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The Impact of Clinical and Craniofacial Changes on the Surgical Outcomes of Lateral Pharyngoplasty in the Treatment of Obstructive Sleep Apnea

Nelson Solcia-Filho[1] Bruno Bernardo Duarte[2,3] Aurélio Rochael Almeida[4] José Luis Braga de Aquino[5]

[1] Clínica de Otorrinolaringologia e Cirurgia BucoMaxilo Facial, Campinas, SP, Brazil
[2] Serviço de Otorrinolaringologia, Hospital PUC-Campinas, Pontifícia Universidade Católica de Campinas, Campinas, SP, Brazil
[3] Faculdade de Medicina, Pontifícia Universidade Católica de Campinas, Campinas, SP, Brazil
[4] Faculdade de Medicina, São Leopoldo Mandic, Campinas, São Paulo, Brazil
[5] Programa de Pós-Graduação em Ciências da Saúde, Pontifícia Universidade Católica de Campinas, Campinas, SP, Brazil

Address for correspondence Nelson Solcia-Filho, Clínica de Otorrinolaringiologia e Cirurgia BucoMaxilo Facial, Campinas, SP, Brazil (e-mail: nsolcia@msn.com; nsolcia@msn.com).

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Abstract

Objective To verify if maxillomandibular retrusion, obesity, and increased neck circumference are factors of worse surgical prognosis for lateral pharyngoplasty in apneic patients.

Materials and Methods We evaluated 53 patients with obstructive sleep apnea who underwent lateral pharyngoplasty. Clinical evaluation was performed before the surgical procedure and included the measurement of body mass index (BMI) in kg/m^2, neck circumference in centimeters, and a clinical evaluation of the facial profile obtained through the natural position of the oriented head. The polysomnographic evaluation was performed with at a minimum of 6 months after surgery, and polysomnographic results were correlated with the preoperative clinical data.

Results The mean age of the patients was 38.8 years; the mean BMI was of 29.28-kg/m^2, and 84.9% of the sample was composed of men and 15.1% of women. There was a significant reduction in the mean value of the main respiratory parameters verified by polysomnography, such as apnea-hypopnea index (AHI) from 31.60 events per hour to 8.15 ($p < 0.001$); NadirO$_2$ went from 81% to 85% ($p = 0.002$) and mean oxyhemoglobin saturation from 94% to 95% ($p = 0.024$). It was also observed that the greater the maxillomandibular retrusion, the lower the mean reduction of the AHI after surgery. The increase in neck circumference proved to be a factor associated with the surgical outcome, and for each 1-cm decrease in the neck circumference, the chance of surgical success increased 1.2-fold.

Keywords
- craniofacial abnormalities
- obstructive sleep apnea
- cephalometry
- polysomnography

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Conclusion Lateral pharyngoplasty is an efficient surgical obstructive sleep apnea treatment. The lower the neck circumference measurement, the greater the chances of surgical success, and clinically evaluated maxillomandibular retrusion can reduce the magnitude of improvement in respiratory parameters after lateral pharyngoplasty in apneic patients.

Introduction

Obstructive sleep apnea (OSA) is a common chronic disease that impacts the health and quality of life of millions of people around the world.[1] It is characterized by the collapse of the pharynx while breathing during sleep, which can cause daytime and nighttime symptoms, as well as occupational, metabolic, and cardiovascular consequences.[2]

The prevalence is quite high in the general population; in a study carried out with 1,042 individuals living in São Paulo, Brazil, the authors[3] found a prevalence of 32.8%.

The pathophysiology of OSA is multifactorial and has not yet been fully understood.[4] It is known that the topography of collapses during sleep inspiration involves the pharynx. Roughly speaking, the disease results from the imbalance between the dilating forces and the collapsing forces of the upper airway. The main mechanism that keeps the pharyngeal tube patent during sleep is given by the contraction of the dilator muscles, especially the contraction of the genioglossus muscle, and the main constricting force is the negative intraluminal pressure of the pharynx.[4]

The different factors that make up the multifactorial mechanism of the disease etiopathogenesis are the low threshold for awakening, the instability of ventilatory control, genetics, obesity, neuromuscular factors, and unfavorable anatomical factors.[5] Among the anatomical factors that tend to narrow the pharynx, macroglossia, hypertrophy of the palatine tonsils, obesity, and unfavorable craniofacial skeletal characteristics such as maxillomandibular retrusion can be highlighted.[4]

Lateral cephalometry is one of the most studied radiographic exams used to characterize skeletal changes; however, according to Miles et al.,[6] there is no evidence to support the argument that cephalometric features are the basis for the direct etiology of OSA. However, other authors[2] have found craniofacial skeletal differences among OSA patients when evaluating their cephalometrics, evidencing a relationship with the disease; among the differences, severe mandibular retrusion and the position of the hyoid bone up to the enlarged mandibular rim should be included.

