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HEAD AND NECK

Expansion sphincter pharyngoplasty: analyzing the technique based on anatomy

Ela Cömert[1] · Ayhan Cömert[2] · Ziya Şencan[1]

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Abstract

Purpose The purpose of this study is to evaluate the effect of the different surgical techniques of expansion sphincter pharyngoplasty (ESP) on the dimensions of the oropharyngeal airway.

Methods The techniques that were evaluated included the preservation and transection of the palatopharyngeus (PP) and superior pharyngeal constrictor (SPC) muscle attachment and transposition of the PP muscle to the hamulus of the medial pterygoid plate and the palatal musculature. Surgical techniques were applied in twenty half heads.

Results The preservation of the PP–SPC attachment inhibited the transposition of the PP muscle to the hamulus and resulted in comparable enlargement in the medial–lateral dimension in the oropharyngeal airway when the PP muscle was transposed to the palatal musculature. After transection of the PP–SPC attachment, significant enlargement was observed in anterior–posterior and medial–lateral directions in the oropharyngeal airway when the PP muscle was transposed both to the hamulus and the palatal musculature. The distances measured after both the transposition techniques were similar.

Conclusion The present study is a basic study demonstrating how different techniques of ESP affect the position of the soft palate. The PP–SPC attachment can be transected in the patients with anterior–posterior palatal and lateral wall collapse to pull the soft palate anteriorly in addition to prevent the lateral wall collapse. The PP–SPC attachment can be preserved in the patients with only lateral wall collapse. Nevertheless, the clinical consequences of these static changes need to be evaluated in clinical studies.

Keywords Expansion sphincter pharyngoplasty · Obstructive sleep apnea syndrome · Anatomy · Surgical technique · Palatopharyngeus muscle

Introduction

Surgical treatment of the obstructive sleep apnea syndrome mainly focuses on widening the airway or preventing the collapse at the retropalatal and retroglossal regions. Velopharyngeal surgery is one of the most commonly performed procedures for the treatment of retropalatal collapse. Because of the limited success rates of classic surgical procedures, new surgical techniques have been introduced to improve the outcome. Expansion sphincter pharyngoplasty (ESP) is one of those surgical techniques described by Pang and Woodson in 2007 [1]. Based on their definition, ESP consists of tonsillectomy, expansion pharyngoplasty including rotation of the palatopharyngeus (PP) muscle, partial uvulectomy, and approximation of the tonsillar pillars. They identified the PP muscle, transected its inferior end horizontally, isolated and left with its posterior surface partially attached to the superior pharyngeal constrictor (SPC) muscle. They sutured the

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✉ Ela Cömert
drelacomert@gmail.com

1 Department of Otolaryngology, Kırıkkale University School of Medicine, Ankara Yolu 7. Km, 71450 Yahşihan, Kırıkkale, Turkey

2 Department of Anatomy, Ankara University School of Medicine, Ankara, Turkey

PP muscle to the palatal musculature laterally and apposed the tonsillar pillars [1]. Their postoperative endoscopic findings revealed a significant reduction of the lateral pharyngeal wall collapse on Muller's maneuver [1]. Consequently, Ulualp reported the use of ESP in the pediatric population with remarkable outcomes [2]. In the following publication of Pang et al., the principle of ESP was described as isolating the PP muscle, rotating it supero-anterolaterally to remove the bulk of the lateral pharyngeal wall and to create the lateral wall tension [3]. Later on, their technique is modified by the fixation of the PP muscle to the hamulus of the medial pterygoid plate and the separation of the PP muscle from the SPC muscle [4–6]. Hamulus of the medial pterygoid plate represents the most anterior and lateral attachment of the palatal aponeurosis on the hard palate. By this modification, the attachment point of the PP muscle flap was placed more anteriorly when compared to the palatal musculature which is posterior to the hamulus and the palatal aponeurosis. Eventually, although the controversies over whether the PP–SPC attachment is preserved or transected and whether the PP muscle is attached to the hamulus or the palatal musculature, the ESP became an excepted surgery for the treatment of obstructive sleep apnea syndrome.

Studies from recent literature agree on the effectiveness of ESP on the patients with lateral wall collapse [2, 7]. Studies also support that the ESP maintains better results over uvulopalatopharyngoplasty to widening in the retropalatal space and better postoperative apnea–hypopnea index values when compared with uvulopalatopharyngoplasty [8, 9]. However, there are no studies comparing the effects of different techniques of ESP described in the literature on the oropharyngeal airway.

