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Five surgical maneuvers on nasal mucosa movement in cleft palate repair – a cadaver study

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Abstract

INTRODUCTION—This biomechanical study aims to characterize the nasal mucosa during palatoplasty, describing the soft tissue attachments at different zones and quantifying movement following their release.

METHODS—Palatal nasal mucosa was exposed and divided in the midline in 10 adult cadaver heads. Five consecutive maneuvers were performed: (1) elevation of nasal mucosal off the maxilla; (2) dissection of nasal mucosa from soft palate musculature; (3) separation of nasal mucosa from palatine aponeurosis; (4) release of mucosa at the pterygopalatine junction; (5) mobilization of vomer flaps. The mucosal movements across the midline at the midpalate and posterior nasal spine following each maneuver were measured.

RESULTS—At the midpalate, maneuvers 1–4 cumulatively provided 3.8 mm (36.9%), 4.9 mm (47.6%), 6.1 mm (59.2%), and 10.3 mm, respectively. Vomer flap (10.5 mm) elevation led to mobility equivalent to that of maneuvers 1–4 ($p=0.72$). At the posterior nasal spine, cumulative measurements after maneuvers 1–4 were 1.3 mm (10%), 2.4 mm (18.6%), 5.7 mm (44.2%), and 12.9 mm. Here, vomer flaps (6.5 mm) provided less movement ($p<0.001$). Maneuver 4 yielded the greatest amount of movement of the lateral nasal mucosa at both the midpalate (4.2 mm, 40.8%) and posterior nasal spine (7.2 mm, 55.8%).

CONCLUSION—At the midpalate, complete release of the lateral nasal mucosa achieves as much movement as the vomer flap. At the hard-soft palate junction, the maneuvers progressively add to the movement of the lateral nasal mucosa. The most powerful step is release of attachments along the posterior aspect of the medial pterygoid.

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Keywords

Palate dissection; Biomechanical; Cadaver study

INTRODUCTION

Classic works, including Millard's Cleft Craft and dissection studies by Dickson, Fara, Kriens and Latham have greatly contributed to our understanding of palatal anatomy and musculature in both normal and cleft palates.¹⁻⁵ Cadaver studies by Boorman and Sommerlad helped us to better appreciate the role of the levator palati and the importance of its reconstruction in cleft defects.^{6, 7} The velum consists of several distinct layers with characteristic components: 1) an oral mucosa layer containing mostly glandular tissue, 2) a middle muscle layer consisting of longitudinal fibers of the musculus uvulae and transverse fibers of the levator veli palatini, 3) a superoanterior layer consisting primarily of the tensor veli palatini tendon, 4) a posteroinferior layer (uvula proper) consisting of a mixture of glandular, and 5) the nasal mucosa.^{8, 9} Careful tissue handling and management of each of these components are important to an intact and functional repair of cleft palate defects.

Avoidance of post-operative fistula is an important goal in cleft palate surgery. The incidence of cleft palate fistulas is reported to range from 0 to 76%¹⁰⁻¹², whereas the recurrence rate of palatal fistulas may be as high as 65%.¹³ In an eloquent systematic review of 9294 patients from 44 studies by Hardwicke et al., the incidence of fistula in cleft lip-cleft palate was 17.9%, significantly higher than in cases of cleft palate alone (5.4%).¹⁴ The authors emphasized that the incidence of postoperative oronasal fistulae is likely misrepresented, since reported figures miss small or asymptomatic defects. Fistulas become clinically significant when they lead to distorted speech from nasal air escape or regurgitation of oral contents.^{15, 16} It has been suggested that oronasal fistulas occur primarily because of repair under tension. Losken et al. described various surgical maneuvers that can be useful in providing a tension-free palate repair.¹⁷ Having identified higher fistula rates in patients with Veau 3 and Veau 4 cleft palates, the authors recommended a double-opposing Z-plasty for narrow clefts (i.e., <8 mm) and two-flap palatoplasty for wider clefts. Regardless of technique, fistulae remain a challenge for cleft surgeons, both in prevention and repair.

Achieving primary closure of the cleft palate is now possible in almost all cases with use of local tissues. The anatomy of the palate has been extensively described, with a predominant focus on palatal musculature. In regards to oral mucosal closure, a biomechanical study by Mendonca et al. described the soft tissue attachments at different zones and quantified their movements following release.¹⁸ The authors showed that the greatest advancement occurred with dissection overlying the palatine aponeurosis posterior to the hard/soft palate junction (5.7 mm). Furthermore, additional dissection along the hamulus, without fracture, added significantly to the release (3.5 mm, $p < 0.05$). As a corollary to the previous work, this study aims to characterize the *nasal mucosa* during palatoplasty, describing the soft tissue attachments at different zones and quantifying the mucosal movement following their release to assist in cleft closure.

