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Biomechanical Strength of Human Nasal Septal Lining: Comparison of the Constituent Layers

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Objective/Hypothesis: **Nasal septal perforation is a common complication following surgery involving the nasal septum. Septoplasty, septorhinoplasty, and submucosal resection may result in the inadvertent resection of perichondrium, which may predispose the patient to septal perforations.** ***Study Design:*** **Controlled human cadaver study testing the biomechanical strength of the constituent layers of nasal septal lining.** ***Methods:*** **Uniform samples of nasal septal mucosa, perichondrium, and a composite of both layers were obtained from five fresh human cadavers. The mechanical tensile strength of these layers was evaluated and compared with the Instron 4301 Mechanical Testing System (Canton, MA).** ***Results:*** **Mixed-effects regression analysis demonstrated a significant difference in the tensile strength of the three groups (mean values ± SD: mucosa, 662 ± 308 g; perichondrium, 1370 ± 798 g; composite, 2340 ± 1252 g). All three pairwise comparisons among the three groups showed a significant difference in tensile strength.** ***Conclusion:*** **The perichondrial layer imparts the majority of the biomechanical strength to septal lining. Lining flaps containing both perichondrium and mucosa are stronger than flaps with either perichondrium or mucosa alone. Dissection in the subperichondrial plane during septal surgery provides a stronger septal flap and may prevent the development of nasal septal perforation during nasal surgery.** ***Key Words:*** **Nasal septum, nasal mucosal lining, nasal septal perichondrium, tensile strength.**

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INTRODUCTION

Septorhinoplasty, septoplasty, and submucosal resection are commonly performed surgeries in which modification of the nasal septum occurs. Septal perforation is a common complication following these procedures with rates that vary from 2% to 8% for submucosal resection and from 1.6% to 5.4% for septoplasty.[1]

Individuals with nasal septal perforations have prolonged nasal crusting, epistaxis, abnormal nasal airflow, or whistling during nasal breathing. The presence of a violated mucosal layer may lead to mucosal infection or perichondritis. Most perforations are small and anterior, interfering with the humidification of inspired air. Larger perforations can lead to atrophic rhinitis. In rare instances, perforations may enlarge over time and eventually encompass the structural support areas of the nasal septum, leading to structural compromise of the nasal dorsum or tip.

The standard septoplasty technique involves a sharp hemitransfixion or Killian incision through mucoperichondrium in the region of the caudal septum. Subperichondrial and subperiostial elevation is then performed on each side of the septum to access the septal cartilage and bone. On exposure of the septal framework, resection or modification of the cartilage and bone is performed to alleviate nasal obstruction or to obtain grafting material for rhinoplasty. The mucoperichondrial flaps are then reapproximated through a running trans-septal quilting suture.[2]

A common error in nasal septal surgery is inadvertent dissection in a supraperichondrial, submucosal plane. This leads to the resection of perichondrium or periostium with the cartilage and bone, leaving only mucosal flaps apposing each other. We think that mucosa-only flaps, lacking the additional strength and support of the perichondrial layer, predispose the patient to immediate or delayed septal perforation. The present study aimed to test this hypothesis with comparative data on the biomechanical strength of the separate layers of human cadaveric nasal septal lining.

MATERIALS AND METHODS

The nasal septa were harvested en toto from five fresh human cadaver specimens. The quadrangular cartilage was sharply excised from the osseous septum. Under magnification with a dissecting microscope the layers of the nasal septal lining

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were dissected from each septal cartilage specimen. On one side of each septum, a composite flap of both perichondrium and mucosa was dissected. Access to this plane of dissection was gained with a No. 15 blade scalpel, and elevation was performed with a Freer elevator. On the opposite side of the septum, the mucosal layer was initially dissected from the septum, leaving the perichondrium on the cartilage. This plane was accessed with a superficial incision through the septal mucosa at the edge of the caudal septum. The Freer elevator was used to scrape obliquely downward until the distinctive perichondrial layer became exposed. The mucosa-only layer was elevated with the Freer elevator from the underlying perichondrium. A distinct plane of dissection was evident in this elevation and readily followed. After the mucosal layer was removed, the remaining perichondrium was elevated from the cartilage in the same manner as the composite specimen.

