Anatomy of the nasal latero-lateral cartilage articulation: a micro-MRI study in human specimens

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Abstract

Purpose To study the anatomy of the latero-lateral joint (LLJ) between the upper lateral (ULC) and lower lateral (LLC) crus of the nasal cartilages, usually described as a scroll articulation.

Methodology Six nasal pyramids were taken in monobloc from fresh cadavers and imaged on micro-MRI with 0.4 mm slice thickness. Images were jointly interpreted by two head and neck radiologists and one surgeon. The junction between the ULC and LLC, the presence of ligaments and of sesamoid or accessory cartilages were assessed.

Results Eight LLJs could be analyzed, with four types of junctions: hook-shaped cephalic border of the LLC turned towards the nasal fossa and linear caudal border of the ULC (n = 3), hook-shaped caudal border of the ULC and linear cephalic border of the LLC lateral crus (n = 1), hook-shaped border of both cartilaginous edges with clinging (n = 1) (scroll articulation) or without clinging (n = 3). No ligament or sesamoid cartilage was found, but posterior accessory cartilages were seen in 75% of the cases.

Conclusion The classical scroll articulation of the LLJ has been observed in only 1/8 cases on micro-MRI images. The anatomy of the LLJ could explain the surgical difficulty in raising the tip of the nose in some patients and not in others.

Keywords Nose deformities · Nasal cartilages · MRI · Nasal septum · Lateral crus · Rhinoplasty

Introduction

The nasal pyramid skeleton is made of bones and cartilages, all potentially exposed to a wide range of deformations following malformations, trauma, growth problems, etc. [11]. The cartilaginous nose corresponds to the nasal septum (quadrangular cartilage (QC)), and classically the symmetric triangular or upper (ULCs) and alar or lower lateral cartilages (LLCs) [2]. ULCs frame the lateral sides of the mid-third of the nasal pyramid and LLCs, in conjunction with sesamoid or accessory cartilages, encircle the nostrils more or less completely [20] (Fig. 1).

Surgical procedures are intended to restore the anatomical and physiological structures of the nose, and therefore, require advanced knowledge of their anatomy [9, 21]. These cartilages are classically thought to be derived from a single cartilaginous framework [7], but there is scarce information on their connections or articulations [17, 20]. Classical surgical anatomy describes these structures as 5 single entities (i.e., two ULCs, two LLCs and 1 QC), connected by ligaments [5]. LLCs are described composed of a medial and lateral crura, joined in a dome, also called middle crus [5].
ULCs have been thought to be continuous with the septal cartilage in their cranial part, and separated from it in their caudal part [19]. Even though issues of incorrect terminology in nasal anatomy and surgery have been described in 2003 by Huizing [12], it has recently been advocated, using micro-MRI, that the upper lateral cartilages were not two distinct anatomic structures linked to the quadrangular cartilage but two continuous septolateral cartilages, made of 2 crura, medial (forming the QC) and lateral (forming the ULC), joined in a dome, like the LLCs [20]. In the present manuscript, to simplify terminology, the term ULC will refer to the lateral crura of the septolateral cartilage. Even though the anatomy of the junction between the ULC and LLC (the so-called “scroll area”) is poorly known because of the difficulty of its anatomical dissection, it is usually described as an S-shaped connection [7], but can also vary from appositional, over-riding, and under-riding, with a “longitudinal scroll ligament” [5]. According to anatomic dissections, LLCs’ middle crura or domes are thought to be linked to each other by an interdomal ligament, LLCs’ medial crura by a “footplate sling”, while intercrural ligaments link the cephalic border of the entire alar cartilages including its three crura [5].

Variations in the morphology of the latero-lateral cartilaginous joint (LLJ) have not yet been evaluated using MRI. Moreover, MRI has recently been proposed as a tool for patient-specific silicon alar construct in nasal reconstruction using manual segmentation, but only in one cadaver and one healthy volunteer [21]. Thus, in the present anatomic study, we sought to study using micro-MRI the junction between ULC and LLC, i.e., the LLJ, and also the connection between the ULCs and LLCs, and between both LLCs, especially looking at their joining means and the presence of sesamoid or accessory cartilages.

