The Osseocartilaginous Vault of the Nose: Anatomy and Surgical Observations

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Abstract

**Background:** The dorsal hump and dorsal aesthetic lines have been considered bony and cartilaginous structures. Knowledge of the anatomy of the osseocartilaginous vault is essential for obtaining aesthetically pleasing results of rhinoplasty.

**Objectives:** The authors described the morphology, embryology, and clinical relevance of the nasal vault and the changes that occur in this area during rhinoplasty.

**Methods:** Dissections were performed on 15 fresh adult cadavers to examine the anatomy of the osseocartilaginous vault. Intraoperative endoscopic examination of the vault also was performed in 9 rhinoplasty patients before and after dorsal hump reduction.

**Results:** In the cadaver study, the average length of the dorsal keystone area, measured along the dorsal septum, was 8.9 mm, and the average width was 4.9 mm. No significant difference in length was observed between cadaver subgroups with straight or humped nasal profiles. The extent of lateral overlap of the nasal bones with the cephalic portion of the upper lateral cartilages varied. In rhinoplasty patients, the average length of the cartilaginous vault exposed during dorsal reduction was 7.6 mm.

**Conclusions:** The aesthetic lines and profile of the nose before dorsal reduction are dictated by the cartilaginous vault. After reduction, the dorsal lines are determined by the bony vault edges. In routine rhinoplasty, reduction of dorsal height generally corresponds to removal of the dorsal cartilaginous septum.

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An aesthetically pleasing result of rhinoplasty depends on thorough knowledge of nasal anatomy. Even with open rhinoplasty, it can be challenging to control the precise relationship of the nasal structures. The results of cadaver dissections have indicated that the relationships between the nasal bones, upper lateral cartilages (ULCs), and cartilaginous dorsal septum are unpredictable in the keystone area, where the bony vault overlaps the cartilaginous vault dorsally (ie, dorsal keystone area [DKA]) and laterally (ie, lateral keystone area [LKA]). Additionally, the soft-tissue envelope overlying the keystone area is the thinnest tissue in the nose with virtually no subcutaneous fat and with underlying muscles that merge into aponeurotic tissue. Because of this anatomy, extraordinary attention to detail is required during hump reduction to create a smooth dorsal profile and continuous dorsal aesthetic lines.

Most rhinoplasties involve some amount of hump reduction, which typically disrupts the DKA. Significant hump reduction can involve complete reorganization of the anatomic relationships of the keystone area. Dorsal hump reduction also may require osteotomy and or middle vault surgery to avoid an open roof deformity. The anatomy of the osseocartilaginous vault of the nose has been described previously, but a precise examination of these structures

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is lacking. In the present study, we determine the dimensions and organization of the osseocartilaginous vault, examine anatomic changes that occur in the vault during rhinoplasty, and discuss the embryology and clinical relevance of this area.

METHODS

Dissection of Cadavers

Dissections were performed on 15 fresh cadavers (30 hemi-noses) without signs of nasal trauma or previous rhinoplasty at time of autopsy at Semmelweis University in Budapest, Hungary. The soft-tissue envelope was excised from the nasal dorsum and sidewalls, and the perichondrium of the ULCs was removed under loupe magnification (4.3). Measurements of the intact osseocartilaginous vault from the nasofrontal suture line (NFSL) to the anterior septal angle (ASA) were made, and reference points were noted in frontal and lateral views (Figure 1). The nasal bone then was removed en bloc, and the dimensions of the underlying cartilaginous vault were determined. Photographs were obtained throughout the dissection (Figures 2 and 3). Where indicated, measurements within the cadaver group were compared by t test.

Patients

A series of 9 patients who underwent open rhinoplasty by the senior authors between November, 2013 and December, 2013 were evaluated consecutively and prospectively. This was done in accordance with guiding principles of the Declaration of Helsinki. Patients were included who presented for reduction or modification of dorsal height. Exclusion criteria were previous nasal surgery or nasal trauma. All patients provided written informed consent.