Each specimen was placed in a moist saline sponge. Uniform 1 × 3-cm rectangles were cut from each specimen. Nine mucosa-only, 11 perichondrium-only, and 14 composite specimens were obtained from the five cadaver septa. The samples were labeled to allow for comparison of specimens within each cadaver source.

Each rectangular specimen was secured into the mechanical testing system (Instron 4301 Mechanical Testing System [Canton, MA]). This instrument measures tensile strength as determined by the force necessary to tear a specimen (failure). The ends of each specimen were immobilized between two plates of a small vice lined with fine-grit sandpaper. The plates were compressed to secure the specimens into the apparatus with 1 cm of overlap between each vice plate apparatus at each end of the specimen, leaving a 1 × 1-cm exposed portion of specimen (Fig. 1). The mechanical testing system was configured to gradually pull the two ends of the specimen apart until it failed. In all cases, the failure occurred in the center of the exposed portion of the specimen, suggesting that the edge of the compression plates of the vice did not create an extrinsic severing force. Inspection of the overlapping segments of each specimen revealed that they did not migrate or move during the test, indicating a secure fixation of the specimen. The mechanical testing system recorded the force in the highest value of tensile force in grams attained for each specimen, the value that reflected the force required for failure of the specimen (the value immediately drops to zero once the specimen fails and tension is lost). Statistical analysis was then performed, as described below.

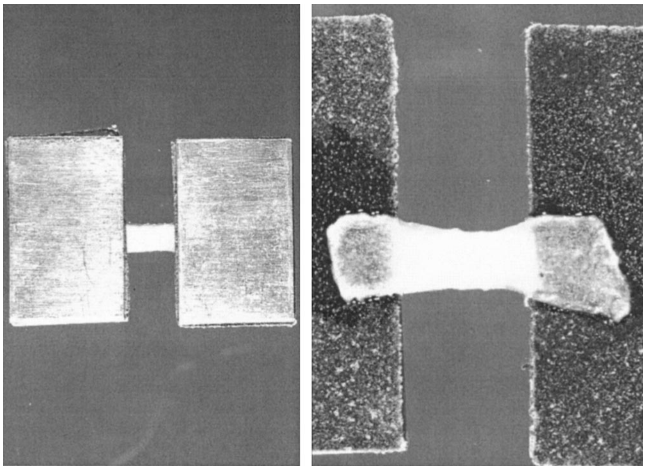

Fig. 1. Septal flap specimen secured in the mechanical testing system. (**A**) A 1 × 1-cm portion of specimen is exposed between the fixation vices. A small degree of stretch has occurred after a short time in the mechanical testing system during which the two stabilized ends of the specimen are pulled apart. (**B**) Further stretch with resultant deformation. The exposed central portion of specimen eventually fails at the middle of the segment when its tensile strength is exceeded. The medium-grit sandpaper that lines the immobilization plates is evident. Inspection after each experiment reveals no migration or motion of the fixation areas of the specimens that are bound within the plate/sandpaper vice.

RESULTS

Dissection in both the subperichondrial plane and the supraperichondrial, submucosal plane was met with little resistance and no damage to the continuous sheet of septal lining obtained. On gross examination, the perichondrium-only layer was a thinner, gray fibrous layer of tissue, whereas the mucosa-only layer was thicker, spongier, and redder. Although histological analysis was not performed to determine the exact composition of each specimen, the layers were obtained through dissection in natural, easily dissected planes. Therefore, the constituent layers obtained were thought to mimic the flaps that were likely to be encountered during septal surgery.

The mechanical strength of the three different combinations of nasal septal tissue was compared and recorded (Table I). The mucosal specimens had a mean tensile force of 662 g (SD = 308 g), the perichondrium samples had a mean tensile force of 1370 g (SD = 798 g), and the composite specimens had a mean tensile force of 2340 g (SD = 1252 g) (Fig. 2).

Mixed-effects regression with fixed-location effect and a random-subject effect, which takes into account the association of multiple measurements on the same subject, was then performed. The hypothesis of no difference in the strength of the three types of tissue yielded a P value of 0.0002. Analysis of the pairwise comparisons of least-squares mean values of the tensile strength of the septal tissue layers demonstrated the following: mucosa versus composite, $P < .0001$; perichondrium versus composite, $P = .01$; and mucosa versus perichondrium, $P = .05$ (Table II).