METHODS

A total of 10 fresh adult cadaver heads were obtained for this study of the palatal anatomy. Dissections were carried out under 2.5x loupe magnification. The temporomandibular joint was disarticulated and the mouth was opened, allowing for full exposure of the entire hard and soft palate. Careful attention was paid to avoid disrupting the attachments around the lateral oral cavity, pharynx, and tongue. The midline of the palate was identified and marked with ink. The palatal widths at the hard/soft palate junction (posterior nasal spine) and at the midportion of the soft palate were measured. Additionally, the palatal length from the incisor to the posterior nasal spine and posterior nasal spine to the uvula tip were measured. All measurements were taken by a single investigator.

The posterior nasal spine in the midline was identified. A #15 stainless steel blade was used to incise the midline of the oral palate from the central incisions to the posterior nasal spine and uvula. The oral mucosa was then dissected off the hard palate using a periosteal elevator. A bone rongeur was used to remove the central portion of the hard palate surrounding the vomer and to expose the nasal mucosa. The nasal mucosa adjacent to the vomer was then divided longitudinally to simulate a bilateral cleft deformity.

Five maneuvers of nasal mucosa dissection were identified and described (Figures 1–5). The dissection was performed in sequential fashion, from maneuver 1 to maneuver 2, followed by maneuver 3 and then maneuver 4, with the final maneuver being maneuver 5, creation of the vomer flaps. In maneuver 1, each nasal mucosal flap is elevated bluntly from the lateral walls of the maxilla to the level of the inferior turbinate (Figure 1). This first maneuver begins at the vomer and continues lateral and cephalad as the nasal mucosa attaches to the maxilla. Unlike a true cleft, the nasal mucosa is distinct from the oral mucosa. Maneuver 2 involves dissecting the nasal mucosa from the oral mucosa and surround muscles on the velum (Figure 2). In maneuver 3, the palatine aponeurosis is separated from the nasal mucosa, allowing for release from the hamulus (Figure 3). Maneuver 4 produces release of the nasal mucosa at the pterygopalatine junction (Figure 4). During this maneuver, the nasal mucosa flap edge (created from maneuver 3) is pulled towards the midline to reveal a ligamentous attachment at the pterygopalatine junction. The attachment is easily released, using a #9 periosteal elevator. The endpoint for release is based on both laxity and tactile feedback from bone. It is not easily visualized as it is deep in the skull base. Finally, maneuver 5 is the creation of superiorly-based vomerine flaps (Figure 5). Following each maneuver (#1–4) the medial edge of the nasal mucosa was pulled medially towards the marked midline with forceps. The amount of movement beyond the midline was measured with a paper ruler at the midportion of the hard palate (MP) and at the posterior nasal spine (PNS). The amount of movement for the vomer flaps at both of these landmarks (MP and PNS) was measured by pulling the flap laterally with forceps.

The mid-palate and posterior nasal spine served as key reference points for measurement, as post-operative fistulas have been frequently described in these regions.¹⁶ A combination of sharp and blunt dissection was performed over each area and measurements were taken before proceeding. Data were obtained on both sides of the palate. The cumulative

movement is the sum of the right and left flap excursion across the midline. Results were compared using student's *t*-test.

RESULTS

The age range of the 10 heads was between 79 and 97 years old (mean $\pm$ standard deviation: 84.4 ± 5.5). Four specimens were male and six were female. The mean width across the midportion of the hard palate (MP) was 33.4 ± 3.2 mm (range: 30–38 mm), whereas the mean palatal width across the posterior nasal spine (PNS) was 44.6 ± 4.7 mm (range: 40–55 mm). The mean palatal length from the central incisors to the PNS was 57.8 ± 6.3 mm (range: 45–58 mm), and the mean palatal length from the PNS to the tip of the uvula was 29.9 ± 4.6 mm (range: 23 – 38 mm). No palate scars were noted during the initial dissection. This data is summarized in Table 1.