There are many difficulties in standardizing a method of clinical evaluation of the craniomaxillofacial characteristics in relation to the anteroposterior position of the maxilla and mandible. Lateral cephalometry, with its internal landmarks (craniometric points) and their tracings, compose what is best known for classifying craniomaxillofacial abnormalities.

The natural head position (NHP) has been adopted as the most habitual, physiological and natural body posture, and its alignment with the cervical spine is determined by the balance of the head and body when the individual focuses the eyes on a point in the distance at eye level.[7] This head position, adopted by the patient in his daily life, reproduces more faithfully his facial profile.[8]

Individuals with OSA and craniomaxillofacial deformity acquire postural compensations, such as cervical hyperextension and forward head projection, and may develop kyphoscoliosis.[9]

Andrews[10] adopted a promising and proprietary methodology to determine the best anteroposterior position of maxillary anterior incisor teeth for aesthetic purpose in patients to be treated orthodontically or through orthognathic surgery. He then demonstrated that in normal patients, the incisors of those individuals with excellent facial harmony would be located in a position determined by a vertical line situated between the forehead's facial-axis (FFA) point and the glabella. Another posterior study showed that the vertical glabella line can be adopted as a reference in determining the anteroposterior position of the maxilla.[11]

Treatments for OSA are classified as clinical (nonsurgical) and surgical; nonsurgical treatments include behavioral measures, speech therapy, myofascial exercises, intraoral mandibular advancement devices and positive airway pressure (PAP) devices.[2]

Surgical treatment of the upper airways is suitable for selected patients and is often recommended for symptomatic patients who cannot tolerate PAP. Surgical treatments include oropharyngeal surgeries such as lateral pharyngoplasty (LP), uvulopalatopharyngoplasty (UPPP) and expansion pharyngoplasty, palatal procedures, robotic surgeries of the base of the tongue, hypoglossal nerve neurostimulation, skeletal surgeries, and tracheostomy.[2]

The surgeries classified as oropharyngeal, which treat the pharyngeal region through an oral approach, are the most performed surgeries for the treatment of OSA. Due to the limited number of patients who benefit from the success of the surgery that used to be performed in the past, the UPPP, and due to unsatisfactory results, another oropharyngeal surgery was proposed: LP, which was described for the first time in 2003.[12] When compared with UPPP, LP showed better clinical and polysomnographic results, according to the study conducted by Cahali et al. in 2004.[13] Since then, some studies have corroborated these positive LP results in the treatment of OSA.[14,15] Despite these promising results, it is not yet known which OSA patients have better chances of surgical success, which is still a challenge in the clinical practice.

Hence, the objective of the present study was to verify if there is a relationship involving the pre- and postoperative polysomnographic results of LP in the treatment of OSA, the anteroposterior position of the maxilla and mandible assessed clinically, the body mass index (BMI; kg/m^2), and cervical circumference assessed before the surgical procedure.

Materials and Methods

The present study was submitted to and approved by the Ethics Committee for Human Research of the Pontifícia Universidade Católica de Campinas (PUC-Campinas), under Opinion no. 4.607.394 and CAAE no. 43116420.5.0000.5481. All participating patients read and signed the Free and Informed Consent Form (FICF) in advance to confirm participation in the present study.

Study Design

The present is a prospective cohort study carried out at the Obstructive Sleep-Disordered Breathing (SDB) outpatient clinic of the Otorhinolaryngology Service of the PUC-Campinas hospital.

As of 2010, a total of 137 patients between 18 and 65 years of age diagnosed with OSA via type 1 polysomnography underwent LP. The sample consisted of 53 patients with available pre- and postoperative type 1 polysomnographic exams. Postoperative polysomnography was performed not less than 6 months after the procedure. Those individuals who agreed to participate in the study were evaluated and clinical and polysomnography data were collected in scheduled returns to the SDB outpatient clinic of the otorhinolaryngology service. The patient selection steps can be seen in the Flowchart in ►**Figure 1**.

Sleep Monitoring

Type-I polysomnography) was performed in the sleep laboratory. The results were reviewed according to the standard protocol reported in the American Academy of Sleep Medicine handbook.

Surgical Procedure

Patients underwent LP surgery, a surgical procedure described by Cahali.[12] Lateral pharyngoplasty has been modified several times since its creation and these modifications are called versions of the technique. The outcome evaluated was obtained with the use of the 5th and 6th versions of this surgical technique. Some patients underwent concomitant nasal surgery (septoplasty with turbinectomy of the inferior turbinate tissue). When there was a combination of the 2 surgeries, the nasal surgery was always performed first, followed by LP. Drug-induced sleep endoscopy (DISE) was not performed before the procedure to verify the site of pharyngeal obstruction due to technical difficulties in performing such exam in our service and also because there is no formal requirement to indicate the procedure based on DISE, according to studies authored or coauthored by Cahali.[12–14]

The inclusion and exclusion criteria for performing the LP were based on studies authored or coauthored by Cahali:[12–14,16]

a) Patients aged > 18 years who usually snored;
b) Patients with an apnea-hypopnea index (AHI) greater than five and who did not tolerate or refused CPAP therapy;
c) Patients subjectively selected for having bulky lateral oropharyngeal tissues.