The purpose of this study is to provide an overview of the normal anatomy of the soft palate musculature, demonstrate how the anatomy is altered after the ESP techniques and evaluate the effect of the different surgical techniques of ESP on anterior–posterior and the medial–lateral dimension of the oropharyngeal airway.

Methods

For this anatomical study, 20 formalin-fixed half heads (10 paired and 10 non-paired) of 15 cadavers (9 males and 6 females, age between 60–72 years) with mid-sagittal section were used. There were 12 left and 8 right half heads. The study was exempt from review by the Institutional Review Board.

In all specimens, nasal cavity, nasopharynx, oral cavity and oropharynx were anatomically preserved and the position of the soft palate, uvula and tongue was in the neutral position. Each specimen was dissected under the surgical microscope (Zeiss OPMI 9-FC) by the same surgeon (EC). Direct measurements of the shortest distances between the structures described below were measured with the measuring probe and read against the digital caliper accurate to 0.01 mm. All data were measured independently by two authors (EC, ZŞ) and repeated twice, and their average values were calculated.

The surgical techniques which were evaluated in this study included

- Preservation of the PP–SPC attachment and transposition of the PP muscle either to the hamulus or the palatal musculature 1 cm posterior to the hamulus.
- Transection of the PP–SPC attachment and transposition of the PP muscle either to the hamulus or the palatal musculature 1 cm posterior to the hamulus.

Three positions of the soft palate were defined according to the position of the PP muscle as follows:

- Neutral position: measurements at the neutral position before the transposition of the PP muscle.
- After transposition to hamulus: measurements after the transposition of the PP muscle to the hamulus of the medial pterygoid plate.
- After transposition to palatal musculature: measurements after the transposition of the PP muscle to the palatal musculature 1 cm posterior to the hamulus.

Three distances were measured at each of the three positions of the soft palate as follows:

- u-lpw: the medial–lateral distance from the midpoint of the base of the uvula to the lateral pharyngeal wall.
- msp-ppw: the anterior–posterior distance between the midpoint of the soft palate (midpoint between the base of the uvula and posterior nasal spine) and the posterior pharyngeal wall (Fig. 1).
- u-ppw: the anterior–posterior distance between the midpoint of the base of the uvula and the posterior pharyngeal wall (Fig. 1).

Dissections

The half head was placed in the horizontal position. The mucosa of the lateral nasopharyngeal wall and posterior surface of the soft palate was removed. Antero-posterior measurements at the neutral position were taken. Inferior and posterior to the pharyngeal opening of the eustachian tube, the levator veli palatini (LVP) muscle was dissected. The LVP muscle coursed inferiorly, anteriorly and medially, enlarged through its course and inserted widely into the middle of the velum. The tensor veli palatini (TVP) muscle was dissected inferior and anterior to the pharyngeal opening of