Surgical Techniques

Patients were evaluated with a nasal endoscope (Karl Storz, Germany) during open rhinoplasty. The subperichondrial plane was entered along the cartilaginous dorsum with a No. 15 blade and a Daniel-Çakir elevator. As dissection proceeded cephalically, the ULCs were carefully exposed until the osseocartilaginous junction was encountered. The subperiosteal plane was entered laterally, and the skin sleeve was lifted in a continuous subperichondrial-subperiosteal plane. Photographs were obtained with a nasal endoscope, and points were marked to evaluate changes in the vault during hump reduction (Figure 4 and Video 1).

Figure 1. (A) Dissection of cadaver showing the osseocartilaginous vault in the frontal view. NFSL, nasofrontal suture line; N, nasion; S, sellion; K, keystone point; U", most caudal point of the dorsal border of the upper lateral cartilage that is united through cartilage with the dorsal septum; U', most caudal point of the dorsal border of the upper lateral cartilage that is not separated from the dorsal septum macroscopically; U, most caudal point of the dorsal border of the upper lateral cartilage; ASA, anterior septal angle. (B) The osseocartilaginous vault in the lateral (profile) view. MCL, medial canthal ligament; NFPSL, nasoprefrontal suture line; J, most caudal point of the nasomaxillary suture line; J', most cranial uncovered point of the lower lateral border of the upper lateral cartilage; X, widest point of the frontal process of the maxilla; P, piriform aperture; ScrP, most caudal point of the lower lateral border of the upper lateral cartilage.
The bony dorsum then was reduced by means of manual and powered rasps (Bien-Air, Bienne, Switzerland). After the bony cap was removed, the postreduction osseocartilaginous vault was photographed with the nasal endoscope.

The postreduction keystone point (K') was marked along with changes in the length and width of the vault. Cartilaginous reduction then was performed and documented with photographs (Figure 5 and Video 2).

Figure 2. (A) Dissection of cadaver showing the osseocartilaginous vault in the lateral view. (B) The vault in the lateral view with the nasal bone raised. (C) The osseocartilaginous vault in the dorsal view. (D) The vault in the dorsal view with the nasal bone raised.
RESULTS

Cadaver Dissections

Osseocartilaginous Vault

Fifteen Caucasian cadavers (30 heminoses), including 7 females and 8 males with an average age of 67 years (range, 44-95 years) were dissected. The dimensions of the intact osseocartilaginous vault are shown in Table 1 and Figure 1. The size and form of the osseocartilaginous vaults varied widely in cephalocaudal and anteroposterior directions. In the cephalocaudal direction, the average midline length from the NFSL to the most caudal point of the dorsal border of the ULCs (U) was 41.3 mm. The average distances from the NFSL to the nasion, the sellion, and the keystone point (K) were 5.3, 11.6, and 24.7 mm, respectively. The average distances from K to U and from K to the ASA were 15.8 and 20.1 mm, respectively. The average distance from U to the ASA was 4.4 mm, whereas the average distance from the widest point of the frontal process of the maxilla to the piriform aperture was 6.5 mm.

In the caudal portion of the ULCs, an apparent cleft was observed between the ULCs and the septum in 9 of the heminoses (30%). The average length from U to the cranial border of this cleft ($U_0$; ie, the most caudal point of the dorsal border of the ULCs that was not separated from the dorsal septum macroscopically) was 1.55 mm. When the perichondrium of the septum and ULCs was removed, this cleft was visible as a separation that ranged from 3 to 25 mm in length. In 2 heminoses, the cleft occurred along the entire length of the cartilaginous dorsum. The clefts on the left and right heminoses of each cadaver varied in length and were not symmetric.

Cartilaginous Vault

En bloc elevation of the nasal bone enabled visualization of the keystone area with readily distinguishable DKA and LKA. The dorsal cartilaginous septum creates the DKA, whereas the cephalic portions of the ULCs create the paired LKAs. A separation was noted along the cartilage under the nasal bone that corresponded to the dorsal aesthetic lines (Figure 6). This separation was essentially a cephalic continuation of the separation between the ULCs and the dorsal septum.

