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Dorsal Hump Reduction Based on the New Ethmoidal Point Classification: A Clinical and Radiological Study of the Keystone Area in 138 Patients

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Abstract

Background: Hump resection often requires reorganization of the keystone area.

Objectives: The authors sought to describe the importance of the point where the perpendicular plate of ethmoid joins the septal cartilage (SC) and the nasal bones (NB) (Ethmoidal point [E-point]) for hump resection surgical planning.

Methods: Measurements from mid-sagittal slices in nasal computed tomography scans taken in adult Caucasian patients between January 2015 and December 2018 were compared between patients seeking primary rhinoplasty due to a nasal hump and patients not seeking rhinoplasty (control group). Patients with previous nasal surgery or trauma, genetic or congenital facial disorders, and high septal deviation were excluded. The length of overlap between NB and SC was compared between the 2 groups. The location of the E-point in relation to the beginning of the nasal hump in the cephalocaudal direction was documented in the patients seeking rhinoplasty.

Results: The study population included 138 patients, 69 seeking and 69 not seeking rhinoplasty (96 females). The mean age was 32.9 years (range, 18-55 years). The length of overlap between NB and SC was similar between both groups (11.7 ± 3.3 vs 10.8 ± 3.3; $P = 0.235$). The E-point was located before the beginning of the nasal hump in 97% (67/69) of nasal hump patients, and it could be found a mean distance of 2.3 (±2.3) mm cephalic to the latter.

Conclusions: As a rule, the perpendicular plate of the ethmoid does not contribute to the nasal hump; therefore, only in exceptional cases should this be addressed while performing dorsal reduction.

Level of Evidence: 3

3
Therapeutic

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Among Caucasians, most aesthetic rhinoplasty patients require dorsal hump reduction and as such a variable degree of the reorganization of the middle third.[1,2] To achieve success in these patients, a thorough knowledge of the relation between the nasal structures in the keystone area is crucial. Failing to do so will lead to dorsal irregularities, inverted-V deformities, or excessive narrowing of the middle vault, requiring revision surgery due to aesthetic and/or functional complaints.[3]

The keystone region results from the fused paired nasal bones (NB) cephalically, paired upper lateral cartilages (ULCs) caudally, septal cartilage (SC) anterior-inferiorly, and perpendicular plate of the ethmoid bone (PPE) postero-inferiorly.[4] Despite being described as separate structures, the SC and ULCs form a single cartilaginous unit (henceforth designated by ULC-SC-U) with an M-shaped contour and only separate inferiorly at a level just above the anterior septal angle.[3,5] In fact, SC and ULCs share the same embryological origin.[6] Another common misconception is that the ULCs have some sort of lateral skeletal support. Its lateral support comes only from its attachment to the NB (pyriform aperture ligament—lateral and dorsal), its fusion to the SC, and their common perichondrial and periosteal linings.[5]

Therefore, the relation between the paired NB and the ULCs is crucial for the stability of the osteocartilaginous vault. Inferiorly, the paired NB present an inward curved bony spine that overlaps the ULC-SC-U, which in turn articulates the PPE.[5] The bony dorsum is, therefore, a cap over the cartilaginous dorsum.[3] The amount of NB overlapped with the ULCs and SC will set the point where the PPE joins the SC in the dorsal keystone area.[5] Because it is an important landmark in modern rhinoplasty techniques, this point will henceforth be designated as E-point (Ethmoidal point). To our knowledge, the amount of overlap between ULCs and paired NB and its importance has not been thoroughly evaluated in large studies.

Moreover, the contribution of the ULC-SC-U for the development and structure of the nasal hump, as opposed to a majorly bony contribution, has not been fully appreciated. The purpose of this study is to identify and evaluate the relation between the ULC-SC-U and the bony components of the keystone area in scanned patients seeking and not seeking rhinoplasty. The authors also discuss some clinical implications for different surgical approaches to the bony-cartilaginous dorsum and highlight this new landmark in the anatomy of the nasal dorsum, the E-point.

METHODS

Study Patients

A total of 138 patients who underwent nasal computed tomography (CT) at our medical institution between January 2015 and December 2018 were included in the study. There were 69 patients seeking primary rhinoplasty due to a nasal hump, and another group of 69 matched patients who did not seek rhinoplasty (control group) were selected. Only adult Caucasian patients without previous nasal surgery or trauma were included. Patients with genetic or congenital facial disorders were excluded. Patients with a high septal deviation were also excluded from this study because in such patients the relation between the PPE and the different contributors to the keystone area cannot be appreciated on a midsagittal CT scan.

This study was approved by the local ethical committee of Hospital da Luz Arrábida, V. N. Gaia Portugal (President Dr. Palhares Delgado) and was carried out in accordance with the guidelines of the Declaration of Helsinki on human studies. Informed consent was obtained from all the participants.

