

COMPARISON BETWEEN PHARYNGEAL FLAP SURGERY AND SPHINCTEROPLASTY: NASOMETRIC AND AERODYNAMIC ANALYSIS

Comparação entre cirurgia do retalho faríngeo e esfínteroplastia: análise nasométrica e aerodinâmica

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ABSTRACT

Purpose: to compare the effect of pharyngeal flap surgery and sphincteroplasty on hypernasality and velopharyngeal closure in the velopharyngeal insufficiency management, by means of instrumental assessment. **Methods:** thirty patients with repaired cleft palate±lip, submitted to surgical treatment for velopharyngeal insufficiency (15 pharyngeal flap and 15 sphincteroplasty) were evaluated before and, at least, 1 year after surgery. Hypernasality was estimated by means of nasalance scores (acoustic correlate of nasality) obtained by nasometry considering a cutoff score of 27%. Velopharyngeal closure was determined by the velopharyngeal area measurement. Nasalance scores were obtained by nasometry, during the reading of a set of 5 sentences containing exclusively oral sounds, considering the cutoff value of 27%. Velopharyngeal area was provided by the measurement of velopharyngeal area by means of pressure-flow technique and was classified as: 0 to 4.9 mm²=adequate; 5 to 19.9 mm²=borderline and ≥20mm² inadequate. Differences between the two techniques were accepted as significant when $p < 0.05$. **Results:** before surgery nasalance mean scores were 43±8.4% and 45±14.2% and velopharyngeal area mean were 51±35.4mm² and 69±29.2mm² for the pharyngeal flap and sphincteroplasty groups, respectively. After surgery, nasalance mean scores were 27±10.1% and 31±14.2% and velopharyngeal area mean were 3.6±5.5mm² and 24±32.7mm² for the pharyngeal flap and sphincteroplasty groups, respectively. The reduction of the nasalance scores and velopharyngeal area was statistically significant in both groups. **Conclusion:** these results suggest that pharyngeal flap was shown to be more efficient than sphincteroplasty in the elimination of hypernasality and adequacy of velopharyngeal closure in the patients studied.

KEYWORDS: Cleft Palate; Velopharyngeal Insufficiency; Rhinomanometry

■ INTRODUCTION

Velopharyngeal insufficiency (VPI) is defined as a fault in the velopharyngeal closure, where part of

the current air is deviated to the nasal cavity leading to the occurrence of symptoms that may impair speech in different ways¹⁻⁵. VPI's most representative symptom is hypernasality, which may persist even after primary correction of the palate. In such cases, secondary surgery is required⁶⁻¹⁰. Pharyngeal flap and sphincteroplasty are among the surgical techniques used for VPI correction. Both procedures aim to reduce the space between oro and nasopharynx, thus reducing symptoms resulting from insufficient velopharyngeal closure^{5,6,11}.

The pharyngeal flap technique consists of the construction of a myomucosal flap uniting the posterior wall of the pharynx to the soft palate,

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constituting a bridge between both, delimiting two lateral orifices. Flap height and width should be determined in accordance with the size of velopharyngeal gap and the degree of movement of the pharynx's lateral walls. These should be evaluated prior to surgery, enabling the construction of the flap in accordance with the needs of each case². Sphincteroplasty was proposed as a physiological solution for correcting VPI. In this technique, the myomucosal flaps are removed from the posterior pillars and from the lateral walls of pharynx, on each side. They are then sutured to each other and inserted in the posterior wall of the pharynx. This creates a single central orifice surrounded by mucosa and muscle at the level of the velum palatinum. The technique aims to create a "dynamic sphincter" that controls air passage from the oral portion to the nasal portion during speech^{2,6,12}.

The determination of surgical results for VPI correction in general is done by auditory-perceptual assessment of speech associated with instrumental evaluation. For such, use of at least one of the following instrumental methods is recommended: nasoendoscopy, videofluoroscopy, nasometry or pressure-flow technique¹³. The latter two, which were used in this study, are considered indirect methods, the results of which lead to verifying the functional status of the velopharyngeal mechanism. Nasometry and pressure-flow technique, by providing quantitative data, contribute greatly to following up on surgical treatment using pre- and post-surgical comparisons¹⁴.