As individual steps, each maneuver provided an incremental increase in movement of the mucosa beyond the previous maneuver at the midpalate: maneuver 1 (3.8 mm, 36.9%); maneuver 2 (1.1 mm, 10.7%); maneuver 3 (1.2 mm, 11.7%); maneuver 4 (4.2, 40.8%). Likewise, for the posterior nasal spine: maneuver 1 (1.3 mm, 10.1%); maneuver 2 (1.1 mm, 8.5%); maneuver 3 (3.3 mm, 25.6%); maneuver 4 (7.2 mm, 55.8%). When performed in the order proposed (maneuver 1, 2, 3, 4), the largest cumulative movement of the nasal mucosa across the midline occurred after maneuver 4 at both the MP (10.3 ± 1.3 mm) and PNS (12.9 ± 1.7 mm). The vomer flaps alone resulted in a mean width of 10.5 ± 1.2 mm at the MP and 6.5 ± 2.0 mm at the most posterior aspect of the vomer (PNS equivalent). As seen in Figures 6 and 7, the amount of medial movement provided by the combination of maneuvers 1–4 is equivalent to the amount of lateral movement provided by the vomer flap alone at the MP ($p = 0.72$); however, the vomer flap provides significantly less movement when compared to maneuvers 1–4 at the PNS ($p < 0.001$).

Of note, maneuver 4 involves release of the nasal mucosal attachments off the pterygopalatine junction. We discovered this ligamentous attachment to be present in a consistent fashion in all of our cadaver dissections. Independently, release of this attachment resulted in the greatest lateral movement. Histological studies of this attachment revealed that it primarily collagen in nature (Figure 8).

DISCUSSION

The nasal lining has been described as an unforgiving, thin, and difficult to mobilize structure.¹⁹ However, closure of this layer is believed to be critical to the success of the cleft palate repair, particularly in the minimization of fistula development. Management of the nasal mucosa and its biomechanics in obtaining tension-free repair has not been well described in the literature. Clinically, closure of the nasal lining has been limited to turnover flaps, placement of dermal substitutes, and recruitment of additional tissues from local or regional flaps.^{20–22} Full mobilization of the nasal mucosa is a useful technique to repair wide cleft or fistula defects; here we describe a series of maneuvers to release the nasal mucosa and quantify these movements following each maneuver.

In addition to achieving velopharyngeal sphincter competence and normal speech resonance, most cleft surgeons would agree that a well-healed palate without a fistula or excessive scars is of critical importance following palatoplasty. We focused our measurements at the midportion of the hard palate (MP) and the posterior nasal spine (PNS), as most fistulas tend to occur in these regions. Using the Pittsburgh Fistula Classification System, the MP and PNS correspond to Type IV (hard palate) and Type III (junction of hard/soft palate), respectively.^{16, 23} Of the 640 patients with cleft palate repairs reviewed by the Pittsburgh group, the most common fistula type was Type IV, present in 119 palates (46.7%). The next most common fistula was Type III, present in 45 palates (17.6%). Fistulas may result from wound breakdown, secondary to closure under tension, infection, trauma, hematoma or compromise of a vascular pedicle.²⁴ Our results indicate that when tension is at the hard palate, the vomer flap is a powerful tool and achieves as much movement as complete release of the lateral nasal mucosa achieved in maneuvers 1–4. In contrast, at the PNS, vomer flaps add little mucosal closure. Instead, our proposed maneuvers progressively increase the movement of the lateral nasal mucosa. Notably, the most powerful maneuver is release of the attachments at the region of the medial pterygoid.

Cleft palate repair has experienced a paradigm shift in utilization of the nasal mucosa. Some proposed that nasal lining closure was not mandatory if adequate oral lining coverage was achieved.¹⁹ The nasal component was neglected for some period of time until Furlow described mobilization of the nasal mucosa as he found it particularly useful when the oral lining could not be closed.²⁵ He reported that the oral defect would heal as long as the nasal mucosa was intact. Liu et al. reported successful nasal lining mobilization in both primary (Bardach's technique) and secondary palatoplasty (Furlow's technique).¹⁹ The authors emphasized that a hockey stickshaped respirator should be used to bluntly dissect the nasal mucosa off of the lateral bony structures. This levering technique prevents sheering and buttonholing that often occurs with sharp dissection of this delicate structure. We also found this technique to be helpful in maintaining an intact nasal mucosal dissection, noting its effectiveness as previously described.