Measurements

CT images were acquired with a Siemens Somatom Perspective 128-slice (Siemens AG, Forchheim, Germany). The images were obtained from a helical acquisition in the axial plane, with reconstructions in sagittal and coronal planes (0.75-mm slices). With the help of an otolaryngologist, the same radiologist took measurements in all patients. On mid-sagittal CT scans, we defined the landmarks employed in the analysis, detailed in Figure 1 and Table 1.

Then we measured the following linear distances: nose length (A-B); length of external nose under which NB can be found (A'-F); length of overlap between NB and ULCs, that is, the distance between the E-point and the NB tip (E-F); length of superficial nasal hump (D-C); and length of NB directly under the superficial nasal hump (D'-F). We also measured the angle defined by the NB and the PPE (G-E-H). Further, we calculated the proportion of external nose under which NB can be found (A'-F/A-B), the proportion of NB located under the external nose under which there is overlap with the ULCs (E-F/A'-F), and the proportion of superficial nasal hump under which there is NB (D'-F/D-C). Also, we calculated the difference between the length of overlap between NB and ULCs and the length of NB directly under the superficial nasal hump (E-F minus D'-F), that is, the distance between the E-point and the beginning of the nasal hump.

Data regarding gender, age, and ethnicity were collected as well.

Statistical Analysis

All statistical analysis was performed in the software SPSS version 24 (IBM Corp., Armonk, NY). Categorical variables are presented as frequencies and percentages, and continuous variables as means and standard deviations or as

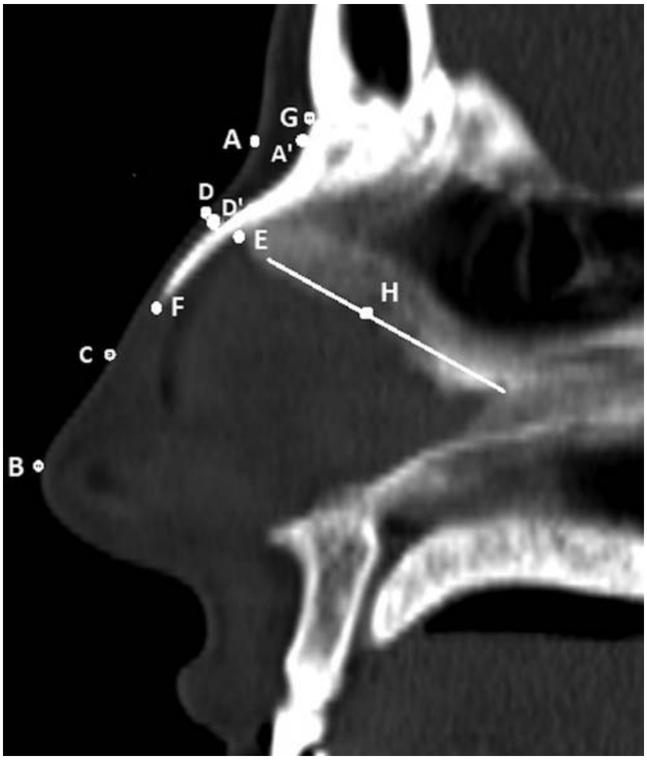

Figure 1. Landmarks employed for measurements on a nasal computed tomography scan of this 32-year-old male patient with a noticeable nasal hump. A, selion; B, pronasale; C, beginning of superficial nasal hump; D, ending of superficial nasal hump; C', beginning of nasal hump on bone; E, Ethmoidal point; F, Rhinion; G, nasion; H, Ethmoidal axis point.

medians and interquartile ranges for variables with a skewed distribution. Normal distribution was verified using Shapiro-Wilk test or using skewness and kurtosis values. Differences among paired groups were evaluated using paired Student's *t* test for normally distributed data and Wilcoxon test if the normal distribution was not present. Statistical significance was defined as $P < 0.05$. Pearson's correlation coefficient was utilized to access the correlation between the different variables. We employed multiple linear regression to identify the variables that strongly contributed to the distance between the E-point and the beginning of the nasal hump.

RESULTS

Study Population

The study population included 138 Caucasian patients (42 males, 96 females). The mean age at nasal CT was 32.9 years (range, 18-55 years). The 2 groups of the study had a similar mean age (33.1 ± 9.42 years in the control group vs 32.6 ± 9.07 years in the nasal hump group; $P = 0.757$) and sex distribution (31.9% males in the control group vs 30.4% males in the nasal hump group).