The surgery exclusion criteria were: morbid obesity, presence of uncontrolled hypothyroidism or under control for < 1 year, and major deformities of the maxilla or mandible.

Control of therapeutic success was assessed by type-I polysomnography performed at least 6 months after LP. The surgical success was assessed using the Sher[17] criterion, with a reduction of at least 50% of the preoperative AHI value with a final AHI value < 20.

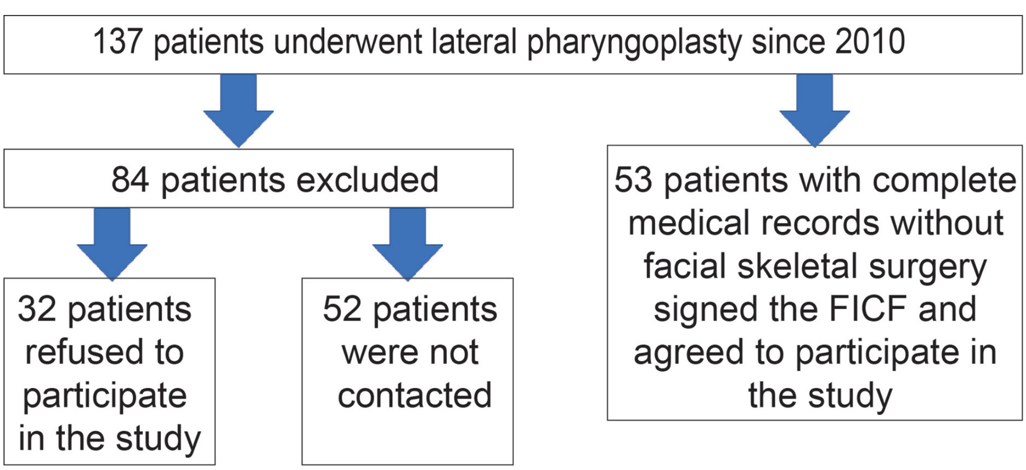

Fig. 1 Facial profile assessment method, using a 90-g plumb, millimeter ruler, oval mirror placed at a distance of 1 m, with the natural position of the head oriented, and “intrapupillary” gaze. The distance between the gingiva and the thread shows the maxillary mandibular retrusion in millimeters.

Age, gender, neck circumference (NC; cm), BMI (kg/m^2), facial profile measurements and type-I polysomnography data before and after LP were assessed and correlated.

Technique for Assessing Facial Profile and Neck Circumference

An oval mirror measuring 1.5 m in height by 50 cm in width, without straight edges, a 90-g plumb and millimeter rulers sterilized in ethylene oxide were used in the medical visit room.

The steps were as follows:

1) Patient standing, with feet at shoulder width, postural alignment was sought (tragus, shoulder, pelvic waist, knee, and lateral malleolus).[18] The patient was asked to stay in NHP, positioned in front of a 1.5 m. vertical oval mirror and one meter away, looking horizontally at the level of his/her pupils ("looking into their own eyes") and at that moment the head was oriented so that the tragus would be aligned with the other points (shoulder, pelvic waist, knee and lateral malleolus). It is of great importance to perform the head orientation due to postural adaptations in apneic patients or with craniofacial deformities patients. ►**Figure 2** shows the difference between NHP and oriented NHP, which can completely change the result of the evaluation.

2) The plumb is brought closer to the face until reaching the soft glabella. This is what we called the glabellar vertical line (GVL).

3) The distances measured from the maxilla and the mandible, using a millimeter ruler between the cervical anterior incisor teeth, natural or prosthetic, or the buccal gingiva when the patient was edentulous, to the GVL, are called the maxillary glabellar line (MaxGL) and the mandibular glabellar line (MandGL) (►**Figure 3**).

4) The measured distance is in millimeters. The best placement is the zero (0) value, that is, when the cervical anterior incisor teeth, natural or prosthetic, or the buccal gingiva, are touching the GVL. Values to the left will be considered negative and maxilla and/or mandible mean retro positioning. When the front of the GVL is a positive value, it means a maxillary and/or mandibular protrusion.

The NC was measured in the same oriented NHP using a measuring tape in centimeters that was placed in the middle of the neck and in the anterior middle part of the neck, just below the laryngeal prominence.

The pre- and post-LP polysomnography variables were related to the measurements of BMI (kg/m^2), NC, MaxGL, and MandGL and analyzed, with the null hypothesis being rejected when $p < 0.05$.