DISCUSSION

The nasal septum is made up of the nasal spine of the frontal bone, the perpendicular plate of the ethmoid, the medial segments of the nasal bones, the vomer and crest of the sphenoid, the nasal crest of the palatine bone, the nasal crest of the maxilla, the premaxilla and nasal spine, the quadrangular cartilage, and the upper lateral cartilage. These components are covered in a layer of perichondrium or periostium, which is lined with nasal mucosa. The transition zone between perichondrium and perios-

TABLE I.
Mechanical Tensile Strength of Each Flap Assessed by Force Necessary to Shear Segment.

Location	n	Mean force (g)	SD	Minimum force (g)	Maximum force (g)
Mucosa	9	662.22	307.92	328	1173
Perichondrium	11	1370.45	797.55	561	2497
Composite	14	2340.86	1252.03	505	4384

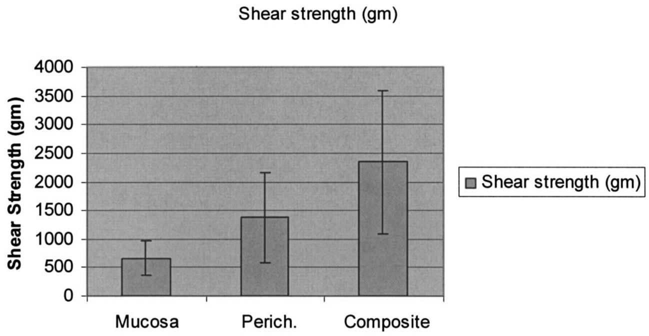

Fig. 2. Mean tensile strength of nasal septal layers as assessed on Instron 4301 Mechanical Testing System. SD bars are included.

tium represents an area of high risk for septal perforation during nasal surgery, especially at the junction of the quadrangular cartilage and the ethmoid and vomer osseo-cartilaginous junction.[3]

Many nasal surgeons in training are admonished by their teachers to remain in a subperichondrial plane during elevation of the septal lining. In addition to maximizing the vascular supply to the lining flaps, the incorporation of the perichondrium into the lining flaps increases their strength and may decrease the risk of perforation. Elevation in a supraperichondrial, submucosal plane leads to loss of the perichondrial layer in the areas in which septal cartilage is removed, leaving only mucosa to provide strength and support to the septal structure. This mucosal layer may be more apt to perforate without the underlying perichondrial layer. These perforations can lead to complications for the patient ranging from recurrent epistaxis and infections to perichondritis and the saddle-nose deformity.

The mechanism of septal perforation probably varies from patient to patient. Incomplete elevation of septal lining before resection of septal cartilage and bone, removal of septal spurs with sharp edges, vascular compromise, and postoperative crusting or trauma may all lead to immediate or delayed septal perforation after surgery. Irrespective of the cause, it is likely that maximizing the strength of the lining flaps through subperichondrial flap elevation provides the most resistance to perforation. In addition, stronger septal flaps are more resistant to external stresses (trauma, nasal steroid sprays, etc.). The present study provides preliminary evidence which suggests that this practice may reduce the risk of iatrogenic nasal septal perforation. The data clearly demonstrate that the perichondrial layer has a higher resistance to tensile force and suggest a significant contribution to the septal strength after cartilaginous resection.

TABLE II.
Pairwise Comparisons of Least-Squares Mean Values of Tensile Strength of Nasal Septal Tissue Layers.

	Mucosa vs. Composite	Perichondrium vs. Composite	Mucosa vs. Perichondrium
P value	<.0001	.01	.05

Based on the results of the present preliminary investigation, further studies are warranted in which more detailed information about septal lining mechanical strength may be obtained. Different models of biomechanical strength may be used to more realistically mimic the intraoperative forces that stress the septal lining. In addition, the lining from different regions of the nasal septum may be tested to determine whether there are regional differences in strength. As well, the septal lining specimens may be examined histologically to determine the exact composition of the dissected constituent layers.

CONCLUSION

The perichondrial layer imparts the majority of the biomechanical strength to septal lining. Lining flaps containing both perichondrium and mucosa are stronger than flaps with either perichondrium or mucosa alone. Dissection in a subperichondrial plane in the approach to septoplasty may lead to a stronger septal lining flap available for closure and therefore to a decreased risk of septal perforation.

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