Measurements in Patients Seeking and Not Seeking Rhinoplasty

Statistical analysis showed a considerable difference between groups (Table 2). The patients seeking rhinoplasty presented a longer nose ($P < 0.001$), a larger proportion of the external nose had NB underneath ($P < 0.001$), and a larger proportion of the NB under the external nose had the ULC-SC-underneath. Also, the nasal hump group presented a smaller angle between NB and PPE ($P < 0.001$). This difference remained statistically significant when comparing the measurements in the different gender and age groups.

Measurements by Gender and Age

Females presented a statistically smaller nose (45.2 ± 1.2 mm vs 49 ± 3.9 mm, $P < 0.001$) and a larger proportion of bone under the nasal hump (36.7 ± 6.7% vs 34 ± 3.9%, $P = 0.001$). This difference remained statistically significant when making the same comparisons in the control and nasal hump patient groups. Although not reaching statistical significance, the distance between the E-point and the beginning of the nasal hump was larger in female patients (2.3 ± 3.4 mm vs 1.8 ± 2.4 mm, $P = 0.063$).

Age showed a statistically significant negative correlation with the distance between the E-point and the beginning of the nasal hump ($r = −0.271$, $P = 0.02$). The remaining measurements did not correlate with age.

Measurements in Patients Seeking Rhinoplasty (Nasal Hump Group)

Regarding nasal hump patients, a mean 50.7% of the length of the superficial nasal hump had underlying NB beneath it. In the cephalocaudal direction, the nasal hump started a median distance of 2.3 mm after the E-point. As can be seen in Figure 2, in most patients (67/69, 97%) this value was null or positive (ie, the superficial nasal hump started after the E-point) and only in 2 (3%) exceptional cases was negative (ie, the superficial nasal hump started before the E-point). To evaluate the effect of the different anatomic measurements and age on the distance between the E-point and the beginning of the nasal hump, we performed a multivariate linear regression model. In this model (R square = 0.82, adjusted R square = 0.666), an increase of 1 mm in the length of overlap between NB and the ULCs increased the distance between the E-point and the beginning of the nasal hump by 0.46 mm ($\beta = 0.46$, adjusted $\beta = 0.66$, $P < 0.001$) (Table 3).

Table 1. Landmarks Utilized for Measurements and Their Definitions

Landmarks	Definitions
External nose	
A	Selion: deepest point at intersection between forehead slope and proximal dorsum
B	Pronasale: most protruded point of apex nasi
D	Beginning of superficial nasal hump
C	Ending of superficial nasal hump
NB and septum	
A'	Beginning of nose on bone: point along NB directly beneath sellion (beginning of external nose)
D'	Beginning of nasal hump on bone: point along NB directly beneath beginning of superficial nasal hump
E	E-point: point located under NB where ULCs and SC unit join PPE
F	Rhinion: inferior border of NB, with junction of bony and cartilaginous nasal frameworks[a]
G	Nasion: point at middle of nasofrontal suture line
H	Ehtmoidal axis point: point along anterior border of PPE defining its axis in sagittal plane

[a]Also designated as "keystone point" according to Palhazi nomenclature.[1]

Table 2. Measurements in Patients Seeking and Not Seeking Rhinoplasty

	Total (n = 138)	Control group (n = 69)	Nasal hump group (n = 69)	*P* value
Nose length (A-B), mean (SD), mm	46.4 (4.2)	44.8 (3.3)	48.1 (4.1)	<0.001
NB under nose (A'-F/), mean (SD), mm	16.7 (3.86)	15.27 (3.6)	18.23 (3.6)	<0.001
Proportion of NB under nose to nose length (A'-F/A-B), mean (SD), %	36 (6.9)	33.9 (6.8)	37.9 (6.4)	<0.001
Overlap between NB and ULCs (E-F), mean (SD), mm	10.7 (3.16)	11.7 (3.3)	10.8 (3.3)	0.235
Proportion of overlap between NB and ULC-SC-U to NB under nose length (E-F/A'-F), mean (SD), %	66.5 (20)	73.4 (2)	59.4 (18.5)	<0.001
Angle between NB and PPE (G-E-H), mean (SD), °	110 (15)	115.4 (13.5)	105.3 (14.8)	<0.001
NB under nasal hump (D'-F), mean (SD), mm	—	—	8.4 (2.4)	—
Superficial hump length (D-C), mean (SD), mm	—	—	16.7 (2.71)	—
Proportion of overlap between superficial nasal hump and NB (D'-F/D-C), mean (SD), %	—	—	50.7 (15.8)	—
Distance between E-point and beginning of nasal hump, mean (SD), mm	—	—	2.3 (2.3)	—

DISCUSSION

In the era of increasing old/new concepts of preservation rhinoplasty and nose anatomy, the importance of keystone anatomy preservation during surgical interventions dorsum is still the cornerstone. This is true for aesthetic reasons because it acts as a diverging point in the dorsal aesthetic lines and for functional reasons, because the ULCs play the main role in the dynamics of the internal nasal valve.[4] A critical analysis of the anatomy and embryology of the keystone area is presented.