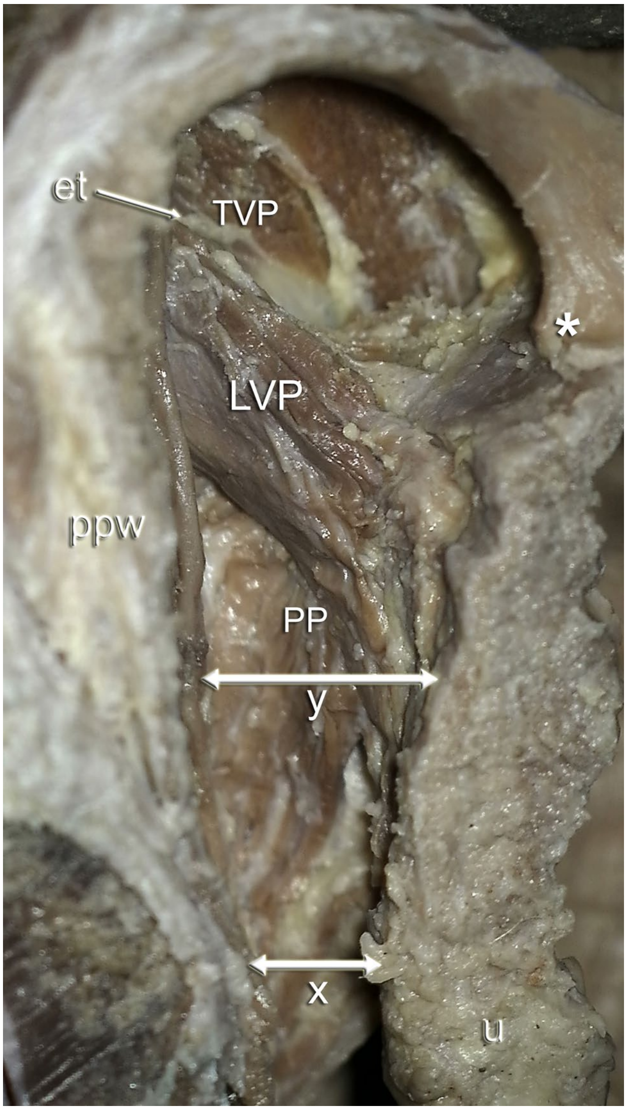

Fig. 1 Microscopic view of the left half head showing the measurements between the base of the uvula and posterior pharyngeal wall (*x*) and middle of the soft palate and posterior pharyngeal wall (*y*) at the neutral position (4 × magnification). *TVP* tensor veli palatine, *LVP* levator veli palatine, *PP* palatopharyngeus, *et* eustachian tube, *ppw* posterior pharyngeal wall, *u* uvula; *posterior nasal spine

the eustachian tube, coursing medially and inferiorly and forming a tendon. Inferior to the medial fibers of the LVP muscle, the palatal attachment of the PP muscle was identified and dissected inferiorly and laterally demonstrating its fibers connecting with the SPC muscle. Later on, the dissection was carried out through the anterior surface of the soft palate. The palatine tonsil was identified and tonsillectomy was performed. The medial–lateral distance from the midpoint of the base of the uvula and the lateral pharyngeal wall was measured as the neutral position. The mucosa and the soft tissue component of the posterior 1/3 of the hard palate and all the soft palate were removed to demonstrate the palatal muscles. From the hamulus, the tendon of the TVP muscle fans outward to form the palatal aponeurosis. Posterior to the aponeurosis, the free ends of the LVP muscle fibers were identified that attached to the palatal soft tissues spreading all through the soft palate and connecting with uvular muscle in the middle. The palatoglossus muscle was dissected from its origin from the lateral part of the soft palate, forming the anterior pillar, to its insertion onto the tongue.

Surgical techniques

At the end of the dissection, all the mucosa and glandular layer of the soft palate were removed to demonstrate the palatal muscles (Fig. 2a). As described in the original technique, the PP muscle was transected horizontally from its inferior end posterior to the tonsillar fossa and dissected superiorly to form an isolated bundle [1].

First, the attachment of the PP muscle to the SPC muscle was preserved and the PP muscle was dissected up to the superior border of the tonsillar fossa. The bundle was coursed posterior to the palatoglossus muscle, rotated laterally and superiorly. Dissections of all half heads revealed that the preservation of the attachment inhibited the transposition of the PP muscle to the hamulus. The technique including preservation of the PP–SPC attachment and transposition of the PP muscle to the hamulus could not be applied and no distances were measured related to this technique. Afterward, the PP muscle bundle was transposed 1 cm posterior to the hamulus that corresponds to the most anterior and lateral part of the palatal musculature behind the palatal aponeurosis. Dissections revealed that this technique only caused lateral enlargement of the oropharyngeal airway but did not cause anterior movement of the soft palate. Only the medial–lateral distance (u-lpw) was measured.

Later on, the dissection was carried out by transecting the attaching fibers of the PP muscle to the SPC muscle. The bundle was transposed first to the hamulus (Fig. 2b) and then to the palatal musculature 1 cm posterior to the hamulus (Fig. 2c) (see Online Resource 1). Both of these techniques resulted in the anterior displacement of the soft palate and lateral enlargement of the oropharyngeal airway. Both the anterior–posterior and medial–lateral distances were measured at each attachment point.

Statistical analysis

Shapiro–Wilk test was used to determine the distribution of homogeneity and normality of the variables among the groups of measurements. The *One-Way Analysis of Variance* (ANOVA) test was used to determine differences among groups of parametric variables. *Post Hoc* analyses were performed using the *Tukey Multiple Comparison* test.