Materials and methods

Specimens

Six adult nasal pyramids were removed in monobloc from frozen cadavers after 48 h’ thawing. The bony pyramid was released from the face, then the QC was sectioned along the vomer rail including the adjacent perpendicular ethmoidal plate up to the root of the nose. The specimens were placed in a conservation medium of physiological saline solidified by agarose, supplemented with antibiotics. These six nasal pyramids have been studied in micro-MRI. Only four could be included, the other 2 sets of images being of insufficient quality for proper measurements. Hence, the present study was based on a series of 8 LLJs (2 per nose).

Studies on anonymously donated specimens do not require review board approval in our institution.

Imaging technique

Images were acquired on a 3 T MR Scanner (Magnetom Prisma; Siemens Healthcare, Germany) with an 8-channel array coil initially developed for small animals (8 Channel Array Rat, Rapibiomed GmbH) and a 3D turbo-flash sequence with water excitation (repetition time: 30 ms; echo time: 11.6 ms; 8 excitations; GRAPPA acceleration factor: 2; matrix: 512×512; field of view: 54×54 mm²; 6/8 partial Fourier acquisition factor in phase; slice thickness: 0.4 mm; tilt angle: 30°) and a resolution of 0.1×0.1x0.4 mm³ for an acquisition time of 1 h 37 min. The resulting images and relevant anatomy are shown in Fig. 2.
Image analysis

All images were displayed on a dedicated workstation (Vitrea console, Canon Medical Systems, Zoetermeer, Netherlands) and independently read by two head and neck radiologists with 8 (R.G.) and 7 (G.D.) years of experience and one head and neck surgeon (A. H.). A nasal pyramid was not included in case of artifacts or if all cartilages could not be entirely measured and analyzed with confidence.

The axial plane was defined as perpendicular to the dorsum, the frontal and the sagittal plane defined by the latter.

The junction between the ULC and the LLC (defined as the LLJ) was analyzed in the frontal plane and classified as continuous (no gap between the two cartilages on any slice) or discontinuous (presence of a gap between the two cartilages at least on one slice) with measurement of the diastasis between the two cartilages using a digital caliper in millimeters. Its morphology was described as joining, overriding, curling [7] or as an articulation like roman tiles (the so-called “scroll articulation”) [14] (Fig. 3). The axes of the cartilaginous edges were also studied.

The anterior junction between the LLCs was analyzed in all three planes, looking for the presence of an anterior inter-domal ligament, a “footplate sling” joining the medial crura, and intercrural ligaments linking the cephalic border of the three crura.

The volumes and thicknesses of the following structures were measured (respectively by manual contouring and measurement of the thinnest and thickest part of the structure):

- Right and left LLC
- Right and left ULC (their medial limit being defined as the top of the QC)

For the sake of comparison, the volume of the QC was also defined.

Observers were free to navigate in the three planes to look for the presence of sesamoid cartilages (small rounded cartilages, adjacent to the LLJ) or accessory cartilages (linear, posterior to the alar cartilages, part of the alar ring) [6].
Statistical analysis

Qualitative values are expressed with an inter-observer agreement rate. Quantitative values are presented as medians and interquartile ranges. For each imaging measurement, intraclass correlation coefficients (ICC) were calculated to assess interobserver variability [16]. ICC values below 0.5 were considered poor, between 0.5 and 0.75 moderate, between 0.75 and 0.90 good, and above 0.9 excellent.

Results

No continuity was found in any of the joints, nor did we find any ligament or sesamoid cartilages. In contrast, we found accessory posterior cartilages in 75% of the cases, linked to the posterior border of the LLCs, without ligaments (Fig. 4).

Four kinds of LLJs were found and corresponded to mixed patterns of the usually described types of LLJs (Fig. 5):

- Hook-shaped aspect of the cephalic border of the lateral crus of the LLC turned towards the nasal fossa, in front of a linear caudal border of the ULC (n = 3).
- Hook-shaped aspect of the caudal border of the ULC turned towards the nasal fossa, in front of a linear cephalic border of the lateral crus of the LLC (n = 1).
- Hook-shaped aspect of the cephalic border of the lateral crus of the LLC turned towards the nasal fossa, in front of a hook-shaped aspect of the inferior border of the lateral crus of the ULC turned towards the skin, but without clinging, the joint thereby forming an “X” (n = 3).
- Hook-shaped aspect of the cephalic border of the lateral crus of the LLC turned towards the nasal fossa, hook-shaped aspect of the inferior border of the lateral crus of the ULC turned towards the skin, with slinging aspect (n = 1), i.e., the so-called “scroll articulation” (S-shaped).

