Online Supplemental Text:

Postoperative applications of velopharyngeal MRI:

Palatoplasty

Palatoplasty is performed to reconstruct the LVP muscle sling and retroposition the LVP muscle within the palate.[1,2] Post-surgical imaging should show an increase in effective velar length, indicating a more posterior LVP placement following surgery and an increase in total velar length. Ideally, these two modifications should result in complete closure of the velopharyngeal port and resolution of the patient's hypernasal speech (Online Supplemental Figures 3 and 4).

Buccal Myomucosal Flap

Buccal myomucosal flaps provide additional palate length and retroposition the LVP muscle within the palate.[3] Post-surgical imaging typically shows increased length and thickness of the velum. Additionally, the buccal myomucosal flaps are placed just behind the posterior bony palate, which will be visible on the MRI as a rounded protrusion on the nasal surface of the velum at this region (Online Supplemental Figures 5 and 6). The LVP should also be more posteriorly positioned, although this can be difficult to appreciate due to the bulk of the buccal myomucosal flaps.

Pharyngeal Flap

The pharyngeal flap procedure creates a static obstruction in the center of the velopharyngeal port, rather than changing the velar length or directly repairing the LVP muscle function. The pharyngeal flap procedure involves elevation of mucosa from the posterior pharyngeal wall, keeping the mucosa intact superiorly at the adenoid pad, and suturing the inferior edge of the mucosa flap into the palate (Online Supplemental Figure 7).[2] On post-

surgical imaging, the midline flap connecting the posterior wall of the pharynx and the patent lateral aspect of the velopharyngeal ports are shown. The caudal portion of the flap base in the midline should be at or above the level of the palatal plane; a flap base below the palate plane is often associated with incomplete correction of VPI.[4] In these cases, the pharyngeal flap may be tethering the velum in a lowered position, preventing velopharyngeal closure. Although variable, loss of movement of the velum during speech suggests an adhesive or tethered flap. On oblique coronal images, residual gaps to the right and left of the flap should be evident at rest; however, these gaps should close completely during phonation.[5] A residual gap during phonation may indicate persistent VPI and should therefore be noted (Online Supplemental Figure 8).

Sphincter Pharyngoplasty

In sphincter pharyngoplasty, with or without concomitant palatoplasty, bilateral myomucosal flaps are raised from the posterior tonsillar pillars and/or lateral pharyngeal walls and sutured on the posterior pharyngeal wall.[6] The procedure narrows the overall diameter of the velopharyngeal valve and creates a prominence along the posterior pharyngeal wall, thereby reducing the degree of velar movement needed to obtain a complete seal between the velum and the pharyngeal wall (Online Supplemental Figures 9 and 10).[7] After the procedure, the highest inset point of the myomucosal flap should present at the base of the adenoid glands. In the setting of low-lying adenoid tonsillar tissue, an inferior adenoidectomy can be performed to obtain the desired inset level.[8]

References:

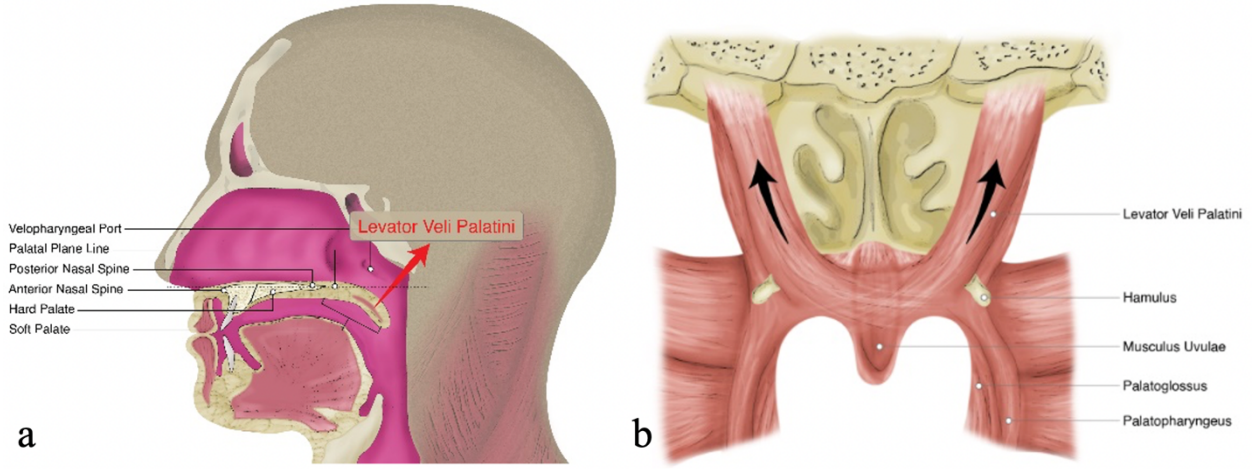
1. Sie KCY, Tampakopoulou DA, Sorom J, et al. Results with Furlow Palatoplasty in Management of Velopharyngeal Insufficiency. *Plast Reconstr Surg*. 2001:17-25.
2. Sie KC. Cleft palate speech and velopharyngeal insufficiency: surgical approach. *B-ENT*. 2006;2:85-94.
3. Mann RJ, Neaman KC, Armstrong SD, et al. The double-opposing buccal flap procedure for palatal lengthening. *Plast Reconstr Surg*. 2011;127(6):2413-2418. doi:10.1097/PRS.0b013e3182131d3e
4. Yoshida H, Stella JP, Ghali GE, et al. The modified superiorly placed pharyngeal flap: Part IV. Position of the base of the flap. *Oral Surgery, Oral Medicine, Oral Pathology*. 1992;73(1):13-18.
5. Akgüner M, Karacá C, Barutçú A, et al. Evaluation of velopharyngeal pathophysiology and velopharyngeal insufficiency with magnetic resonance imaging. *Eur J Plast Surg*. 1998;21:118-128.
6. Chiu LL, Sie KCY. Sphincter pharyngoplasty for management of velopharyngeal insufficiency. *Operative Techniques in Otolaryngology - Head and Neck Surgery*. 2009;20(4):263-267. doi:10.1016/j.otot.2009.10.009
7. Nam SM. Surgical treatment of velopharyngeal insufficiency. *Arch Craniofac Surg*. 2018;19(3):163-167. doi:10.7181/acfs.2018.02082
8. Bohm LA, Padgitt N, Tibesar RJ, et al. Outcomes of combined furlow palatoplasty and sphincter pharyngoplasty for velopharyngeal insufficiency. In: *Otolaryngology - Head and Neck Surgery (United States)*. Vol 150. ; 2014:216-221. doi:10.1177/0194599813513715

Online Supplemental Tables:

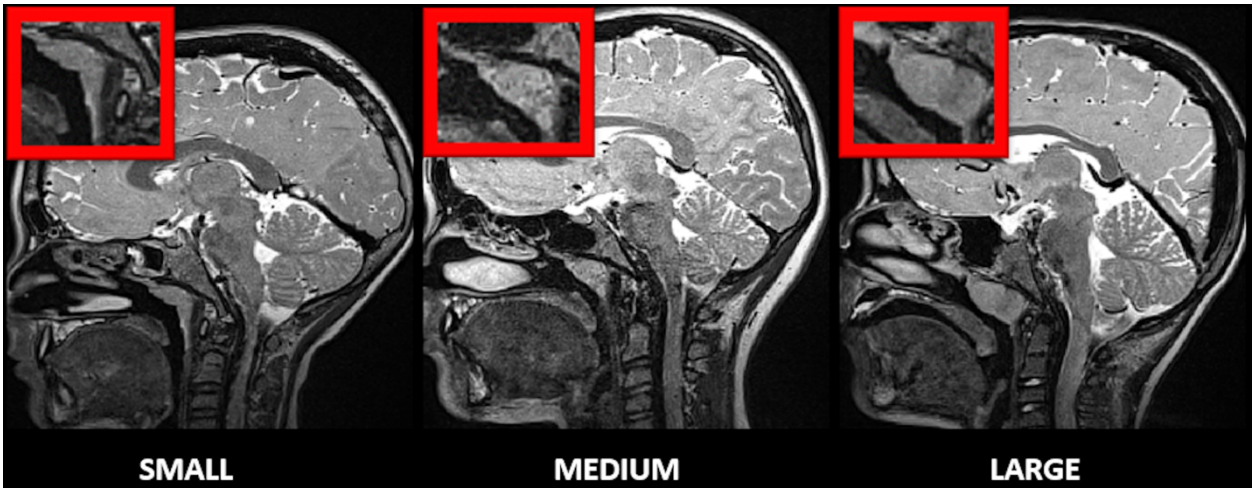
Online Table 1. The technical parameters used at our institution to obtain a VPI MRI of adequate quality.