Statistical Analysis

A nonnormal distribution was verified using the Shapiro-Wilk test, so nonparametric tests such as Wilcoxon were used to compare pre- and postoperative variables. After these comparisons, the effect sizes were calculated (Cohen d)[19] for the differences found at 5% significance level.

The associations between the cases of each of the categories of the origin and surgical success (Pearson Chi-Squared test) variables were evaluated, and the distributions of the polysomnographic variables were compared before and after the surgery in each of the categories of surgical success (Wilcoxon signed-rank test) and at each time point (pre- and post-surgical) regarding the success or failure of the surgery (Mann-Whitney U test). A correlation analysis was performed between the polysomnographic and cephalometric variables (Spearman correlation test). Subsequently, a univariate binary logistic regression analysis was performed,

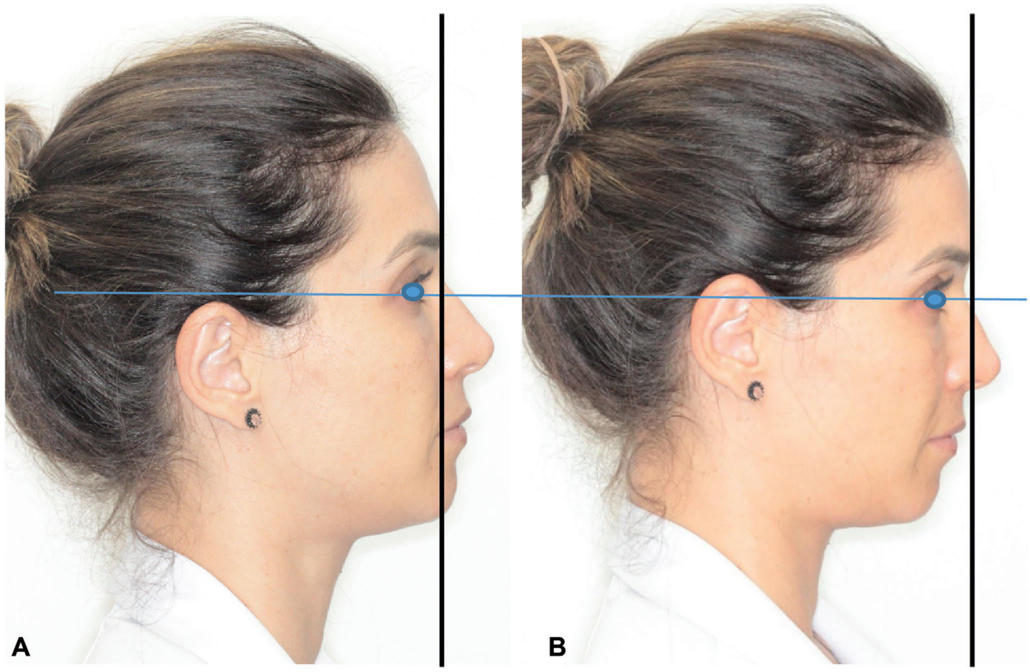

Fig. 2 (**A**) Model in natural head position with postural compensation. (**B**) Model in natural oriented head position to avoid postural compensation.

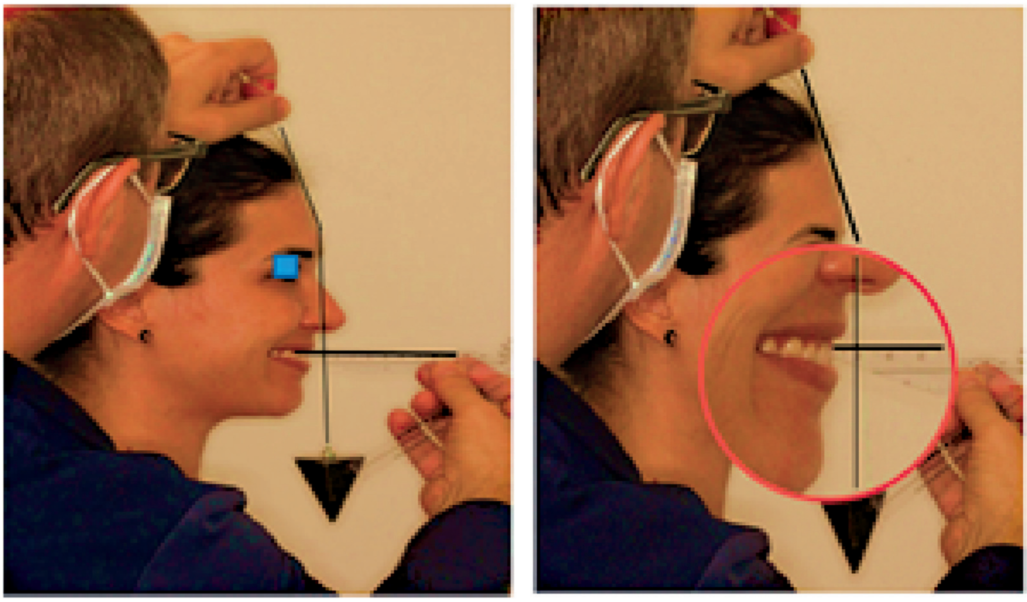

Fig. 3 The reduction in the apnea and hypoapnea index (AHI) after surgery was positively associated with the variables maxillary GL and mandibular GL, which means that the smaller the maxillary mandibular retrusions, the greater the AHI reductions after surgery, yielding improved surgical outcome.