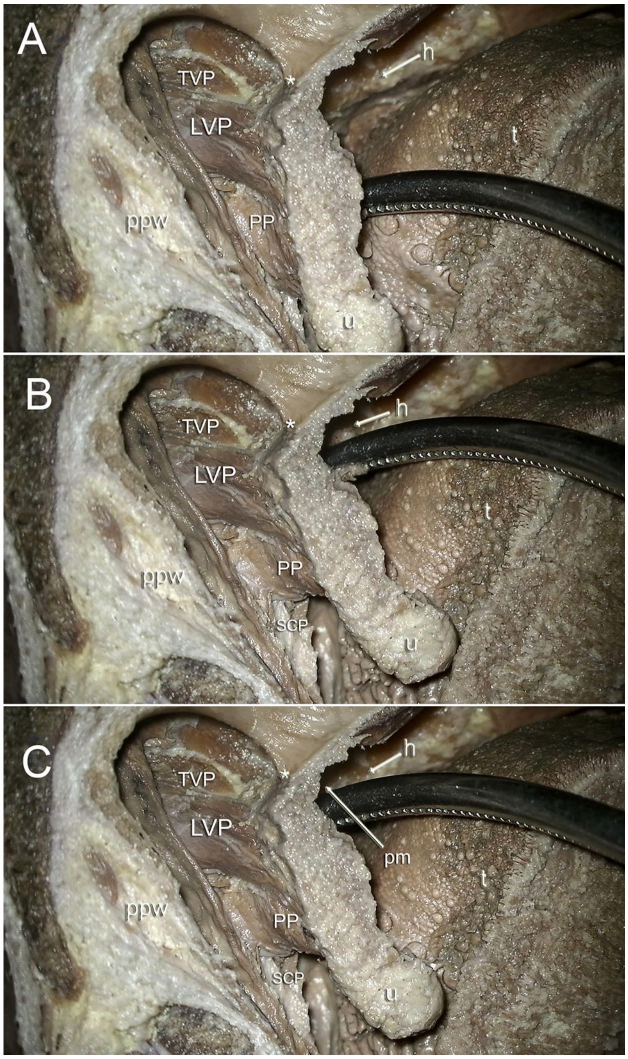

Fig. 2 Microscopic view of the left half head demonstrating the position of the soft palate in neutral position (**a**), after transection of the PP-SCP attachment and transposition of the PP muscle to the hamulus (**b**) and the palatal musculature (**c**) (4×magnification). *TVP* tensor veli palatini muscle, *LVP* levator veli palatini muscle, *PP* palatopharyngeus muscle, *ppw* posterior pharyngeal wall, *SCP* superior pharyngeal constrictor muscle, *h* hamulus, *u* uvula, *t* tongue, *pm* palatal musculature; *posterior nasal spine

The *Logistic Regression* test and *Likelihood Ratio* test were applied to the variables to predict the "best" surgical technique for widening the oropharyngeal airway. A value of $p < 0.05$ was accepted as statistically significant.

Results

The mean ± SD (standard deviation) value of the u-lpw distance was 17.56 ± 1.67 mm when the PP–SPC attachment was preserved and the PP muscle was transposed to the palatal musculature. The *Post Hoc* analyses revealed significant difference when compared with the neutral position (mean difference = − 1.974, $p = 0.001$), whereas the u-lpw distances were comparable when the PP–SPC attachment was preserved and transected (mean difference = − 0.226, $p = 0.896$).

Likelihood Ratio test revealed no superiority between preservation or transection of the PP–SPC attachment and transposition of the PP muscle to the hamulus or the palatal musculature for widening medial–lateral oropharyngeal airway ($X^2 = 1.033$, $p = 0.597$).

The mean ± SD (standard deviation) values of the distances in the neutral position, after transection of the PP–SPC attachment and transposition of the PP muscle to the hamulus and the palatal musculature, are presented in Table 1. Statistically significant differences were detected in all distances between the positions of the PP muscle (Table 1). The *Post Hoc* analyses revealed significant differences between the neutral position and after transposition of the PP muscle both to the hamulus and the palatal musculature in all distances. However, no significant difference was detected in all the distances between the transposition of the PP muscle to the hamulus and the palatal musculature. Data are presented in Table 2.