	Scan Time (s)	TR (ms)	TE (ms)	TES Factor	Matrix M x P	Slice Gap (mm)	Slice Thickness (mm)	FOV
3D T2	155	2500	331		256 x 256	-0.45	0.9	Variable
Resting Sagittal	8	4256	138	99	244 x 335	0	3.5	Variable
Resting Coronal Oblique	8	4245	138	99	245 x 235	0	3.5	Variable
/i/ Sagittal	8	4256	138	99	246 x 235	0	3.5	Variable
/i/ Coronal Oblique	8	4256	138	99	247 x 235	0	3.5	Variable
/s/ Sagittal	8	4256	138	99	248 x 235	0	3.5	Variable
/s/ Coronal Oblique	8	4256	138	99	249 x 235	0	3.5	Variable

Online Supplemental Figures:

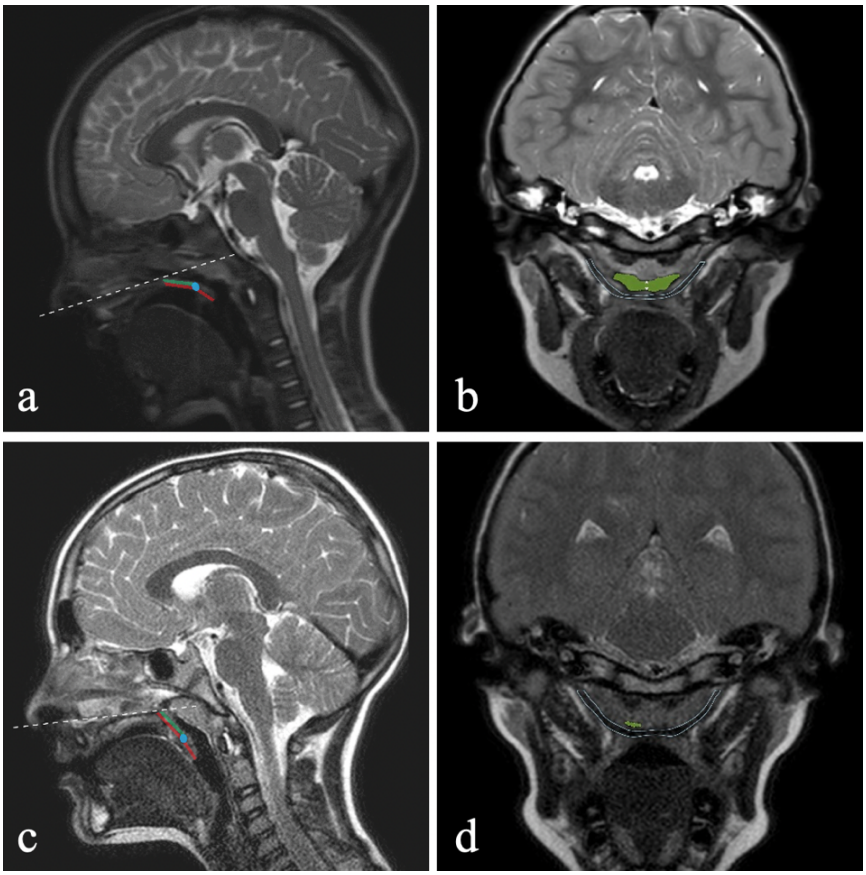


Online Figure 1. (A) A sagittal image of structures of the hard and soft palate and direction of contraction of the levator veli palatini. (B) A coronal image of the levator veli palatini, neighboring structures, and the direction of muscular contraction.