The DKA

The dorsal septum widens dorsally and creates in cross-section a T-shaped suspension for the bony vault. In the 15 cadavers, the average length of the DKA along the midline from K to the most cephalic extent of the cartilaginous vault was 8.9 mm (range, 4-14 mm). Of 5 noses (33%) with no hump on profile view, the average length of the DKA was 9.6 mm (range, 6-12 mm). Of 10 noses (67%) with a hump on profile view, the average length of the DKA was 8.6 mm (range, 4-14 mm). The DKA lengths in the...
subgroups with or without nasal humps did not differ significantly, as ascertained by t test. The average width at the widest part of the DKA was 4.9 mm (range, 3-9 mm). The location of the widest transverse diameter was inconsistent, but was usually at the caudal end of the DKA.

**The LKA**
The LKA was found in 24 heminoses (80%) and was highly variable. When the LKA was present in the cadavers, the transition from DKA to LKA corresponded to 1 of 3 patterns: continuous, stepped, or minimal joint. The stepped transition pattern could be subgrouped as sharp-edged or rounded (Figure 7). For cadavers in which the LKA was absent, the bony cap did not extend beyond the interface of the dorsal septum and ULCs.

**Patients**
The 9 rhinoplasty patients evaluated in this study all were Caucasian women and had an average age of 23.8 years (range, 20-28 years). Endoscopic examination after removal of the bony cap during open rhinoplasty revealed that the extension of the cartilaginous vault under the bony cap created the dorsal aesthetic lines on the skin surface. The average length of the exposed DKA was 7.6 mm (range, 4-10 mm). Because the bony cap was treated by rasping during rhinoplasty, the size of the native DKA could not be determined in these patients. However, the intact cartilage vault was exposed after bony cap reduction in 9 of 9 patients (100%). Deepening of the sellion superior to the hump was achieved with a powered burr. The postoperative dorsal aesthetic lines were determined cephalically by the edges of the bony vault, which typically was treated with osteotomy, and caudally by the cartilage vault after reconstruction with spreader flaps or spreader grafts.

**DISCUSSION**
Our anatomic findings in cadavers and rhinoplasty patients can be considered within the contexts of the embryology of the dorsum, the continuity of the ossecartilaginous vault, and rhinoplasty techniques.
Table 1. Dimensions of the Osseocartilaginous Vault (n = 30 heminoses)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Average Distance, mm</th>
<th>Range, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFSL to U</td>
<td>41.3</td>
<td>35-48</td>
</tr>
<tr>
<td>NFSL to N</td>
<td>5.3</td>
<td>2-7</td>
</tr>
<tr>
<td>NFSL to S</td>
<td>11.6</td>
<td>9-15</td>
</tr>
<tr>
<td>NFSL to K</td>
<td>24.7</td>
<td>22-27</td>
</tr>
<tr>
<td>K to U</td>
<td>15.8</td>
<td>11-21</td>
</tr>
<tr>
<td>K to ASA</td>
<td>20.1</td>
<td>15-25</td>
</tr>
<tr>
<td>S to K</td>
<td>13.1</td>
<td>7-17</td>
</tr>
<tr>
<td>U to ASA</td>
<td>4.4</td>
<td>1-8</td>
</tr>
<tr>
<td>X to P</td>
<td>6.5</td>
<td>2-11</td>
</tr>
<tr>
<td>U to U'</td>
<td>0.6</td>
<td>0-3</td>
</tr>
<tr>
<td>U to U&quot;</td>
<td>6.2</td>
<td>3-14</td>
</tr>
<tr>
<td>K to J</td>
<td>13.5</td>
<td>9-19</td>
</tr>
<tr>
<td>X to NMSL</td>
<td>5.6</td>
<td>3-10</td>
</tr>
<tr>
<td>U to ScrP</td>
<td>11.3</td>
<td>8-16</td>
</tr>
<tr>
<td>J to J'</td>
<td>-0.63</td>
<td>-4 to 3</td>
</tr>
<tr>
<td>J' to ScrP</td>
<td>6.3</td>
<td>4-10</td>
</tr>
</tbody>
</table>