Nasometry is a non-invasive technique that permits an indirect check of speech resonance, that is, hypernasality or hyponasality, by measuring nasalance, a physics measure that reflects the quantity of acoustic nasal energy during speech expressed in percentage¹⁴. Nasalance is determined, primarily, by velopharyngeal sphincter activity, which is why nasalance deviations are indicative of VPI^{3,15,16}. The pressure-flow technique evaluates velopharyngeal mechanism in its functional aspect, providing objective data about the aerodynamic repercussions of any failure in velopharyngeal function¹⁴. It provides quantitative data about the velopharyngeal function in a non-invasive manner, making it possible to check the extension of velopharyngeal closure during production of the plosive phone [p]¹⁷. The literature demonstrated that areas smaller than 5mm² are suggestive of adequate velopharyngeal closure, 5 to 9mm², of adequate-borderline closure, 10 to 19mm², of borderline-inadequate closure and, equal to or greater than 20mm², of inadequate closure¹⁸.

Many studies have demonstrated the success and the complications of secondary surgical

techniques employed for VPI treatment, using different methodologies for the analysis of surgical results. Some employed direct instrumental evaluations, through nasoendoscopy and videofluoroscopy^{12,19-22} and others, indirect instrumental evaluations such as nasometry and pressure-flow technique^{12,17,21,23-26}. Previous studies conducted at the Laboratory of Physiology^{17,26} investigated the effect of the pharyngeal flap surgery on the speech and breathing of patients with residual VPI, since this is a routine surgery performed at HRAC-USP. An investigation of the effect of the pharyngeal flap on upper airways revealed that the flap led to the appearance of permanent respiratory symptoms, such as, oral breathing, snoring and difficulty in breathing during sleep in 36% of the patients as a result of the reduction in nasopharyngeal dimensions after surgery, evaluated by the pressure-flow technique²⁷. Another study analyzed speech outcomes obtained before and after pharyngeal flap surgery in 241 individuals, using nasometric and aerodynamic evaluations. The authors verified that the pharyngeal flap was effective in reducing hypernasality in 68% of the cases in accordance with nasometry and in improving velopharyngeal closure in 66% of the patients, according to aerodynamic evaluation (pressure-flow technique)¹⁷. Recently, the effect of the pharyngeal flap was compared to another technique for VPI correction, secondary palatoplasty with intravelar veloplasty. The authors verified that, in patients submitted to pharyngeal flap surgery, hypernasality was absent in 70% and velopharyngeal closure was adequate in 80%. In those submitted to secondary palatoplasty with intravelar veloplasty, hypernasality was absent in 34% and velopharyngeal closure was adequate in 50%. Therefore, the pharyngeal flap was more efficient than intravelar veloplasty for correcting hypernasality and for adequate velopharyngeal closure²⁶.

Sphincteroplasty surgical results have also been frequently compared to other surgical techniques, in isolation or combined, aimed at establishing the most effective technique for correcting velopharyngeal insufficiency^{12,21,28}. A large group of researchers compared the speech results obtained before and after sphincteroplasty in 45 individuals, and the pharyngeal flap in 52 individuals, using perceptual, nasometric and nasoendoscopy evaluations. The authors verified that both surgical techniques were equally effective in reducing nasalance scores and eliminating hypernasality, which occurred in 76% of the cases submitted to sphincteroplasty and 81% of the pharyngeal flap cases²¹. Likewise, other researchers did not verify significant differences between one group of 26 patients submitted

to sphincteroplasty and one group of 22 patients submitted to pharyngeal flap surgery, evaluated using nasometry, nasoendoscopy and videofluoroscopy. The authors showed a VPI rate of 11.5% after sphincteroplasty and 9% after pharyngeal flap¹². Through perceptual assessment, a study recently compared the speech results of 20 patients submitted to isolated sphincteroplasty, 38 submitted to pharyngeal flap and 38 submitted to sphincteroplasty combined with the Furlow technique. The authors verified a significant reduction in hypernasality after surgery in the three groups studied. However, they demonstrated that the resonance results were significantly better for the groups with pharyngeal flap and sphincteroplasty combined with the Furlow technique, compared to the isolated sphincteroplasty group²⁸.