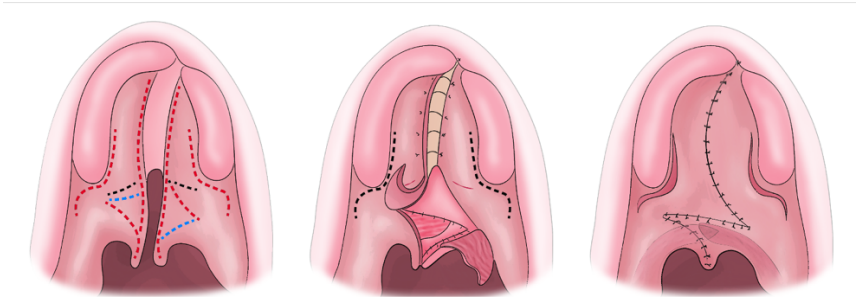
Online Figure 2. Sagittal images of variation in size of the pharyngeal adenoidal tissue include small, medium, and large. The adenoids develop rapidly during infancy and reach a plateau

between 2 and 14 years of age before regressing rapidly around age 15 years, making them a critical for MRI interpretation for VPI treatment planning. Images courtesy of Dr. Jaime Perry.

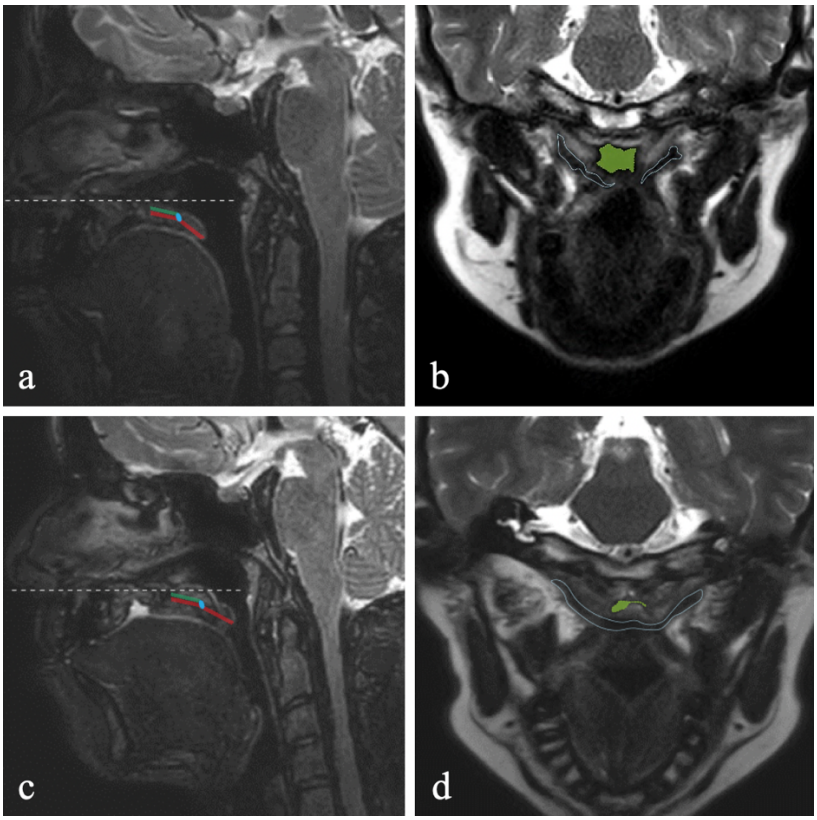


Online Figure 3. (a) Midline sagittal T2 image through the soft palate during rest on a patient with history of cleft palate and VPI. Both the effective velar length (green line) and velar length (red line) are abnormally short. (b) Coronal oblique T2 image along the plane of the LVP (blue outline) at the level of the velopharyngeal port during /s/ phonation in a patient with a history of cleft palate and VPI. The LVP (blue outline) remains intact along its length. The velopharyngeal port remains patent despite the attempted phonation. (c) Midline sagittal T2 image through the soft palate during rest on a patient with history of cleft palate and VPI status post z-palatoplasty. The effective velar length (green line) has been increased and velar length overall (red line) is

also increased. (d) Coronal oblique T2 image along the plane of the LVP (blue outline) at the level of the velopharyngeal port during /s/ phonation in a patient with a history of cleft palate and VPI status post z-palatoplasty. The LVP (blue outline) remains intact along its length. The velopharyngeal port (green) is now appropriately closed.