in which success was defined as follows: 1 (success), when postsurgical AHI < 20 or postsurgical AHI 50% lower than the pre-surgical AHI. This surgical success criterion is based on the work of Sher.[17] After the univariate analyses, the adjustment of the explanatory model of the outcome was performed. Variables with p-values < 0.30 and using the stepwise-backward method were included for the fit of an explanatory multiple model, allowing to fit an explanatory multiple model with one of the variables of interest in the study significantly associated with the outcome with a level of significance of 5%.

Results

A total of 53 patients were evaluated, whose mean age was 38.80 (± 9.77) years old, of which 45 (84.9%) were men and 8 (15.1%) were women, with mean ages of 38.89 (± 9.37) and 38.38 (± 12.18) years respectively. Out of the 53 patients, 88.7% (n = 47) underwent nasal surgery concomitantly with LP.

►**Table 1** shows the values of the clinical and polysomnographic variables before and after the surgical procedure. The improvement of the mean and median values measured by type 1 polysomnography may clearly be observed.

Table 1 Comparison between the pre- and postoperative patient parameters.

Variables	All		p-value	Effect size
	Period			
	Preoperative: median (p25; p75); mean (± SD)	**Postoperative: median (p25; p75); mean (± SD)**		
BMI (kg/m^2) (n = 23)	29.28 (26.29; 32.00); 29.07 (± 3.11)	28.85 (25.65; 31.25); 28.71 (± 3.12)	0.635	–
AHI (events/h) (n = 53)	31.60 (18.85; 46.05); 35.01 (± 21.49)	8.15 (3.42; 23.72); 15.85 (± 16.75)	< 0.001	0.97
T < 90 (%) (n = 30)	5.75 (0.50; 9.80); 12.36 (± 21.36)	0.30 (0.00; 7.20); 6.76 (± 18.10)	0.073	–
T < 80 (%) (n = 29)	0.00 (0.00; 0.70); 0.94 (± 2.79)	0.00 (0.00; 0.00); 2.80 (± 15.67)	0.173	–
Minimum O_2 saturation (%) (n = 38)	81.00 (70.00; 85.00); 75.65 (± 12.78)	85.00 (77.00; 88.00); 82.82 (± 7.77)	0.002	0.30
Mean O_2 saturation (%) (n = 31)	94.00 (92.00; 95.00); 93.38 (± 2.91)	95.00 (93.00; 96.00); 94.19 (± 5.28)	0.024	0.33

Abbreviations: BMI, AHI, apnea-hypopnea index.; BMI, body mass index; p25, 25th percentile; p75, 75th percentile; SD, standard deviation.
Notes: Wilcoxon signed-rank test. Effect size = Cohen d. Significance level = 5%.

Table 2 Results of the correlation analysis regarding polysomnographic and cephalometric variables.

Polysomnographic variables	Cephalometric variables		
	Maxillary glabellar line (mm)	Mandibular glabellar line (mm)	Neck circumference (cm)
Preoperative apnea-hypopnea index	0.263	0.171	0.063
	$p = 0.057$	$p = 0.220$	$p = 0.654$
Reduction in the apnea-hypopnea index	0.311	0.296	- 0.053
	$p =$ **0.025**	$p =$ **0.033**	$p = 0.710$

Notes: Spearman correlation test; significance level = 5%; values in bold indicate a significant difference between groups.

The variable "presurgical AHI" was not correlated with the variables maxillary GL, jaw GL, and NC ($p > 0.05$ for all correlation tests). On the other hand, the reduction in AHI (the difference between the pre and postoperative AHI) was shown to be weak and positively associated with the variables maxillary GL and mandibular GL. This means that the higher the maxillary GL and mandibular GL values are, the greater the AHI reductions after surgery (►**Table 2**, ►**Figure 4**).

According to ►**Table 3**, we can observe that there was an improvement, with a decrease in postsurgical AHI values among patients considered to have had successful and unsuccessful surgery. Likewise, in patients who experienced a successful surgery, it was found that the postsurgical AHI was significantly lower than the presurgical AHI, as well as the variables "T < 90" and "T < 80", which were significantly lower in the postoperative period of patients with successful surgery and the variables "minimum and mean O_2 saturation" obtained significantly higher values in the postoperative period of patients with successful surgery.