In the current study, the aim was to compare the effect of the pharyngeal flap and of sphincteroplasty on speech nasality and on velopharyngeal closure using instrumental evaluations for such.

■ METHODS

This retrospective study was developed in the Laboratory of Physiology of the Hospital for Rehabilitation of Craniofacial Anomalies of the University of São Paulo, Bauru-SP with the approval of the local ethics committee for human research, number 153/2011.

Casuistics

Thirty patients with residual VPI were evaluated. They were submitted to surgical correction of the VPI at least 12 months ago; 15 submitted to pharyngeal flap (PF group) and 15 submitted to sphincteroplasty (SP group). The age of the patients ranged between 6 and 38 (average ages of 19 ± 16 for the PF group and 18 ± 11 for the SP group); 12 patients with isolated cleft palate, 13 with unilateral cleft lip and palate, 4 with bilateral cleft lip and palate and 1 with noncleft VPI.

Procedures

The patients were evaluated before surgery (PRE) and, at least, 12 months after pharyngeal flap and sphincteroplasty surgery (POST).

Nasometric Speech Assessment - Nasometry

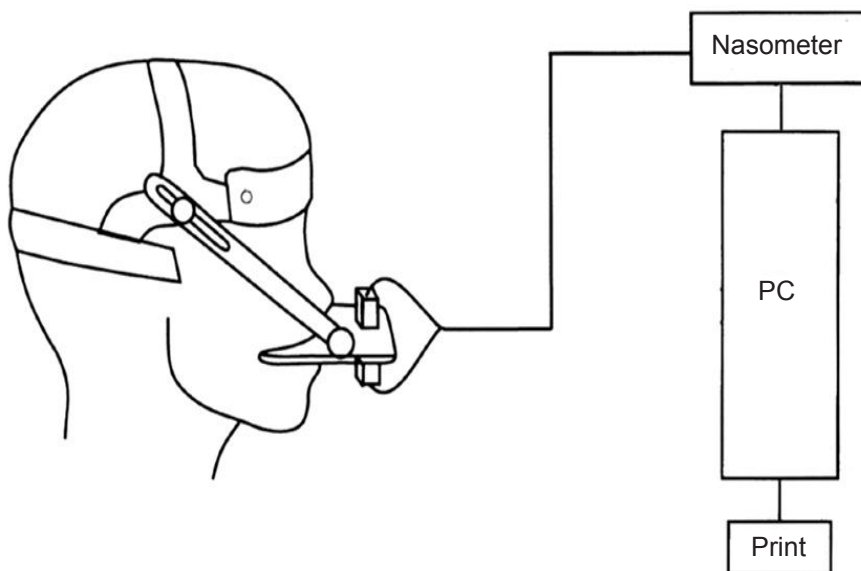
The determination of nasalance (physical correlation of nasality) was done using an IBM nasometer, model 6200-3 (software version 30-02-3.22). The system is comprised of two microphones, positioned one on each side of a sound separation plate, positioned on the upper lip and kept in position using a helmet. The upper microphone

captures the signals from the nasal component of speech. The bottom one captures the signals from the oral component, which are filtered, digitized and analyzed using specific software. The exam is conducted while reading a set of 5 sentences in Brazilian Portuguese, containing exclusively oral sounds, to identify hypernasality²⁹. Patients who are unable to read the text are asked to repeat each sentence to the examiner. As the individual reads the text shown on the computer screen connected to the system, the signals captured by the microphone appear as points on the screen, forming the configuration of a curve. Nasalance is calculated using the numeric ration between nasal acoustic energy and total acoustic energy (sum of nasal and oral acoustic energy), multiplied by 100. A cutoff of 27% is considered the upper limit of normality. That is, values greater than 27% are considered indicative of hypernasality¹⁴. Figure 1 shows the system configuration in a schematic format.