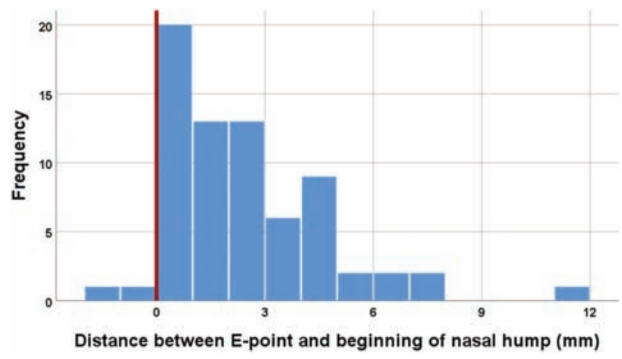

Figure 2. Distribution of patients seeking rhinoplasty according to the distance the between Ethmoidal point (E-point) and the beginning of nasal hump (by absolute frequency). The red line separates patients wherein this value was negative (E2 group) from patients where this value was null or positive (E1 group).

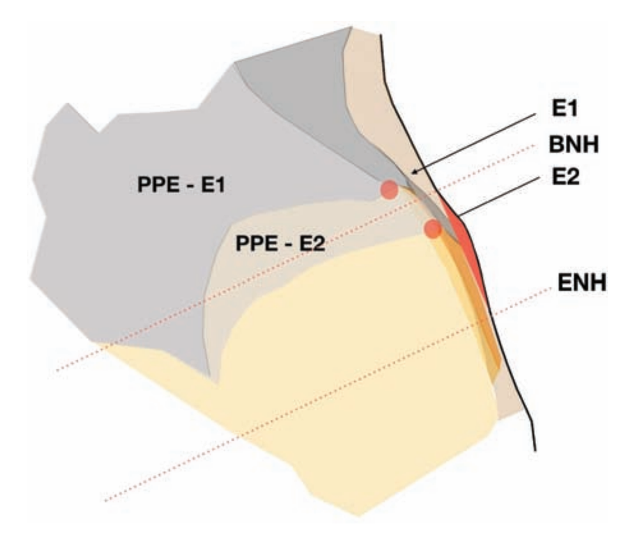

Figure 3. Classification of the Ethmoidal point position in the cephalocaudal direction. BNH, beginning of nasal hump; E1, Ethmoidal point before the beginning of nasal hump; E2, Ethmoidal point after the beginning of the nasal hump; ENH, end of nasal hump; PPE, perpendicular plate of ethmoid.

Table 3. Multivariate Linear Regression Models for Distance Between the E-Point and the Beginning of the Nasal Hump

	Distance between E-point and beginning of nasal hump	
Independent variables	B (adjusted β)	*P* value
Age (y)	−0.03 (−0.129)	0.164
Gender	0.01 (−0.03)	0.99
Nose length (A-B) (mm)	−0.02 (−0.03)	0.76
NB under nose (A'-F/) (mm)	−0.16 (−0.23)	0.03
Overlap between NB and SC and ULCs (E-F) (mm)	0.46 (0.6)	<0.001
Angle between NB and PPE (G-E-H) (°)	0.04 (0.28)	0.003

Only nasal hump patient group, n = 69.

Embryological Basis of the Keystone Area: A Critical Analysis

At birth, the septum is entirely cartilaginous and extends from the sphenoid bone to the columella. Endochondral ossification of the SC begins after 6 months of life near the anterior skull base.[7] Similarly, the ULCs, which at birth extend under the full length of the NB to merge with the cartilaginous anlage of the anterior cranial base, will regress and be replaced by ossification of the ethmoid bone.[8] Apparently, this ossification is balanced by new formation of cartilage, and in fact there is a rapid increase in the cartilaginous nasal septum/total nasal septum proportion during the adolescence growth spurt.[7,9] Most studies agree that high levels of cellular and matrix growth occur at the free end of the nasal septum until early adulthood.[10]

After adolescence, cartilage is gradually replaced by ossification along the junction between SC and perpendicular plate, and thus the area of SC decreases in relation to the total nasal septum.[6,7,11] In our study, age had a negative correlation with the distance between the E-point and the beginning of the nasal hump, which may be explained by ossification of the SC. Similarly, Kim et al found a positive correlation between the area of nasal SC and length of overlap between NB and SC.[12] The importance of postnatal growth of the nasal SC to the development of the midface is still a matter of discussion.[8,13] However, Al Dayeh et al suggested that growth along the nasofrontal suture occurs in response to the anteroposterior growth of nasal SC because the separation of bony elements in the nasofrontal suture occurs after anteroposterior growth of the SC and not the other way around.[14]