In the logistic model fit for the outcome *success*, only the NC proved to be a factor associated with the outcome, with each 1-cm decrease in the NC indicating that the chance of surgical success increased 1.20-fold (►**Table 4**).

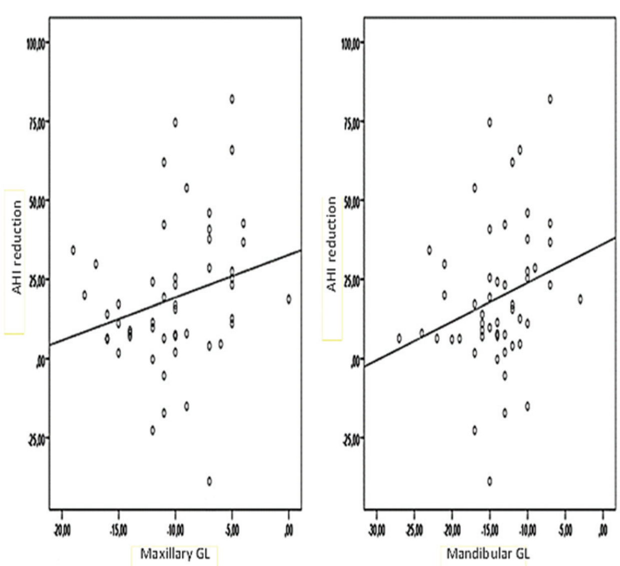

Fig. 4 Chart of the dispersion of the cases studied according to the MaxGL and MandGL measures and the reductions of AHI verified.

Discussion

Obstructive sleep apnea is a highly prevalent disease, with a multifactorial etiopathogenesis, and LP is an effective treatment for this disease, especially in those patients who do not adhere to PAP devices.[12–15]

In the present study, there was no variation in BMI before and after LP; possibly the patients lost weight after surgery and recovered that weight after complete healing. This fact is important because the mean improvement in respiratory parameters verified by polysomnography is due to the surgical procedure per se and not due to weight loss.

Although the mean BMI of patients who obtained surgical success was lower (28.70 kg/m^2) than that of patients with surgical failure (30.62 kg/m^2), there was no statistical significance in the surgical outcome. It is possible that the absence of statistical difference occurs due to the small difference in the average values of BMI between the assessed groups.

Neck circumference > 43 cm in men and > 38 cm in women is a proven risk factor for OSA.[2] In the present study, the mean NC of the patients in the sample was 42.50 cm (± 3.85). The present study demonstrated that the NC is a factor associated with the outcome, and for every 1-cm decrease in the NC, there was a 1.20-fold increase in the chance of surgical success.

We consider this information to be quite relevant, since there are no reports in the medical literature of a relationship between the surgical success of LP for the treatment of OSA and the NC. Therefore, we can suggest the inclusion of this anthropometric clinical variable in the preoperative evaluation of patients who are candidates for the surgical procedure, emphasizing that the chance of surgical success increases with smaller measurements of cervical circumference.

In the present study, DISE was not performed for preoperative assessment of the topography of pharyngeal collapse during sleep. This did not occur due to operational issues of difficult access to this exam in our service. In the study by Elzayat et al.,[15] pre- and postoperative DISE in patients undergoing LP were performed; however, the preoperative DISE did not condition the procedure, since it was already indicated and was performed in the operating room before the procedure. Even without the aid of DISE in the present study, according to the criteria by Sher, the authors achieved a success rate of 70%. Other studies with LP

Table 3 Comparison of the distribution of variables of interest for surgical success.

Variables	Success		
		No ($n = 20$): median (p25; p75)	Yes ($n = 33$): median (p25; p75)
BMI (kg/m^2)	Preoperative	30.62 (29.00; 32.00)	28.70 (25.00; 31.00)
	Postoperative	29.60 (25.00; 32.75)	28.00 (26.98; 30.25)
p-value		0.865	0.838
AHI (events/h)	Preoperative	27.20 (16.65; 44.12)	33.80 (21.00; 46.65)
	Postoperative	32.60 (12.00; 40.10)	6.60 (2.20; 12.15)
p-value		0.314	< **0.001**
T < 90 (%)	Preoperative	3.40 (0.55; 10.32)	6.69 (0.50; 11.15)
	Postoperative	9.80 (0.25; 22.35)	0.10 (0.00; 0.49)
p-value		0.649	**0.001**
T < 80 (%)	Preoperative	0.00 (0.00; 0.55)	0.00 (0.00; 0.70)
	Postoperative	0.00 (0.00; 0.20)	0.00 (0.00; 0.00)
p-value		0.069	**0.001**
Minimum O_2 saturation (%)	Preoperative	81.00 (70.00; 85.00)	81.00 (71.00; 85.00)
	Postoperative	78.00 (74.00; 86.50)	87.00 (82.00; 91.00)
p-value		0.593	**0.027**
Mean O_2 saturation (%)	Preoperative	94.00 (92.00; 96.00)	94.00 (92.00; 95.00)
	Postoperative	94.50 (93.00; 96.25)	95.00 (94.00; 96.50)
p-value		0.552	**0.020**

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; p25, 25th percentile; p75, 75th percentile.
Notes: Wilcoxon signed-rank test; significance level = 5%; values in bold indicate a significant difference between groups.