Velopharyngeal area measurement - Pressure-flow technique

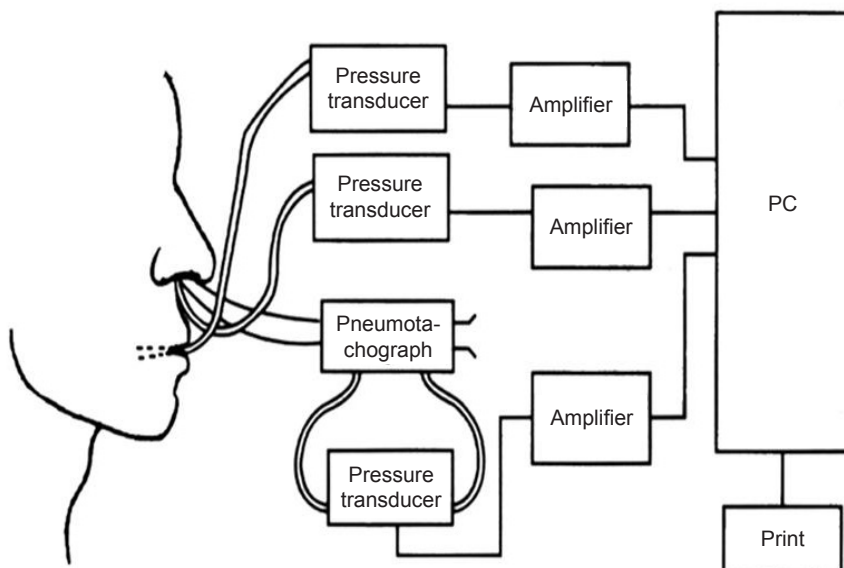
Determination of the velopharyngeal area during speech was conducted using the pressure-flow technique (modified anterior rhinomanometry), using a PERCI-SARS (computer system - version 3.50)³⁰. The principle of the technique is based on the minimal cross sectional area of a constriction (or orifice) may be estimated by the simultaneous measurement of differential pressure between the two sides of the constriction and the airflow that crosses through it³¹.

The velopharyngeal area is determined during the production of the voiceless plosive phone [p], inserted in the word "rampa", produced 4 to 6 times in succession, positioning a catheter inside the oral cavity and another in one of the nostrils. The nasal catheter is kept in position by a nasal obturator that blocks the nostril. Both catheters measure static air pressures transmitted to pressure transducers. Nasal air flow is measured by a plastic tube adapted to the other nostril, connected to a pneumotachograph previously heated and connected to a pressure transducer. The signals from the three transducers (nasal pressure, oral pressure and nasal flow) are sent to the PERCI system for analysis by a specific program. The area considered for this analysis represents the average for multiple productions. Based on the equation, the program itself calculates it: $A = V/k(2DP/d)^{1/2}$, where A=minimum nasal cross-sectional area of the orifice in cm^2 ; V=nasal flow in cm^3/s ; $k=0.65$; DP=oral-nasal pressure in dynes/cm^2 ; d=density of air ($0.001\text{g}/\text{cm}^3$). Figure 2 shows the system configuration in a schematic format.



Source: Trindade et al. Diagnóstico instrumental da disfunção velofaríngea. In: Trindade e Silva Filho. Fissuras labiopalatinas: uma abordagem interdisciplinar. São Paulo: Editora Santos; 2007.p.134.

Figure 1 - Representative schematic of instrumentation for measuring nasalance (Nasometer 6200-3 IBM, Kay Elemetrics Corp., Lincoln Park, NJ, USA).



Source: Trindade et al. Diagnóstico instrumental da disfunção velofaríngea. In: Trindade e Silva Filho. Fissuras labiopalatinas: uma abordagem interdisciplinar. São Paulo: Editora Santos; 2007.p.137.

Figure 2 - Representative schematic for determining velopharyngeal area (PERCI-SARS System, Microtronics Corp., Chapel Hill, NC, USA).

The values found for the velopharyngeal area are analyzed in accordance with the proposed velopharyngeal function classification criteria: 0 to 4.9mm²=adequate velopharyngeal closure; 5 to 9.9mm²=adequate-borderline velopharyngeal closure; 10.0 to 19.9mm²=borderline-inadequate velopharyngeal closure and, 20mm² or more=inadequate velopharyngeal closure¹⁹.