The inter-observer agreement rate for these findings was 100%.

Cartilaginous thicknesses and volumes are summarized in Table 1.

Discussion

This study is to our knowledge the first one to present the cartilaginous anatomy of the LLJ between the lateral crura of the LLCs and the ULCs using micro-MRI. The medial and lateral crura of the septolateral cartilages were classically considered as two separate cartilaginous structures (respectively ULC and QC) until their continuity was recently demonstrated using micro-MRI [20]. We did not find any continuity between the ULC and the LLC in the present study. Moreover, the morphological aspect of their connection was highly variable, with only 1/8 (12.5%) of the LLJs corresponding to the classical anatomical description of a scroll articulation (inter-connected roman tiles). Finally, we did not individualize any ligament or sesamoid cartilage adjacent to the LLJ, but posterior accessory cartilages in 75% of the cases.

In contrast to classical concepts, the Evo-Devo theory supposes that the embryological intermaxillary process give rise to the septolateral cartilages and the embryological lateral olfactory processes to the lower lateral cartilages [13, 17]. Starting from the beginning, the olfactory placodes that appear by the fifth week on the embryo’s head invaginate to form two olfactory wells, their superficial margins
being then vertically separated into two hemi-circumferences called lateral and median olfactory processes. The two median olfactory processes then fuse on the midline to form the intermaxillary process, which invaginates itself, and by the way attracts the two lateral olfactory processes in front of him, without merging of the latter. The septolateral cartilages then develop themselves from the intermaxillary process, while the LLCs develop from each lateral olfactory process. LLCs and septolateral cartilages stay connected together and to the olfactory mucosa, and suspended to the skull base via a continuous fibrous membrane, the olfactory fascia, which develops from the olfactory pits’ walls and seems to invaginates into the pyriform aperture [15].

Our micro-MRI study did not individualize within the olfactory fascia any “radiological” ligamentous structure, especially between the LLCs themselves and between LLCs and ULCs, unlike Daniel and Palhazi [6]. It is, however, worthy to notice that the term “ligament” refers to “a band or sheet of fibrous tissue connecting two or more bones, cartilages or other structures”, leading to a broad definition [1, 6]. To date, the description of the “cartilaginous nose” was based only on anatomical dissections [5–7, 10, 18, 19], inducing a risk of fragile soft tissue distortion. Moreover, even during anatomical dissections, some tissues are difficult to precisely characterize, and it is therefore unclear if the described inter-domal ligaments truly correspond to ligaments, or fibrous or aponeurotic tissue. The results of our study support the fact that the answer to the aforementioned question is truly moot. In the author’s surgical experience of septo-rhinoplasty by disarticulation [14], the surgical dissection aims to preserve the olfactory fascia continuity and its attachment to the skull base, but do not rely on the hypothetic presence of ligaments.

We could individualize accessory posterior cartilages in 75% of the cases, as described by Daniel and Palhazi [6]. The origin of these accessory cartilages is unsure and
debated [16, 17]. In the evo-devo theory [17], they may represent a fragmented cartilaginous differentiation at the level of continuity between the medial and lateral olfactory processes that will develop into the septolateral and alar cartilages. Their presence supports the olfactory fascia concept [13] saying that the human fibrocartilaginous nose is one continuous structure inserted into the piriform aperture that stays connected to the ethmoidal skull base.

In several surgical procedures, nasal tip rhinoplasty draws on bilateral latero-lateral disarticulation with or without resection of the cephalic border of the lateral crus of the LLC to raise the tip of the nose. The “scroll area” is of capital importance as its reconstruction directly influences surgical outcomes [3]. The presence of a cartilaginous continuity between the lateral crura of the ULCs and LLCs, even partial, could influence the success of this procedure. According to our findings and the Evo-Devo theory, the absence of a cartilaginous continuity might be the rule, but larger confirmatory studies are required. Yoo et al., using anatomic specimens, also found that the most type of LLJ was a discontinuous pattern, whereas the classical scroll type was found in only 20% of the cases. They also found an asymmetric junction in about one-quarter of their cases [22]. Drumheller, in 1973, anatomically described three distinct
variations between the cartilaginous LLJ (i.e., joining, alar over-riding and curling), but our study showed mixed patterns of curling, with different amounts of joining and over-riding. A connection between two hook-shaped cartilages clinging together might result in a higher rigidity and robustness than a simple fibro-cartilaginous continuity. We observed only one specimen with this kind of anatomical configuration in our specimens, but its occurrence in the general population remains unknown. We hypothesize that this kind of LLJ could explain the surgical difficulty in some surgical cases to raise the tip of the nose or an asymmetric raise in some patients (this finding was unilateral in our specimen). MRI imaging of the LLJ before surgery may be studied in the future to evaluate if it could help to plan surgical procedures involving the tip of the nose. Deep learning image reconstruction methods have been introduced with promising results regarding scan acceleration and significant improvement in image quality [4, 8], suggesting that in the near future, micro-MRI might be available in clinical practice. On another aspect, MRI study about the volumetric segmentation of the LLCs seems promising to develop silicone grafts despite, for the moment, technical limitations secondary to nostrils movement during breathing [21].