Table 4 Evaluation of variables of interest as predictors of successful outcome in surgery.

Variables	Success		Not fit		Fit	
	No ($n = 20$): median (p25; p75)	Yes ($n = 33$): median (p25; p75)	*p*-value	OR (95% CI)	*p*-value	OR (95%CI)
Age	39.00 (31.00; 47.00)	36.00 (32.00; 45.00)	0.378	0.97 (0.91–1.03)	–	–
Gender: n(%)						
Female	2(10.0%)	6(18.2%)	–	1	–	–
Male	18(90.0%)	27(81.8%)	0.426	0.50 (0.09–2.75)		
BMI (kg/m^2)	30.62 (29.00; 32.00)	28.70 (25.00; 31.00)	0.242	0.84 (0.63–1.12)	–	–
AHI (events/h)	27.20 (16.65; 44.12)	33.80 (21.00; 46.65)	0.355	1.01 (0.98–1.04)	–	–
AHI during REM sleep	26.20 (22.60; 54.35)	22.30 (12.50; 69.80)	0.947	0.99 (0.96–1.03)	–	–
T< 90 (%)	3.40 (0.55; 10.32)	6.69 (0.50; 11.15)	0.921	1.20 (0.03–47.63)	–	–
T< 80 (%)	0.00 (0.00; 0.55)	0.00 (0.00; 0.70)	0.418	0.01 (0.00–0.06)	–	–
Minimum O2 saturation (%)	81.00 (70.00; 85.00)	81.00 (71.00; 85.00)	0.997	0.99 (0.00–17.18)	–	–

(*Continued*)

Table 4 (*Continued*)

Variables	Success		Not fit		Fit	
	No ($n=20$): median (p25; p75)	Yes ($n=33$): median (p25; p75)	*p*-value	OR (95% CI)	*p*-value	OR (95%CI)
Mean O2 saturation (%)	94.00 (92.00; 96.00)	94.00 (92.00; 95.00)	0.497	6.75 (0.00–7.64)	–	–
Maxillary glabellar line	11.00 (10.00; 12.00)	10.00 (5.00; 14.00)	0.185	0.91 (0.79–1.04)	–	–
Mandibular glabellar line	14.00 (13.00; 16.00)	12.00 (10.00; 16.50)	0.239	0.92 (0.82–1.05)	–	–
Neck circumference	44.00 (42.12; 46.00)	41.50 (39.00; 45.00)	0.047	0.83 (0.69–0.98)	0.047	0.83 (0.69–0.98)

Abbreviations: AHI: apnea-hypopnea index; BMI, body mass index;.95%CI, 95% confidence interval; OR, odds ratio; p25, 25th percentile; p75, 75th percentile; REM, rapid eye movement.
Notes: Binary logistic regression; significance level = 5%.

polysomnographic results did not use DISE to establish the procedure and obtained excellent results.[12–14]

One of the anatomical factors predisposing to the development of OSA is the retroposition of the maxilla and/or mandible. The exam most used today to investigate this issue is the radiographic exam called lateral teleradiography with cephalometric tracing. The tracings that determine the maxillomandibular positioning are the SNA (angle between sella, nasion, and subspinale point A) and SNB (angle between sella, nasion, and subspinale point B) respectively.[20–22] However, due to the great skeletal heterogeneity of the skull base, linear or angular measurements passing through the skull base may not be reliable.[23] Other authors, like Andrews,[10] Adams et al.,[24] Rasmussen et al.,[25] Resnick et al.,[26] Gidaly et al.,[27] and Tremont and Posnick,[28] concluded that external landmark assessment of the facial profile for the diagnosis of a craniomaxillofacial abnormality and for orthodontic and orthognathic surgery planning with view at improving functions (occlusion, breathing, OSA) and esthetics tends to be more reliable.

Patients evaluated through the clinical methodology described in the present study had mandibular maxillary retrusion corroborated by the facial profile measurements with the external mark (glabella) obtained; the average of MaxGL being -10.17 ($\pm$ 4.17) and MandGL of -13.98 ($\pm$ 3.85). This is an important datum, as maxillary and/or mandibular retrusion is a risk factor for OSA.[21,29] Most studies related to craniomaxillofacial evaluations use the Frankfort horizontal plane[30] or the NHP, which was described in the 1950s[7,31,32] as a reference for their examinations that were both described $>$ 7 decades ago.