ASA, anterior septal angle; J, most caudal point of the nasomaxillary suture line; J', most cranial uncovered point of the lower lateral border of the upper lateral cartilage; K, keystone point; N, nasion; NFSL, nasofrontal suture line; NMSL, nasomaxillary suture line; P, pinniform aperture; S, sellion; ScrP, most caudal point of the lower lateral border of the upper lateral cartilage; U, most cranial point of the dorsal border of the upper lateral cartilage; U', most cranial point of the dorsal border of the upper lateral cartilage that is not separated from dorsal septum macroscopically; U", most caudal point of the dorsal border of the upper lateral cartilage; U, most cranial point of the dorsal border of the upper lateral cartilage that is united through cartilage with the dorsal septum; X, widest point of the frontal process of the maxilla.

Embryology

The nose, and specifically the bony dorsum, is built on the foundation of the nasal capsule. During the third week of human development, the face consists of 5 mesenchymal primordia that grow from the cerebral capsule: a central frontonasal prominence, paired maxillary prominences, and paired mandibular prominences. The frontonasal prominence elongates to form the frontonasal process, positioned between symmetric nasal placodes. In the fourth and fifth weeks, swellings surround the nasal placodes, subdividing the frontonasal process into 1 medial and 2 lateral secondary nasal processes. The medial secondary process then further subdivides into the right and left medial nasal processes. Ultimately, 4 nasal subdivisions are produced: the paired medial nasal processes and the paired lateral nasal processes.

The nasal capsule is formed by the fusion of these medial and lateral nasal processes. The medial nasal process gives rise to midline structures including the vomer, nasal septum, and dorsum. The medial process comprises a population of neural crest cells that are capable of self-renewal and differentiation into glia, neurons, melanocytes, chondrocytes, or osteoblasts. These cells differentiate to form the nasal cartilage, which is composed of a dorsal ectethmoid and a ventral mesethmoid. The ectethmoid comprises the olfactory system, conchae, and crura, whereas the mesethmoid gives rise to the nasal septum and vomer and determines the size of the nose and the position of the premaxillary bone.

Embryologic development of the nasal bones of the chondrocranial skeleton occurs in concert with that of other nasal structures and facial bones. The facial bones develop intramembranously from ossification centers within the neural crest mesenchyme of the facial prominences. During the eighth week of prenatal development, ossification centers within the frontonasal process appear on the membrane covering the cartilaginous nasal capsule. A primary ossification center contributes to the paired nasal bones, whereas bilateral alae ossification centers can be observed at the onset of vomeral ossification in the maxillary mesenchyme surrounding the cartilaginous nasal septum. Growth of the nose occurs from anteroposterior expansion of the nasal septum rather than from growth of the nasal bones themselves. As the cartilaginous septum expands, growth occurs coronally at the nasomaxillary suture lines, creating the elevated nasal bridge. Inhibited or defective growth of the nasal septum coronally has minimal effects on the height of the middle third of the face, but gives rise to a low nasal bridge and possible concavity of the face.

Osseocartilaginous Vault

In neonates, the intracranial regions of the ULCs ingress at the anterior base of the skull. Few studies have addressed subsequent anterior ingestion of the ULCs in childhood and beyond. The nasal skeleton in neonates is cartilaginous and extends from the cartilaginous primordium of the cranial base. Incidental surgical observations in 3- and 4-year-old patients indicated that the nasal bones are supported along their length by the ULCs. The degree of extension of the ULCs under the nasal bones varies depending on the extent of ingestion into the skull. The nasal bones function as a thin cap over the growing septum and ULCs and are not affected by the extension patterns of the ULCs (Figure 8). Growth of the nasal septum forces the cartilaginous nasal bridge into position, and bony remodeling dictates the final positions of the nasal bones. The bony cap formed by the nasal bones is positioned primarily by growth of the cartilaginous septum. The nasal bones vary in size but collectively form a thin contour over the cartilaginous structures.