Logistic Regression test revealed no superiority between the transposition of the PP muscle to the hamulus and the palatal musculature techniques after transection of PP–SPC attachment for either widening the anterior–posterior or medial–lateral oropharyngeal airway ($B = -3.273$, Wald = 0.657, $p = 0.417$).

Table 1 Measurements of the distances in neutral position, after transection of the PP–SPC attachment and transposition of the PP muscle to the hamulus and palatal musculature. The *One-Way Analysis of Variance* (ANOVA) test, $p < 0.05$

Distances	Neutral position	Transposition to hamulus	Transposition to palatal musculature	*F*	*p*
	Mean ± SD	Mean ± SD	Mean ± SD		
u-lpw	15.58 ± 1.51	18.08 ± 1.69	17.78 ± 1.63	14.328	< 0.001
msp-ppw	11.12 ± 0.80	13.63 ± 1.08	13.35 ± 1.13	37.233	< 0.001
u-ppw	8.91 ± 0.73	11.09 ± 1.03	10.92 ± 0.89	36.709	< 0.001

SD standard deviation, *F* F score, *PP* palatopharyngeus, *SPC* superior pharyngeal constrictor, *u* uvula, *lpw* lateral pharyngeal wall, *msp* midpoint of the soft palate, *ppw* posterior pharyngeal wall

Table 2 Comparison of the distances between the positions of the PP muscle after transection of the PP–SPC attachment, *Tukey Multiple Comparison* test $p < 0.05$

Distances	Positions of the PP muscle	Mean difference	*p*
u-lpw	Neutral/transposition to hamulus	− 2.496	< 0.001
	Neutral/transposition to palatal musculature	− 2.200	< 0.001
	Transposition to hamulus/transposition to palatal musculature	0.296	0.830
msp-ppw	Neutral/transposition to hamulus	− 2.513	< 0.001
	Neutral/transposition to palatal musculature	− 2.233	< 0.001
	Transposition to hamulus/transposition to palatal musculature	0.280	0.657
u-ppw	Neutral/transposition to hamulus	− 2.176	< 0.001
	Neutral/transposition to palatal musculature	− 2.007	< 0.001
	Transposition to hamulus/transposition to palatal musculature	0.169	0.822

PP palatopharyngeus, *SPC* superior pharyngeal constrictor, *u* uvula, *lpw* lateral pharyngeal wall, *msp* mid-point of the soft palate, *ppw* posterior pharyngeal wall

Discussion

Most of the studies on the anatomy and physiology of the soft palate have focused on the cleft palate and its surgical treatment [10]. The interest in the PP muscle begins with the use of superior-based PP muscle flap in cleft palate surgery [11, 12]. This surgical technique is called sphincter pharyngoplasty (SP) and it is used for correcting velopharyngeal insufficiency after palatal surgery [13]. Pang and Woodson inspired by SP, used a superior-based PP muscle flap to treat the lateral wall collapse and called their technique the ESP. Although the SP was represented as a procedure performing a dynamic muscle sphincter [14], studies on the SP demonstrated that the PP muscle could not actively contract when it was used as a superior-based flap. The electromyographic activity could not be observed at the PP muscle either during articulation or swallowing after SP, indicating that the transposition of PP muscle formed a passive bridge instead of creating an active sphincter [13, 15]. Consequently, in both SP and ESP, the sphincter function could not be maintained.

A conservative modification of ESP was presented by Sorrenti et al. called Functional Expansion Pharyngoplasty (FEP) [6]. Although they modified the ESP, they excluded the term ‘sphincter’ from the name of their technique. There were three main differences in FEP when compared with ESP. In FEP, the PP muscle was separated from the SPC muscle and the flap was based on palatal musculature. This was incompatible with the ESP, as Pang and Woodson specifically pointed out the importance of leaving part of the attachment of PP muscle to the SPC muscle. In FEP, a submucosal tunnel was created through the palatal musculature from the apex of the tonsillar fossa without superolateral mucosal incisions of ESP. Finally, the fixation point of the PP muscle flap was the hamulus whereas, the flap was fixed to the lateral palatal musculature in ESP. Later on, the fixation of the PP muscle to the hamulus and creating a submucosal tunnel became widely used modifications of ESP [4, 5]. However, the following publications agreed on leaving a part of the PP muscle attached to the SPC muscle [2, 5].