Growth of these structures occurs especially during the adolescent growth spurt.[8] Growth of the external nose occurs in all 3 planes (vertical, anteroposterior, and transverse). It is of general consensus and the author's clinical experience that a nasal hump (without a nasal trauma history) typically appears during adolescence. Subtelny et al suggested that elevation of the dorsum is due to the NB deviating from its downward and forward path of growth and projecting or becoming inclined in a more forward direction.[15] On the other hand, Akgüner et al and Buschang et al specifically showed that the final shape of the nasal dorsum at the end of adolescence seems to be a

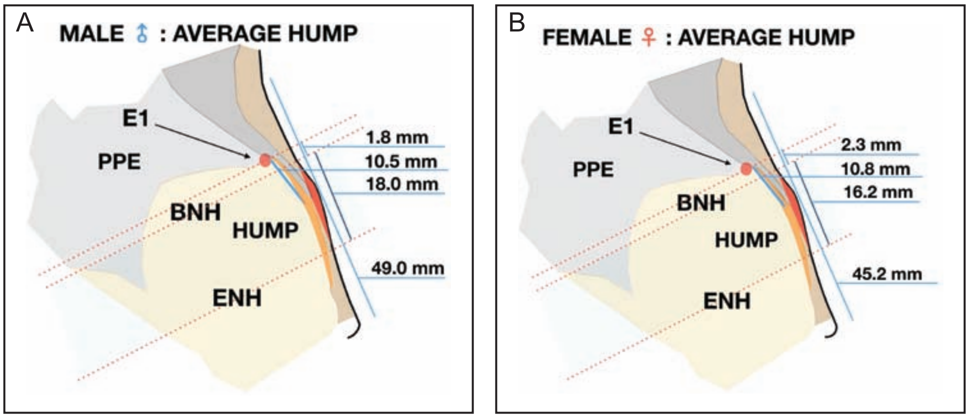

Figure 4. Average nasal hump by gender (n = 69), presenting the most relevant measurements according to gender. (A) Male and (B) female in patients with a nasal hump (E1 group). BNH, beginning of nasal hump; E1, Ethmoidal point; ENH, end of nasal hump (both in cephalocaudal direction); PPE, perpendicular plate of ethmoid.

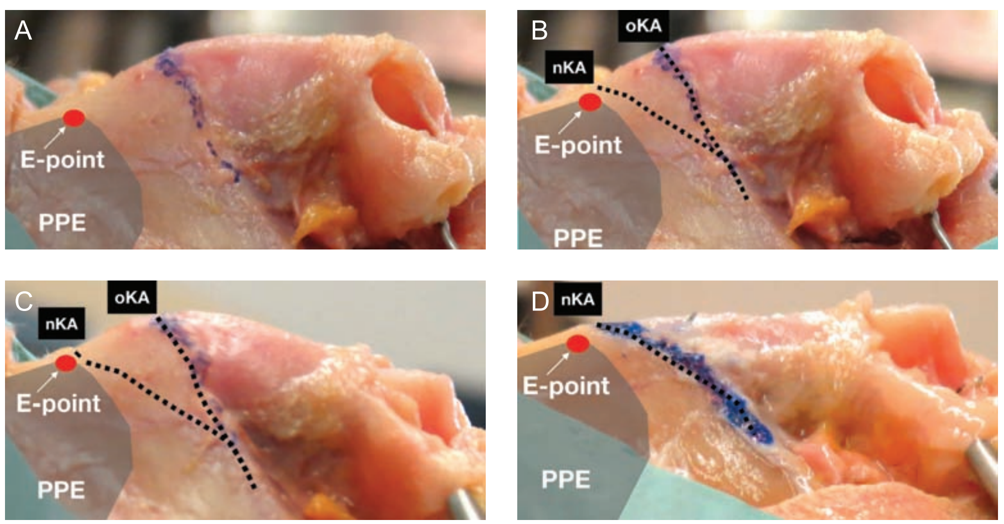

Figure 5. The Ethmoidal point and the Spare Roof Technique on this frozen 72-year-old male cadaver. (A) Relative position of the perpendicular plate of ethmoid (PPE), Ethmoidal point, and hump, (B) old K-area (oKA) and projection new K-area (nKA) in relation with Ethmoidal point, (C) anatomy after taking the strip of cartilaginous dorsal septum, and (D) after performing ostectomy of the caudal NB, relation of the Ethmoidal point with the new K-area. PPE, perpendicular plate of ethmoid.