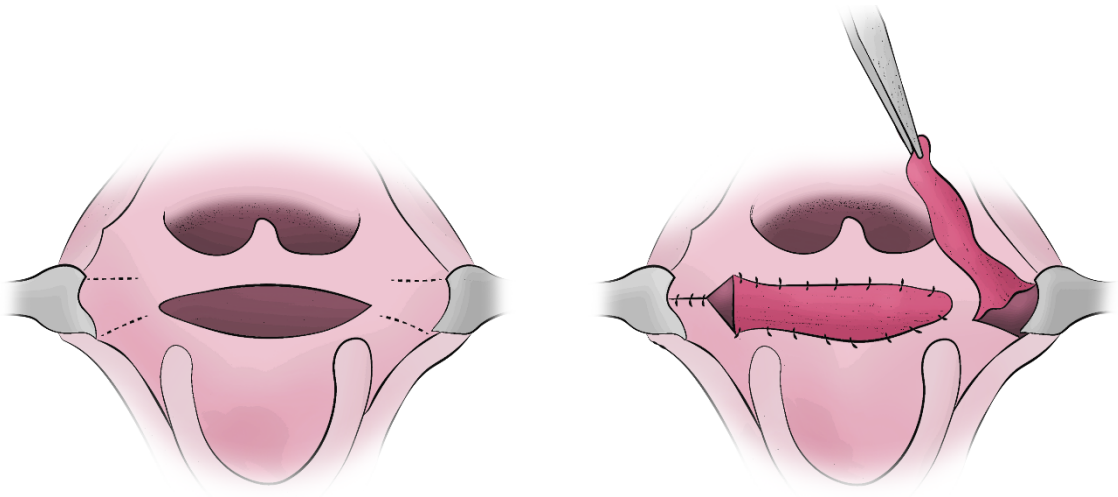


Online Figure 4. Illustration of a z-palatoplasty looking into an open mouth from a caudal vantage point. The left images is presurgical. The middle image demonstrates the ‘z’ shaped incision in the soft palate. The right most image shows the completed surgery, not the u-shaped straited structure near the uvula representing the reconstructed LVP muscle.

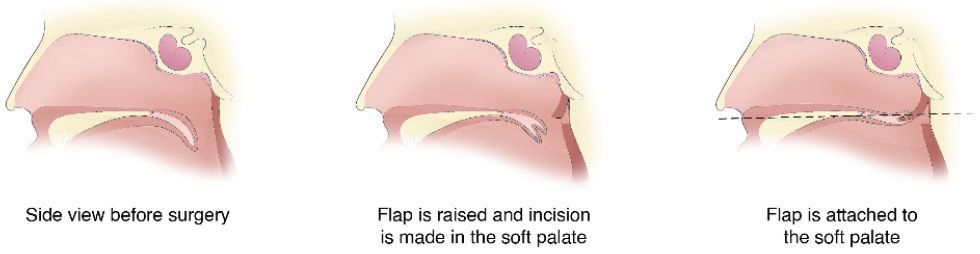


Online Figure 5. (a) Midline sagittal T2 image through the soft palate during rest on a patient with history of cleft palate and VPI. Both the effective velar length (green line) and velar length (red line) are abnormally short. (b) Coronal oblique T2 image along the plane of the LVP (blue outline) at the level of the velopharyngeal port during /s/ phonation in a patient with a history of cleft palate and VPI. The LVP (blue outline) is irregular, asymmetric, and discontiguous in the midline horizontal portion. The velopharyngeal port remains patent despite the attempted phonation. (c) Midline sagittal T2 image through the soft palate during rest on a patient with history of cleft palate and VPI status post buccal myomucosal flap surgery. The effective velar length (green line) has been increased and velar length overall (red line) is also increased. (d) Coronal oblique T2 image along the plane of the LVP (blue outline) at the level of the velopharyngeal port during /s/ phonation in a patient with a history of cleft palate and VPI status post buccal myomucosal flap. The LVP (blue outline) was repaired along its midportion now