During postnatal development and into the second decade of life, the cartilaginous nasal septum functions as the dominant growth center of the midface. An adolescent nasofacial growth spurt begins at approximately 8 to 13 years.
Figure 6. Illustration of the cartilaginous relationship of the dorsal lines and the dorsal keystone area (DKA) in a relatively narrow (A) and relatively wide (B) nasal dorsum.

Figure 7. Illustration of transitions from the dorsal keystone area to the lateral keystone area observed during cadaver dissections. I, continuous; II, rounded stepped; III, sharp-edged stepped; and IV, minimal joint. ULC, upper lateral cartilage.
years of age and ends at 13 to 15 years of age. Before and during this growth spurt, gradual ossification of the septal cartilage occurs, with consequent expansion of the perpendicular plate of the ethmoid and vomer. Thus, the nasal hump results from the underlying cartilaginous vault and thin bony cap rather than from an osseocartilaginous structure comprising equal parts of cartilage and bone. The results of our cadaver dissections can serve as reference guides for rhinoplasty surgeons, who have few opportunities to observe the components of the nasal vault with the skin, perichondrium, and periosteum removed.

**Surgical Techniques**

The primary concern of rhinoplasty patients is the presence of a dorsal hump. To address this concern and avoid unintended consequences, the surgeon must excise the DKA and subsequently modify the remaining dorsum. Dorsal reduction instruments have changed with time from saws, to osteotomes, to rasps, with the application of each instrument becoming successively more conservative. In addition, the transition from en bloc excision to sequential excision has deterred overresection. However, questions remain regarding the most appropriate surgical sequence (ie, addressing cartilage before bone or the reverse) and instrumentation.

On the basis of our anatomic findings, we suggest the following technique for hump reduction: (1) exposure through a continuous subperichondrial/subperiosteal plane, (2) reduction of the bony cap with manual and/or powered rasps, (3) splitting the ULCs to allow for spreader flaps or grafts, and (4) reduction of the dorsal midline septum to achieve the desired profile line. Our results suggest that the bony cap can easily be removed with a rasp to reveal the cartilaginous hump below. Reduction of the bony cap followed by reduction of the cartilaginous hump is our preferred method and the most appropriate approach anatomically. Nevertheless, surgeons should perform the hump reduction technique with which they are most comfortable. Understanding the relationship between the prereduction osseocartilaginous vault and the postreduction vault is more important than the method of reduction.

**Recommendations Based on Results of Clinical Study**

**Bony Cap**

Most dorsal humps are composed of a variable ratio of bone to cartilage. The bony portion of the dorsal hump is most easily and atraumatically treated with a rasp, prior to lowering the cartilaginous hump. This recommendation is in marked contrast to many current and traditional techniques. Some surgeons prefer a 2-step modification of the cartilaginous dorsum that involves lowering the cartilaginous hump before reducing the bony hump by rasping. Considering that the cartilaginous hump is covered with only a thin bony cap, we regard removal of the bone before the cartilage as the more practical method. We suggest the aphorism, “There is no bony hump, just a bony cap.” Removal of the bony cap reveals the cartilaginous hump, which is the only hump. A limitation of our study is that the 9 clinical cases represented only a small subset of rhinoplasty patients. Although no patients have presented to our practice with a thick bony cap, we cannot rule out that this variation exists.

**Exposure of the DKA**

Traditional maneuvers for en bloc removal of a bony hump produced an open roof deformity. In contrast, rasping of the bony cap reveals an intact cartilaginous vault. Some surgeons prefer to remove the bony cap with a 4- to 6-mm-wide osteotome or saw. We suggest that an osteotome removes more bone than necessary and may result in the patient requiring crushed cartilage grafts, particularly when this instrument is coupled with poor surgical technique. We recommend that less-experienced rhinoplasty surgeons consider a rasp because it is less likely to result in irregularities and overresection.

