wiedemeyer V, Berger M, Martini M, Kramer FJ, Heim N. Predictability of pharyngeal airway space dimension changes after orthognathic surgery in class II patients: A mathematical approach. *J Craniomaxillofac Surg*. 2019; 47(10):1504-9. http://dx.doi.org/10.1016/j.jcms.2019.07.024

Wolford LM, Chemello PD, Hilliard F. Occlusal plane alteration in orthognathic surgery--Part I: Effects on function and esthetics. *Am J Orthod DentofacialOrthop.* 1994; 106(3):304-16. http://dx.doi.org/10.1016/S0889-5406(94)70051-6

Zhang N, Liu S, Hu Z, Hu J, Zhu S, Li Y. Accuracy of virtual surgical planning in two-jaw orthognathic surgery: comparison of planned and actual results. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2016; 122(2):143-51. http://dx.doi.org/10.1016/j.oooo.2016.03.004