Data Analysis

Nasalance is expressed in % and velopharyngeal area in mm². The comparison of average values of nasalance and of the pre- and post-surgical velopharyngeal area for the same surgical technique was done using Student's t test for paired samples and the comparison of these two variables between the surgical techniques was done using Student's t test for independent samples. P<0.05 values were accepted as significant.

RESULTS

Mean nasalance scores obtained in the PRE condition were 43±8.4% in patients from the PF group and 45±12.4% in patients from the SP group. In both cases, the values were indicative of hypernasality. In the POST condition, average nasalance decreased to 27±10.1% in the PF group and 31±14.2% in the SP group. Statistical analysis revealed that after surgery both groups presented mean nasalance scores significantly lower than those obtained before surgery. There was no statistically difference between mean nasalance in the two groups in the PRE as well as the POST condition (Table 1). Results showed that after surgery, the PF group began to present a mean nasalance score indicative of normality ($\leq 27\%$), whereas the mean score for the SP group remained indicative of hypernasality. Figure 3 illustrates these results.

Table 1 - Mean scores (\pm SD) of nasalance obtained before (PRE) and after (POST) surgery in the group of patients submitted to pharyngeal flap and to sphincteroplasty

	NASALANCE (%)	
	PF Group (n=15)	SP Group (n=15)
PRE	43(\pm 8.4)	45(\pm 12.4)
POST	27(\pm 10.1) [#]	31(\pm 14.2) [*]

PF-Pharyngeal Flap; SP=Sphincteroplasty; SD=Standard Deviation

[#]Pre vs post (PF group): statistically significant difference-paired T test ($p=0.000$)

^{*}Pre vs post (SP group): statistically significant difference-paired T test ($p=0.010$)

PF Group vs SP Group (PRE): non-significant difference-T test ($p=0.550$)

PF Group vs SP Group (POST): non-significant difference-T test ($p=0.359$)

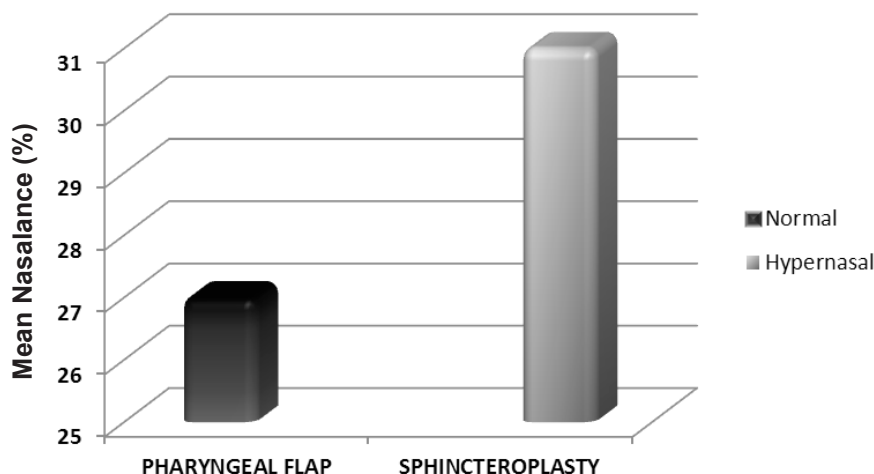


Figure 3: Mean nasalance scores obtained after surgery in patients submitted to pharyngeal flap and to sphincteroplasty.

In Table 2, the mean values are shown (\pm SD) for the velopharyngeal area, obtained in patients from the PF and SP groups, before (PRE) and after (POST) surgery. The patients who presented compensatory articulation in phone [p] were not included in this analysis (2 individuals from the PF group and 3 from the SP group). Before surgery, it was determined that the mean velopharyngeal area in the PF group was $51\pm 35.4\text{mm}^2$ and in the SP group, $69\pm 29.2\text{mm}^2$. Both cases are indicative of inadequate velopharyngeal closure. There was no statistically difference between the velopharyngeal areas of the two groups in the PRE condition. After

surgery, the mean velopharyngeal area reduced to $3.6\pm 5.5\text{mm}^2$ in the PF group and $24\pm 32.7\text{mm}^2$ in the SP group. The statistical analysis showed that the mean velopharyngeal area obtained after surgery was significantly smaller than that obtained before surgery in the two groups studied and that the post-surgical velopharyngeal area for the PF group was significantly smaller than for the SP group. After surgery, the PF group also began to present values indicative of adequate closure, on average, whereas the SP group continued with inadequate velopharyngeal closure. Figure 4 illustrates these results.