In all 9 rhinoplasty patients, rasping of the bony cap down to the desired profile line revealed an intact cartilaginous vault in the midline and laterally and obviated dorsal grafts. There are 2 likely situations in which an intact cartilage vault would not be exposed, resulting in exposure of the underlying mucosa: (1) a patient may have a congenital variation that causes the DKA to be very short and the LKA to be very narrow; or (2) a patient may present with a hump with significant cephalic extension, leading to exposure of the mucosa above an otherwise normal DKA.
Dorsal Profile Reduction
For decades, surgeons performing rhinoplasties have removed the cartilaginous vault as a single unit, including the septum and the ULCs. Excision of equal amounts of these components is likely to cause midvault collapse, especially in patients with short nasal bones who are predisposed to concerns of the midvault. The recently developed split hump technique involves detaching the ULCs from the septum before lowering the dorsal septum to the desired profile line. Our clinical observations indicate that it is possible to address the cartilaginous vault within the bony vault after removal of the bony cap (ie, 4-10 mm above K). Thus, excision of the dorsal septum can extend more cephalically and can include the portion of the dorsal prominence previously attributed to the bony hump. Also, the ULCs can be preserved above K and can be sutured within the confines of the bony vault to close the open roof.

Prereduction Dorsal Lines
The dorsum can be divided into a bony upper third, a cartilaginous middle third, and a lobular lower third. The dorsal lines span the dorsum and create pleasing aesthetic highlights. Our clinical observations indicated that dorsal lines from the radix to the alar cartilages in the nonoperated, atraumatic nose were predominantly determined by the cartilaginous vault; that is, the bony vault did not contribute substantially to the dorsal lines preoperatively. The nasal bones are a representation of the cartilaginous vault below the thin bony cap. In patients with asymmetric dorsal lines, removal of the bony cap revealed an asymmetric cartilage vault that matched the clinical deformity (Figure 4). Similar results were observed in patients with a narrow or wide nose.

Postreduction Dorsal Lines
Whereas prereduction dorsal lines were primarily determined by the cartilage vault, postreduction dorsal lines were determined by their relationship with the bony vault. When dorsal reduction exceeded 4 mm, K was displaced cephalically by 4 to 12 mm to K'. In addition, the caudal edges of the reduced nasal bones often became repositioned laterally and caudally (Figure 9). Because the dorsal septum was reduced and the ULCs were reduced or utilized as spreader flaps, the medial and caudal borders of the nasal bones became the primary determinant of the dorsal lines. This basis of postreduction dorsal lines explains the preponderance of medial and intermediate osteotomies to control the width of the dorsal lines, independent of the need for lateral osteotomies. Subsequent placement of spreader flaps or grafts would ensure integration of the 2 vaults and avoid an inverted V deformity.

CONCLUSIONS
The DKA is defined as the midline of the bony-cartilaginous overlap. The average length of the DKA measured along the dorsal septum was 8.9 mm (range, 4-14 mm) and the average width was 4.9 mm (range, 3-9 mm), as determined by cadaver dissections. There was no significant difference in DKA length between noses with a straight profile and those with a humped profile. For all 9 rhinoplasty patients, the first step in dorsal reduction was removal of the bony cap with a rasp. This revealed an intact cartilaginous vault in both the DKA and the LKA. The average length of the DKA (ie, the exposed cartilage vault) was 7.6 mm (range, 4-10 mm). Preoperatively, the dorsal aesthetic lines and profile are dictated by the cartilaginous vault. After dorsal reduction, the dorsal lines are determined by the edges of the bony vault. For a routine rhinoplasty, reduction in dorsal height primarily reflects removal of the dorsal cartilaginous septum.
Supplementary Material

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REFERENCES