consequence of forward rotation of the lower dorsum.[16,17] As such, nasal hump might be explained by increased vertical growth (compared with anteroposterior growth) resulting in downwards and backward rotation of the lower dorsum and increased convexity of the nasal dorsum.[16] We posit that nasal hump patients have an abnormally increased cartilage growth along the posterior border of the SC leading to an abnormally increased vertical growth, as opposed to patients without a nasal hump whose posterior metabolic and cellular proliferation rates become low in early childhood.[13] An increased cartilage expansion in this region during postnatal nose development could explain why these patients, in our study, presented with a significantly smaller angle between NB and PPE, because the posterior cartilage expansion would push the posterior edge of the SC posteriorly and as such the PPE would form an acuter angle with the NBs. Additionally, this explains why in the vast majority of patients the superficial nasal hump starts in front of the E-point and therefore has no PPE underneath it.

Several autopsy cases have studied and taken measurements at the dorsal (or midline) keystone area. Simon et al reported the midline overlap between the NB and ULCs to be a mean 10.7 mm (range, 3.6-20.3 mm) in Caucasian patients during dissection of cadaveric heads.[4] Another cadaveric dissection study (also in Caucasian patients), by

Palhazi et al, showed this overlap to be a mean of 8.9 mm (range, 4-14 mm), and it did not differ significantly between subgroups with and without a nasal hump.[1] Kim et al reported slightly smaller values in Asian patients (mean, 7 mm; range, 4-10 mm).[12] Our study confirms previous reports (mean value of 10.7 mm; range, 3.6-20.3 mm) of no significant difference between groups. Additionally, we established age and sex did not significantly influence this overlap, and it corresponds to a mean 40.7% (±12.5%) of the length of the NB under the external nose.

In this study we have chosen a CT nasal scan because it is widely available, allows good visualization of facial bones anatomy, and SC can be well discriminated from surrounding soft tissues in most clinical CT protocols.[18] When compared with Cone-beam imaging, CT provides a wider density scale, allowing better discrimination of soft tissue boundaries, a key feature of this work, as well as a higher signal-to-noise ratio. The main drawbacks of conventional CT are the higher radiation dose and lower resolution for bone structure.

Most measurements were similar in patients seeking and those not seeking rhinoplasty. The results show that patients seeking rhinoplasty due to nasal hump had a statistically significantly smaller angle between NB and PPE ($105.3 \pm 14.8°$ vs $115.4 \pm 14.8°$, $P < 0.001$). Patients seeking rhinoplasty also had longer nose length and longer NB length. However, these measurements did not correlate with the angle between NB and PPE, and, as such, that considerable difference should be considered separately.

E-Point Classification: Surgical Implications

Hump resection techniques should be selected according to their capacity to address both the aesthetic and functional needs of the patient. Failing to do so will often result in open roof deformities and lack of bridging tissue between the septum and the NB, which will require additional interventions and also risk postoperative mid vault collapse and contour deficiencies. Our results emphasize the importance of detaching the ULCs from the overlying NB and address the cartilaginous vault within the bony vault.

In this study, we concluded that the nasal hump is a result of SC growth and that the NB form a thin contour over this cartilaginous nasal hump. The caudal portion of the NBs overlying the ULCs is the only bony structure in a nasal hump, and the PPE does not contribute in any way to support the superficial nasal hump. As such, only the ULC-SC-U and overlying NB should need resection. This is in agreement with previous studies, namely by Sadick et al, in which dorsal lines were predominantly determined by the cartilaginous vault (and not the bony vault).[3]