Table 2 - Mean values (\pm SD) of velopharyngeal area obtained before (PRE) and after (POST) surgery in the group of patients submitted to pharyngeal flap and to sphincteroplasty

	VELOPHARYNGEAL AREA (mm^2)	
	Mean (\pm SD)	
	PF Group (n=13)	SP Group (n=12)
PRE	51(\pm 35.4)	69(\pm 29.2)
POST	3.6(\pm 5.5) ^{# ^}	24(\pm 32.7) *

PF-Pharyngeal Flap; SP=Sphincteroplasty; SD=Standard Deviation

[#]Pre vs post (PF group): statistically significant difference-paired T test ($p=0.002$)

*Pre vs post (SP group): statistically significant difference-paired T test ($p=0.010$)

PF Group vs SP Group (PRE): non-significant difference T test ($p=0.228$)

[^]PF Group vs SP Group (POST): statistically significant difference T test ($p=0.034$).

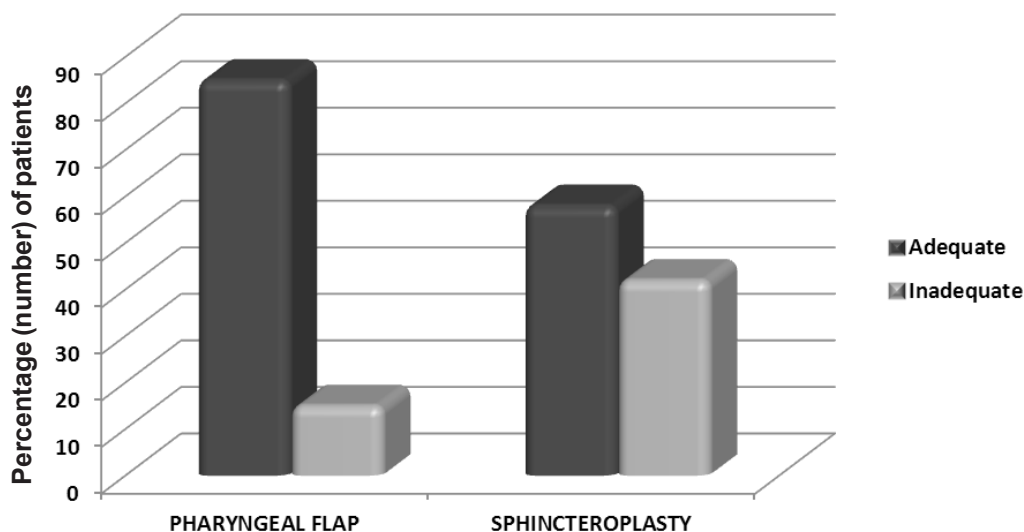


Figure 4: Percentage (number) of patients distributed according to the classification of velopharyngeal closure determined after surgery in the pharyngeal flap and sphincteroplasty groups.

■ DISCUSSION

Among those surgical techniques employed in VPI treatment, pharyngeal flap and sphincteroplasty are still the most used in different craniofacial centers in the world^{12,28,32-34} and the literature has demonstrated the success and the deleterious effects of both these surgical techniques used in VPI treatment secondary to primary palatoplasty. Most studies used the perceptual methodology and/or direct instrumental methods for evaluation velopharyngeal function, such as nasoendoscopy and videofluoroscopy^{12,19-22}. Two studies^{12,21}, in particular, added nasometry to the other evaluations, as one of the methods for investigating nasality in speech and objectively comparing the results of the two surgeries, as was done in this study. Using nasometry, both revealed that the pharyngeal flap as well as the sphincteroplasty were efficient in reducing nasality, with no statistically difference between the two surgical techniques. This result was also verified in this study based on nasometry analysis. However, these results revealed that only in the group of patients submitted to pharyngeal flap surgery was there a normalization of nasalance (average score=27%). The sphincteroplasty group continued with a score of nasalance indicative of hypernasality (31%), suggesting the pharyngeal flap was more efficient than the sphincteroplasty for eliminating hypernasality.