Head posture is the result of a complex and delicate balance between the muscles involved in the cervical-craniomandibular system, whose purpose is to maintain the pharyngeal airway cleared.[33] The forward head posture, commonly related to mouth breathing, is described as an adaptation to enlarge and facilitate the passage of air through the oropharynx.[34,35]

It was then determined that, in order to evaluate these patients who undergo postural adaptations or postural camouflage, the NHP should be standardized, guiding them to maintain the posture that would be the closest to an optimal posture, described by Kendall et al.[18]

Te present study revealed that the more negative the MaxGL and MandGL measurements, the lower the AHI reductions after LP, suggesting that the greater the maxillomandibular retrusions, the worse the surgical results. There are no publications in the literature correlating the position of the maxilla and mandible through clinical analysis of the facial profile and the surgical results of LP. Therefore, with the results obtained through the present work, we can suggest a form of preoperative clinical evaluation with the potential to select patients with greater chances of surgical success with LP.

In the present study, there was a statistically significant improvement in the mean and median of respiratory parameters after the surgical procedure, verified by type-I polysomnography. When we compared the medians of pre- and postoperative LP data, it was found that the AHI was reduced from 31.60 events per hour to 8.15 ($<$ 0.001); nadir O_2 rate increased from 81 to 85% ($p = 0.002$), and oxyhemoglobin saturation time $<$ 90.00% of total sleep time decreased from 12.36 to 6.76%. The surgical success rate, based on the criteria by Sher[17], of the total sample was 62.00%.

These polysomnographic results are in line with those of the largest study on the sixth version of the LP to date carried out by Elzayat et al.[15] It is noteworthy here that the present study used a larger sample, as it evaluated 53 patients undergoing LP, while Elzayat et al.[15] only evaluated 40 individuals. Elzayat et al.[15] achieved 70% surgical success based on the criteria by Sher;[17] the mean AHI was 34.73 events per hour and dropped to 16.59 ($p < 0.001$), and the nadir rate of oxyhemoglobin went from 79.00 to 88.05%.

In the sample of the present study most patients (88.7%) undergoing LP underwent nasal surgery before the oropharyngeal procedure. When comparing the results of LP single procedures patients with those who underwent nasal surgery concomitantly with the main procedure, there was no statistically significant difference in the respiratory data analyzed on polysomnography. This result was totally expected, since several studies that submitted an apneic patient to nasal surgery as a single treatment showed that no polysomnographic parameter was altered after nasal surgery. This can be explained by the pathophysiology of OSA being located in the pharyngeal region, and not being a nasal obstruction.[36] In the evaluation of the oropharynx of the patients before their surgery, most of them had small palatine tonsils, grade I or II. It is known that hypertrophic palatine tonsils (grades III and IV) are necessary for surgical success in 81% of patients undergoing UPPP.[37]

However, $< 10\%$ of adult patients with OSA exhibit hypertrophic palatine tonsils. Patients with normotrophic palatine tonsils (grades I or II) experience surgical success rates in UPPP $< 40\%$. Therefore, the high surgical success even in patients with normotrophic palatine tonsils is very relevant. Mendes et al.[38] obtained good results with patients with normotrophic palatine tonsils submitted to LP.

The present study has some limitations, such as the lack of a control group, whether composed of apneic patients or even of patients with skeletal cephalometric measurements, which restricts the relevance of our findings. Another limitation are the external measurements, because despite having been very well standardized and performed by a single professional, errors may occur in the measurements.

Patients were selected for convenience, with a small sample size, but not very different from clinical studies. A possible selection bias may have occurred because patients who tend to return for anthropometric, craniomaxillofacial, and polysomnographic measurements tend to be those with less clinical and polysomnographic success, since patients who experience a great improvement tend to abandon the treatment.

Finally, the difficulty in comparing data obtained in the present work with data from other works is a limitation, as this type of comparison is not found in the literature.

Although the NC is moderately associated with the outcome of LP, the size of the sample assessed does not allow us to state that this variable and the other variables reviewed together or alone are capable of predicting the surgical success of LP.

Conclusion

Lateral pharyngoplasty proved to be an efficient surgical treatment for patients with OSA, with improvement in sleep breathing parameters evaluated by polysomnography.

Neck circumference proved to be a factor associated with the surgical outcome of LP in the treatment of OSA, and for every 1-cm decrease in the NC, the chance of surgical success increased 1.20-fold.

The more negative the values of the MaxGL and MandGL measurements obtained through the clinical analysis of the craniomaxillofacial profile, the smaller the AHI reductions after LP in patients with OSA.

Contributions of the Authors

All authors contributed to the manuscript writing and revision. All authors approved the final version. The corresponding author attests that all listed authors meet authorship criteria.

Conflict of Interests

The authors have no conflict of interests to declare.

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