In the present study, we aim to examine the impact of the surgical techniques of ESP described in the literature anatomically. We try to demonstrate how the position of the soft palate is effected when the PP–SPC attachment is preserved and transected and when the PP muscle bundle is attached to the hamulus and the palatal musculature. Compatible with the experience of Sorrenti et al., our dissections reveal that preserving the PP–SPC attachment reduces the bulk of the lateral pharyngeal wall and results in only lateral enlargement of the oropharyngeal airway [6]. This attachment also disables the transposition of the PP muscle to the hamulus in cadavers. This modification of the ESP can be used in patients with lateral wall collapse. Accordingly, the elevation of the soft palate was not observed in most of the studies that preserved this attachment, as those studies only mentioned the widening of the lateral oropharyngeal airway and advised the ESP for lateral wall collapse [1, 2, 5]. However, despite Pang and Woodsons’ suggestions on preserving the PP–SPC attachment to create the tension on the lateral wall, studies revealed that the SPC muscle undertook the task of the PP muscle after using PP muscle flap and preserved the lateral pharyngeal wall tension [13, 15].

The LVP muscle is an essential muscle for palatal movements. It has a combined activity with uvula muscle named levator eminence and it is the primary mover in velar elevation [16]. Our dissections reveal that the PP muscle specifically attaches to the body of the LVP muscle before the LVP muscle spreads into the soft palate. Transecting the PP–SPC attachment and pulling the PP muscle anteriorly and superiorly directly pulls the LVP muscle through the same direction and potentiates its effect on velar elevation. Either the PP muscle is transposed to the hamulus or the palatal musculature, the oropharyngeal airway enlarges in both anterior–posterior and medial–lateral directions. In both techniques, the bulk of the lateral pharyngeal wall is removed and the airway behind the uvula base and the middle of the soft palate is enlarged. Our study reveals similar results in two transposition techniques in terms of dimensions of the postsurgical airway. *Logistic Regression* test also supports that no superiority exists among two transposition techniques for either widening the anterior–posterior or medial–lateral oropharyngeal airway. These techniques of the ESP can be used in patients with palatal circumferential collapse, whereas it may result in velopharyngeal insufficiency if the patient only has lateral palatal collapse.

One of the limitations of our study is that our cadavers were fixated by formalin. The formalin fixation is one of the most convenient and most commonly used technique to preserve the cadaver [17]. Unlike the fresh frozen technique, formalin fixation allows the cadaver to be used for several studies for years without decomposition and putrefaction of the tissues and contamination risk during dissections. Using the cadaver for many studies reduces the cost of each study and allows the researcher to increase the number of specimens included in the study to obtain more accurate results. The major disadvantage of formalin fixation is the loss of flexibility. Previous studies support the use of formalin-fixed cadavers for the anatomy and surgery of the oropharyngeal region [18, 19]. In our study, after removal of the minor salivary gland layer of the soft palate and demonstration of the palatal musculature, soft palate movements can clearly be seen during the transposition of the PP muscle. The dissections are performed on half heads in the sagittal section to provide a direct microscopic view to both anterior–posterior and medial–lateral dimensions. Another drawback of the present study is that we cannot present the airway change that occurs when bilateral surgery is performed. Additionally, we can only evaluate the static changes on the soft palate after the ESP. However, the soft palate is a dynamic structure and the clinical consequences of these static changes need to be evaluated in clinical studies. Also, the effect of the soft tissue of the soft palate on obstructive sleep apnea is ignored during the study.

In the light of the literature and our dissections, an LVP muscle-based PP muscle flap with transection of the PP–SPC attachment can be performed for the patients with anterior–posterior palatal and lateral wall collapse to pull the soft palate anteriorly in addition to prevent the lateral wall collapse. When considering the approximation point of the PP muscle flap, both transposition techniques, either to the hamulus or the palatal musculature, have similar results on the widening of the anterior–posterior and medial–lateral oropharyngeal airway. Preserving the PP–SPC attachment is recommended for the patients with lateral wall collapse. Nevertheless, the soft palate is a dynamic structure and the clinical consequences of these static changes need to be evaluated in clinical studies.

Availability of data and material

All data related to the study are available on request.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by EC, AC and ZŞ. The first draft of the manuscript was written by EC and all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval The study is an anatomic cadaveric research. Ankara University Faculty of Medicine Institutional Review Board has confirmed that the study is an exemption and does not require approval.

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