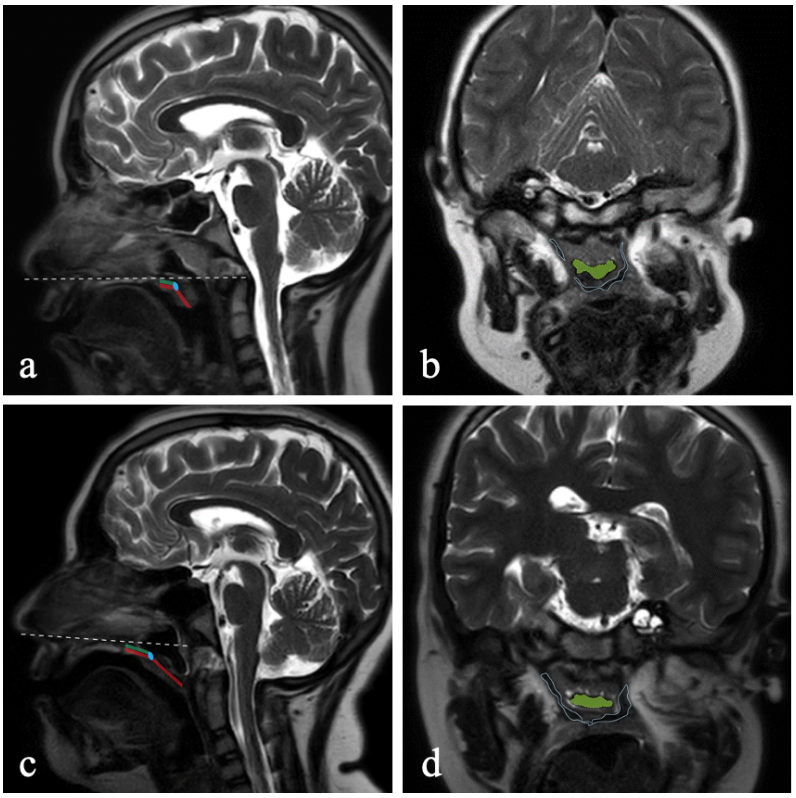
without discontinuity. The velopharyngeal port (green) demonstrates a degree of patency but is much improved.



Online Figure 6. Buccal myomucosal flap surgery showing incision in the soft palate and bilateral myomucosal fat pads of the buccal tissue. The myomucosal tissue is opposed to each other with the gap of the soft palate adding length.

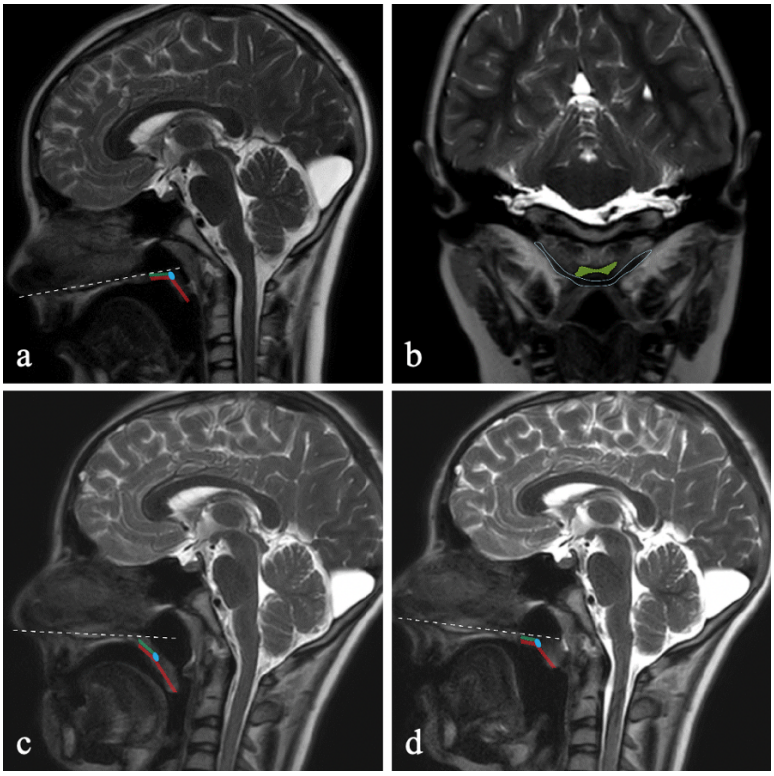


Online Figure 7. Illustrative sagittal midline view through the face demonstrating pharyngeal flap procedure.