In addition to nasal mucosa mobilization, vomerine mucoperiosteal tissue is used routinely during cleft defect repair, either in the form of a simple elevation or a flap. Vomerine flaps are well vascularized and are advantageous because of their simplicity and ease of execution. It aids in providing an effective nasal lining – the tissue quality of the two is very similar – without adding to excessive tissue trauma or surgical time.²⁶ Agrawal et al. presented a comprehensive and simple classification of vomer flaps based on indications related to the clinical situation²⁷. Early concerns that using vomer tissue may result in growth disturbance of the midface were unfounded. Experimental and clinical studies from septal resection, refashioning and reimplantation procedures did not produce any significant growth disturbances or adverse outcomes.^{28, 29} Despite the simplicity and safety in creating vomer flaps, sometimes vomerine tissue is either hypoplastic, too superior or not readily available in a partial or submucous clefts.^{27, 30} Furthermore, our data shows that Agrawal Type I flaps (nasal mucosa back-cut is not made) do not provide as much robust lateral movement at the posterior nasal spine as it does at the midpalate (Figure 6, 7).

The data from the current study have shown that release of a ligamentous attachment tethering the nasal mucosa at the pterygopalatine junction (maneuver 4) results in significant medial movement at both the MP and PNS (Figures 6, 7). Histologically, the attachment is collagen-rich and is distinct from the surrounding nasal mucosa (Figure 8). This structure inserts at the suture joining the medial pterygoid and the palatine bone. Remarkably, the release of this ligamentous attachment allows for over twice the amount of excursion that comes from vomer flaps alone at the PNS ($p<0.001$). Our cleft surgeons have begun to successfully utilize this maneuver to garner and mobilize nasal mucosa in wide clefts. A similar technique for mobilization of the nasal mucosa was recently described in a study of 67 patients who underwent a minimal-incision palatoplasty paired with a cranial base maneuver for nasal mucosa elevation.³¹ Pan et al. suggest maneuvers that aid in complete closure of the nasal mucosa reduce salivary contamination and elongate the velum. Their fistula and velopharyngeal insufficiency rates were lower or at least comparable to that of other techniques.^{15, 16, 32} Anecdotal descriptions of similar tissue release between the pharyngeal constrictors and the pterygoids, referred to as space of Ernst, have been advocated in the literature.⁴

Several limitations exist in our study. Notably, the maneuvers and measurements were performed on elderly non-cleft cadavers. Tissue quality, exposure, and size differences may preclude extrapolation of our findings to a cleft population. Findings associated with adult palatal dissections cannot be directly applied to children and infants. Anatomically, cleft palates have aberrant muscle configurations and oftentimes hypoplastic tensor aponeurosis. In our simulated bilateral clefts, the main results did not differ even after additional analyses to control for palate width (both at the mid-palate and posterior nasal spine). The amount of movement was proportional to the palate size and the greatest amount of movement result from maneuver 4. Potentially, this may not be the case in two cleft patients with similar palatal widths, but different defect widths and existing nasal mucosa. Nonetheless, this study provides baseline data for dissection within different zones of the normal palate, with useful information on the key regions that need to be released in order to obtain mobilization of the nasal mucosa. The techniques described in this paper have been safely and effectively utilized in the clinical setting. Patient follow-up and data analysis are pending for comparison to outcomes seen in current literature.

CONCLUSION

When releasing the nasal mucosa during palatoplasty, we propose that select maneuvers may be based on area of concern for excess tension. At the mid-portion of the hard palate, the vomer flap is a powerful tool and achieves as much movement as complete release of the lateral nasal mucosa. At the hard-soft palate junction, the most notable maneuver involves release of attachments at the pterygopalatine junction.

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Figure 1.
Nasal mucosa (arrow) release at the hard palate.

Figure 2.
Nasal mucosa (arrow) release from the soft palate.

Figure 3.
Release (dashed line) of nasal mucosa from hamulus (arrow).

Figure 4.
Detach nasal mucosa from pterygopalatine junction (arrow).

Figure 5.
Creation of bilateral superiorly-based vomer flaps.

Cumulative Movement at Midpalate (mm)

Figure 6.
Cumulative movement of the nasal mucosa at the midpalate.

Cumulative Movement at Posterior Nasal Spine (mm)

Figure 7.
Cumulative movement of the nasal mucosa at the posterior nasal spine.

Figure 8.
Histology of ligamentous attachment tethering the nasal mucosa to pterygopalatine junction.
Stained with toluidine blue and viewed at 40x magnification.

Table 1

Demographics of cadaver specimens

	Gender	Age (years)	Width at MP (mm)	Width at PNS (mm)	Length from Incisor-PNS (mm)	Length from PNS-uvula (mm)
Mean	---	84.4	33.4	44.6	57.8	29.9
Standard Deviation	---	5.5	3.2	4.7	6.3	4.6
Range	4 males : 6 females	79–97	30–38	40–55	45–58	23–38