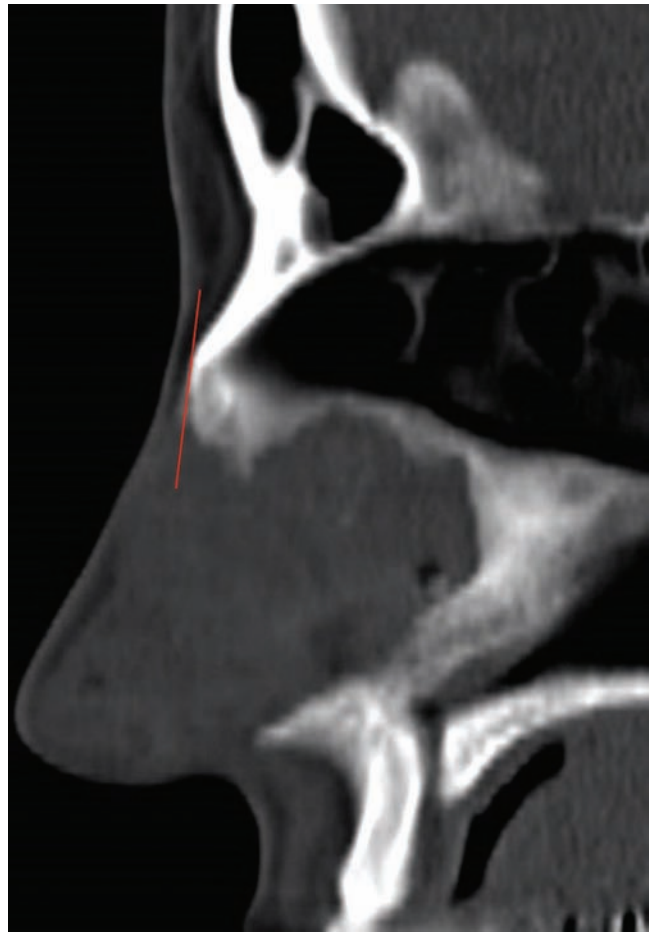

Figure 6. A rare case of E2 classification in which a beveled ostectomy was done (red line). Shown here is the 18-month postoperative computed tomography scan of this 48-year-old male patient.

To the best of our knowledge, we are describing for the first time a new correlation between this landmark in the keystone region anatomy—the E-point—and surgical strategies to dehump. The E-point is the point where the PPE joins the undersurface of the NBs and in front of which the overlap between NB and ULCs begins. Most importantly, as opposed to previous studies, we are describing the relation between anatomical structures and the overlying nasal hump. Our results show that in most patients (with the exception of 2), the E-point will be located before the beginning of the nasal hump (in cephalocaudal direction).

The distance between the E-point and the beginning of the nasal hump was greater in female patients and it decreased with advancing age, probably due to the ossification process of the SC. This value was null or positive (hence the E-point started below or before the beginning of the nasal hump) in the vast majority of the patients, other than for 2 exceptional cases.