On the other hand, a recent study showed that the sphincteroplasty combined with the Furlow technique, as well as the pharyngeal flap, were significantly more efficient in reducing hypernasality than the sphincteroplasty performed in isolation²⁸. However, it is worth emphasizing that a limitation of this study was the fact that the authors employed only perceptual assessment of speech for analyzing results, without, however, evaluating concordance between examiners.

Another evaluation method for checking results of the two surgeries on patient speech in this study was the pressure-flow technique. No other report

in literature used this instrumental method recommended by the *American Cleft-Palate Association*¹³ for comparing these techniques, making the results of the present study unprecedented. This method has been used for many years by the Laboratory of Physiology team for evaluating surgical results for VPI treatment, particularly of the pharyngeal flap and secondary palatoplasty with intravelar veloplasty^{17,24-26,35,36}. In the present study, this technique proved to be an efficient instrument for evaluating sphincteroplasty results, making it possible to compare both. The pressure-flow technique revealed a significant reduction in average velopharyngeal area in both groups studied, as expected, since the objective of the two surgeries is to reduce the space of the velopharyngeal region to promote adequate velopharyngeal closure. However, different from what occurred with nasometry, data analysis revealed that the average velopharyngeal area obtained in patients with pharyngeal flap was significantly smaller than that obtained in patients with sphincteroplasties. Analyzing the degree of velopharyngeal closure, determined from values for the post-surgical velopharyngeal area, it was verified that the group of patients with pharyngeal flap achieved, on average, adequate velopharyngeal closure, whereas the group of patients submitted to sphincteroplasty remained with inadequate velopharyngeal closure. In other words, the velopharyngeal area verified after pharyngeal flap surgery, which was significantly smaller than that verified after sphincteroplasty, seems to have contributed to provide adequate velopharyngeal closure identified in patients with pharyngeal flap.

■ CONCLUSION

These results suggest pharyngeal flap surgery was more efficient than sphincteroplasty in eliminating hypernasality and providing adequate velopharyngeal closure in the patients studied.

RESUMO

Objetivo: comparar o efeito do retalho faríngeo e da esfínteroplastia sobre a hipernasalidade da fala e o fechamento velofaríngeo no tratamento de indivíduos com insuficiência velofaríngea residual, por meio de avaliação instrumental. **Métodos:** foram avaliados 30 pacientes, com fissura de palato±lábio reparada, submetidos à correção cirúrgica da insuficiência velofaríngea (15 com retalho faríngeo e 15 com esfínteroplastia), avaliados antes e, no mínimo, 1 ano após a cirurgia. A hipernasalidade foi estimada a partir dos escores de nasalância (correlato físico da nasalidade) obtidos por meio da nasometria, durante a leitura de 5 sentenças contendo, exclusivamente, sons orais, considerando como limite de normalidade o escore de 27%. O fechamento velofaríngeo foi aferido a partir da medida da área velofaríngea obtida por meio da técnica fluxo-pressão e foi classificado em: 0-4,9mm²=adequado; 5-19,9mm²=marginal e, >20mm²=inadequado. Diferenças entre as duas técnicas foram consideradas estatisticamente significantes ao nível de 5%. **Resultados:** antes da cirurgia, os valores médios de nasalância foram de 43±8,4% e 45±14,2% e de área velofaríngea foram 51±35,4mm², e 69±29,2mm², para os grupos retalho faríngeo e esfínteroplastia, respectivamente. Após a cirurgia, os valores médios de nasalância reduziram para 27±10,1% e 31±14,2% e de área velofaríngea para 3,6±5,5mm² e 24±32,7mm² para os grupos retalho faríngeo e esfínteroplastia, respectivamente. A redução dos valores de nasalância e área velofaríngea foi estatisticamente significativa nos dois grupos. **Conclusão:** estes resultados sugerem que o retalho faríngeo foi mais eficiente do que a esfínteroplastia na eliminação da hipernasalidade e adequação do fechamento velofaríngeo nos pacientes estudados.

DESCRIPTORIOS: Fissura Palatina; Insuficiência Velofaríngea; Rinomanometria

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