This study has limitations, especially the small number of specimens evaluated. We could not compare MRI findings directly to anatomic dissections. Concerning quantitative values, ICC were poor for some parameters, especially LLC thickness, but were considered reasonable for other values; however, given the small sample size this must be interpreted cautiously. A biomechanical study would be ideal to investigate the resistance of the different types of connection between those nasal cartilages but seems difficult to envisage. Also, the relation between the type of LLJ and the risk of nasal tip malposition cannot be truly estimated and would need further studies.

In conclusion, our micro-MRI findings suggest that the classical “scroll area” of the nasal latero-lateral cartilages does not seem to be the most frequent type. Other presentations in the LLJ could explain surgical difficulties to raise symmetrically the tip of the nose in some patients, highlighting the potential role of pre-operative MRI of the cartilaginous nose.

### Author contributions
AH: data analysis, data collection, manuscript writing. GD: data analysis, data collection. GH: statistical analysis, technical support, software. MP: technical support, investigation, resources. PT: manuscript writing, project development. CR: conceptualization, technical support, investigation. RJ: project development, manuscript writing and editing. RG: data analysis, data collection, project development, manuscript writing and editing.

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### Availability of data and materials
Not applicable.

| Table 1 Nasal cartilaginous gap, thicknesses, and volumes |
|----------------------------------------------------------|
| **Maximal latero-lateral cartilaginous gap**              |
| Right side (mm)                                          |
| Reader 1 | 0.4 (0.275–0.7) | 0.45 (0.35–0.625) | 0.65 (0.55–0.825) | 0.89 |
| Reader 2 | 0.65 (0.6–0.775) | 0.65 (0.575–0.75) | 0.7 (0.575–0.85) |
| Reader 3 | 0.86 |
| Left side (mm)                                          |
| Minimum thickness right side (mm)                        |
| Reader 1 | 0.45 (0.375–0.525) | 0.4 (0.4–0.4) | 0.3 (0.3–0.35) | 0.3 |
| Reader 2 | 1.15 (1.025–1.225) | 1.2 (1.175–1.275) | 1.5 (1.4–1.7) | 0.03 |
| Reader 3 | 345.98 (303.527–373.312) | 356.905 (310.025–391.177) | 0.85 |
| Maximum thickness left side (mm)                         |
| Reader 1 | 0.5 (0.5–0.5) | 0.35 (0.3–0.425) | 0.4 (0.4–0.4) | 0.22 |
| Reader 2 | 1.05 (0.775–1.325) | 1.35 (1.1–1.5) | 1.7 (1.525–1.725) | 0.47 |
| Reader 3 | 330.02 (264–398.565) | 338.61 (295.412–384.215) | 319.505 (241.65–399.027) | 0.95 |
| Volume right side (mm³)                                  |
| Reader 1 | 862.83 (811.17–917.732) | 933.165 (825.062–1035) | 844.635 (803.677–892.93) | 0.84 |

**ICC** intraclass correlation coefficient
Quantitative values are presented as medians and interquartile ranges

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In conclusion, our micro-MRI findings suggest that the classical “scroll area” of the nasal latero-lateral cartilages does not seem to be the most frequent type. Other presentations in the LLJ could explain surgical difficulties to raise symmetrically the tip of the nose in some patients, highlighting the potential role of pre-operative MRI of the cartilaginous nose.

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### Availability of data and materials
Not applicable.
Declarations

Competing interests  The authors have no competing interests to declare.

Ethical approval  Studies on anonymously donated specimens do not require review board approval in our institution.

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