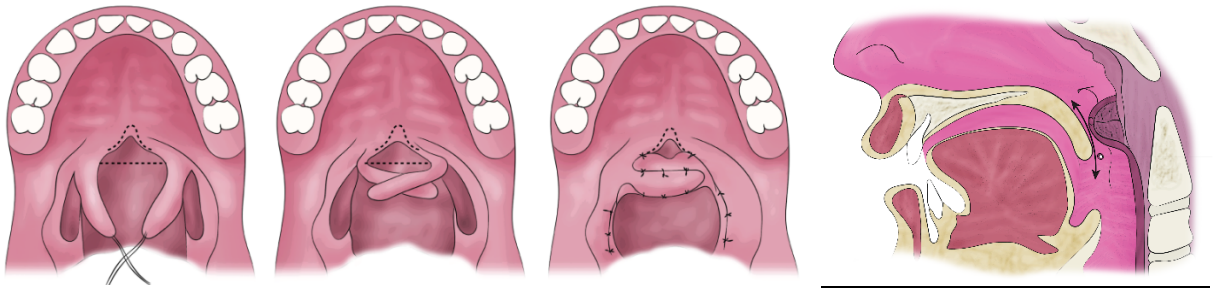


Online Figure 8. (a) Midline sagittal T2 image through the soft palate during /i/ phonation on a patient with history of cleft palate and VPI. The palate is hypodynamic and does not elevate appropriately with phonation. Both the effective velar length (green line) and velar length overall (red line) are abnormally short. (b) Coronal oblique T2 image along the plane of the LVP (blue outline) at the level of the velopharyngeal port during /i/ phonation in a patient with a history of cleft palate and VPI. The LVP (blue outline) demonstrates asymmetric and poor elevation. The LVP is irregular along its length and thinned at the right vertical portion. The velopharyngeal port remains patent despite the attempted phonation. (c) Midline sagittal T2 image through the soft palate during rest on a patient with history of cleft palate and VPI status post phayngeal flap surgery. The effective velar length (green line) has not changed, and velar length overall (red line) is difficult to assess secondary to the new flap insertion. (d) Coronal oblique T2 image along the plane of the LVP There is still a large gap in the velopharyngeal port with poor

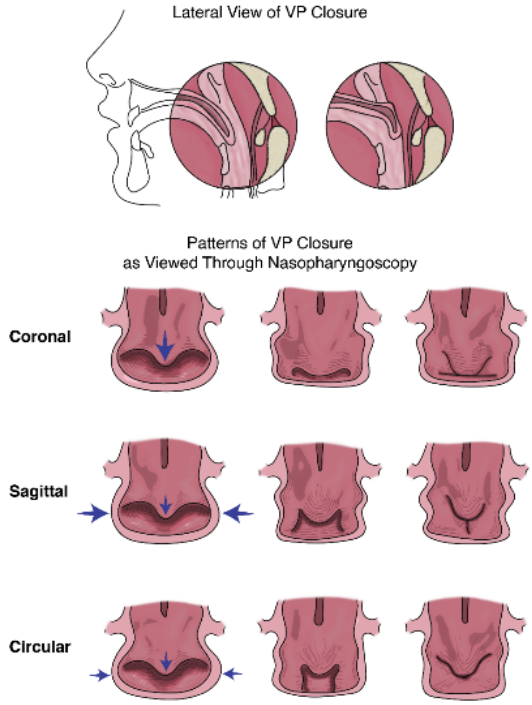
elevation of the LVP. The patient was noted to clinically have hypernasal speech consistent with a failed surgery.



Online Figure 9. (a) Midline sagittal T2 image through the soft palate during /i/ on a patient with history of cleft palate and VPI. The pharyngeal port is inappropriately patent with phonation. There is slightly diminutive effective velar length and minimally hypodynamic elevation of the soft palate during phonation. (b) Coronal oblique T2 images through the level of the pharyngeal port during phonation. The port remains open during phonation. Midline sagittal T2 postoperative rest (c) and phonation (d) images of the palate after sphincter pharyngoplasty. Note the appropriate closure of the velopharyngeal port at the level of the palatal place during phonation as it contacts the newly created sphincter.



Online Figure 10. Sphincter pharyngoplasty illustration.



Online Figure 11. Demonstration of different closure patterns of the velopharyngeal port.