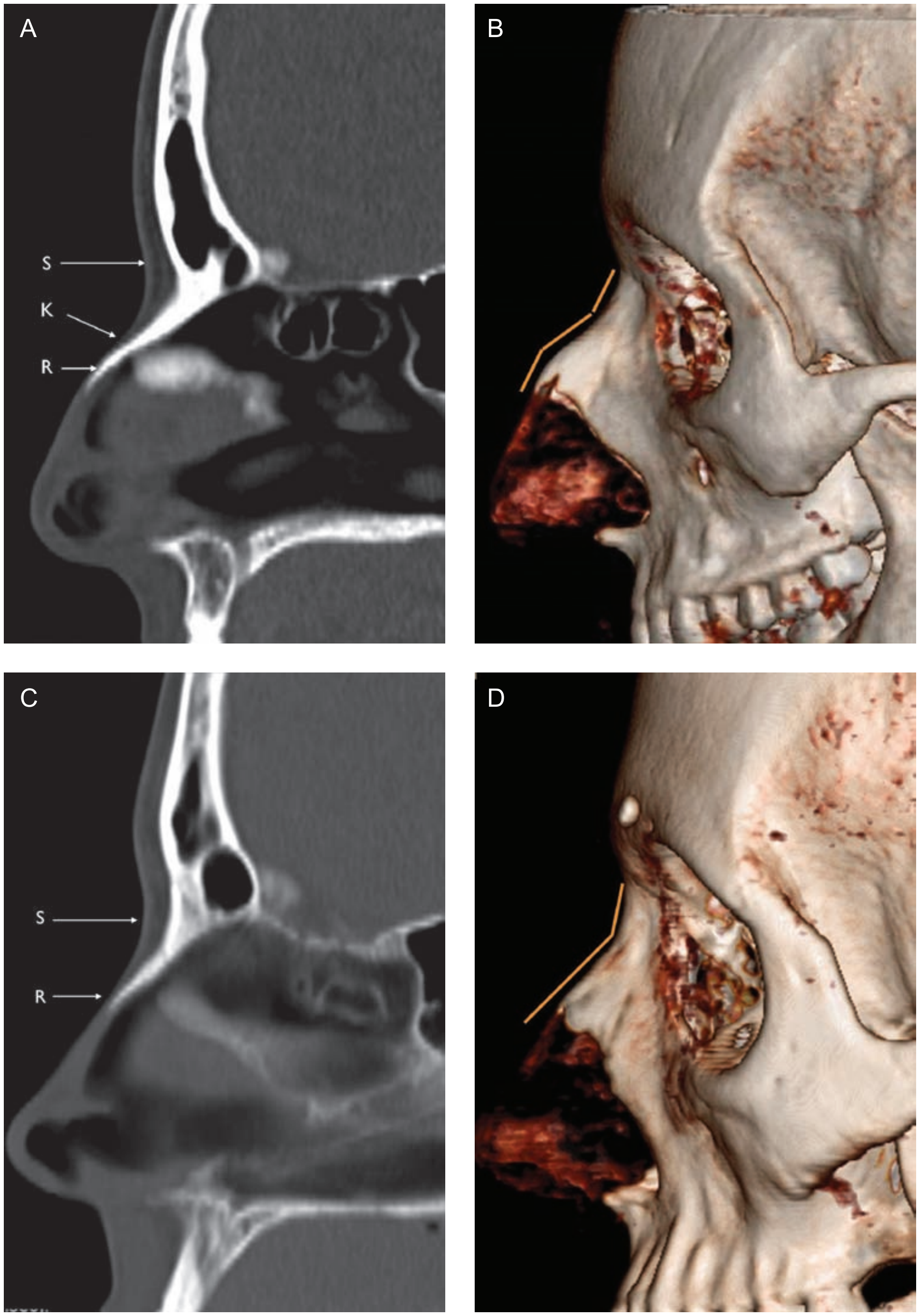

Figure 7. (A) A computed tomography scan of the S-shaped NB of this 42-year-old female patient. (B) A computed tomography scan of a bone reconstruction for the same patient. (C) A computed tomography scan of the V-shaped NB of this 35-year-old male patient. (D) A computed tomography scan of the bone reconstruction for the same patient. S, sellion; K, Khyphion; R, Rhinion.

Based on our findings, we propose a new anatomoclinical classification for the position (in the cephalocaudal direction) of the E-point concerning the position of the nasal hump (Figure 3): E1, when the E-point is situated before the beginning of nasal hump; and E2, when the E-point is situated after the beginning of the nasal hump.

Applying this classification to our data, we found 97% (67/69) in the E1 group and 3% (2/69) in the E2 group. In

Figure 4, we present the "average nasal hump" in both male and female patients to exemplify these measurements and relations. We believe this has surgical implications and contributes to our knowledge of the development of nontraumatic nasal hump. Based on these findings, we suggest that if the patient was already scanned because of sinusitis suspicion, special attention should be focused on the mid-sagittal cut to define the E-point. At this stage, the surgeon should consider different strategies to dehump: E1 patients: the hump is not associated with the PPE; therefore, the optimal strategy for these patients should stop before the E-point (caudocephalic direction). The authors suggest the Spare Roof Technique (SRT) or the Modified Component Dorsal Reduction (MCDR).[19-21] For E2 patients, the hump is above the PPE; therefore after checking the in vivo E-point position, the surgeon should decide if a Modified Push-Down or Let-Down approach should be performed or the SRT/MCDR in a beveled fashion is enough to avoid damaging the PPE.

In fact, even in the 2 patients whose nasal hump started before the E-point, an adequate dorsal line could be achieved with a 0.5-mm tangential (beveled) cut of the inferior portion of the NBs—without intervention in the PPE—as can be seen in Figure 5. Therefore, the authors do not recommend CT scan to be performed in all patients undergoing rhinoplasty. However, if there are other concomitant conditions under investigation that will need a CT scan (sinusitis and others), this tool should be studied to evaluate the E-point.

Lazovic et al described a very useful classification of "V" and "S" shaped NB based on the Khyphion and Rhinion points.[22] The Khyphion only exists in S-shaped NB and is the breakpoint of the bony nasal hump, probably the exact surface equivalent of the E-point. In Figure 6 the difference between the S-shaped and V-shaped NB is clear. When already available, the sagittal CT scan is an interesting tool to determine exactly the relation between the Khyphion, E-point, and beginning of nasal hump[22] (Figure 7).

The limitations of this study are the size of the sample, the noncorrelation between the collected data and the patient reported outcomes measurements in the group seeking rhinoplasty, and the lack of study of child and adolescent CT scans to better understand the development of the E-point. Further studies with larger samples should be conducted.

CONCLUSIONS

Our results suggest that nasal hump is the result of SC growth, probably during the adolescence growth spurt. As such, any bony contribution to it should be considered as a cap over the underlying cartilaginous structures (SC and ULCs). Plus, the PPE does not seem to contribute to the nasal hump. Thus, in the vast majority of patients, there is no need to address the PPE and, most importantly, the ULC-SC-U should be carefully detached from the overlying NB to resect only the elements that contribute to the nasal hump to the extent required. Detailed and correct knowledge of the keystone area is crucial for good postoperative outcomes, and therefore hump resection techniques should be performed according to this knowledge.

These findings are particularly crucial in this new era of preservation rhinoplasty and should be considered when a surgeon is planning a strategy to dehump a specific nose. The first author proposes techniques less aggressive to the structural support of the nasal pyramid such as the SRT and MCDR.[19-21]

Disclosures

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