



Ulnar trochlear notch articular surface has three morphological patterns: a neglected major anatomical feature

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Abstract

Purpose The typical anatomical illustration of the trochlear notch articular surface includes a transverse rough non-articular ridge which separates the olecranon and coronoid part of the joint. This transverse ridge, the “bare area”, is not covered by cartilage and represents the optimal entry point for olecranon osteotomies. Aim of the present study was to encounter the anatomical variations in the morphology of the trochlear notch articular surface.

Methods Two-hundred seventy-three dried ulnae were inspected and a qualitative classification of the variations of the trochlear notch articular surface was done. Correlation to gender and side was examined.

Results Three distinct morphological patterns were observed. Separate olecranon and coronoid facets (Type I) were the most common pattern (165/273, 60.4%). Partial fusion of olecranon and coronoid facets (Type II) was observed in 75 out of 273 bones (27.5%), while a single olecranon and coronoid facet (Type III) was present in 33 out of 273 bones (12.1%). The occurrence of Type II and III was significantly more common in females ($p < 0.001$).

Conclusions The most common morphological pattern of the proximal ulna articular surface was the olecranon and coronoid facets separated by the transverse ridge, which is considered as the typical anatomical pattern. The partial fusion of olecranon and coronoid facets was the second most common pattern (27.5%) and the single olecranon and coronoid facet with no transverse ridge present was the rarest one (12.1%). These variations affect the area covered by cartilage. They are noticeable in an elbow MRI and they may have implications on olecranon osteotomy. Absence of the transverse ridge may confuse the surgeon during elbow arthroscopy.

Keywords Proximal ulna · Sigmoid notch · Bare area · Elbow anatomy · Anatomical variations · Elbow arthroscopy

Introduction

The olecranon and the coronoid processes form the ulnar trochlear notch (incisura trochlearis) which articulates with the trochlea of the humerus. The typical anatomical illustration of the articular surface of the trochlear notch includes a transverse narrow rough non-articular ridge which separates the olecranon and coronoid part of the joint. This transverse ridge is not covered by articular cartilage, and thus it has been described as the “bare area” of the notch [4, 13].

Apart from the typical pattern, where the transverse ridge completely separates the notch, the ridge may half separate the articular surface, either from the ulnar or the radial side, or the articular surface may be single and undivided (Fig. 1). Although these three different variations of the trochlear notch morphology have been described in some old studies from the German literature [5, 6, 12], the classical anatomical and orthopedic textbooks describe solely a completely separated trochlear notch into an olecranon and a coronoid facet [1, 2, 7, 8, 10, 11].

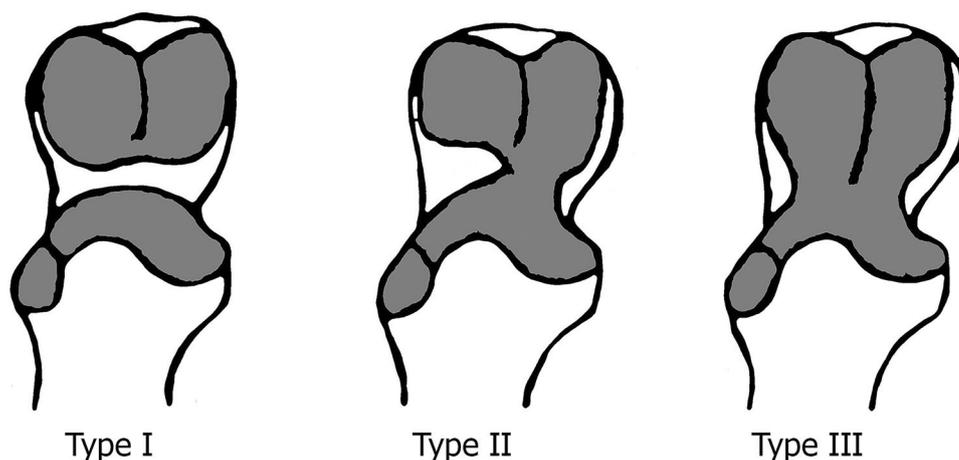
The modern English literature is scarce about the variability of the trochlear notch articular surface morphology with regard to the existence and the extent of the transverse ridge. There are only few old studies on this topic, which include a small sample of bones and did not report the side and gender distribution of these variants [5, 9]. Furthermore, there is no official terminology to describe the transverse

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Fig. 1 The three morphological patterns of ulnar trochlear notch articular surface. Type I: separate olecranon and coronoid facets; Type II: partial fusion of olecranon and coronoid facets; Type III: a single olecranon and coronoid facet



ridge and the three different types of trochlear notch articular surface.

From a clinical point of view, the bare area is an optimal entry point for olecranon osteotomies due to its lack of articular cartilage [1, 7, 13]. However, when there are variations of the articular surface of the ulnar trochlear notch an osteotomy may lead to cartilage damage. Moreover, those variations may have an impact on the prostheses design for elbow arthroplasty, during elbow arthroscopy and also on imaging studies of the elbow joint [4], especially in MRI studies, where the variations are clearly visible [9].

The present study summarizes the non-pathologic anatomic variations of the articular surface of ulnar trochlear including the side and gender distribution.

Materials and methods

This is an anatomic study performed on dried ulnae. Specimens having any evidence of fracture, surgery, postmortem damage, or arthritis were excluded. The sample of the study included 273 unpaired dried ulnae, 138 right and 135 left,

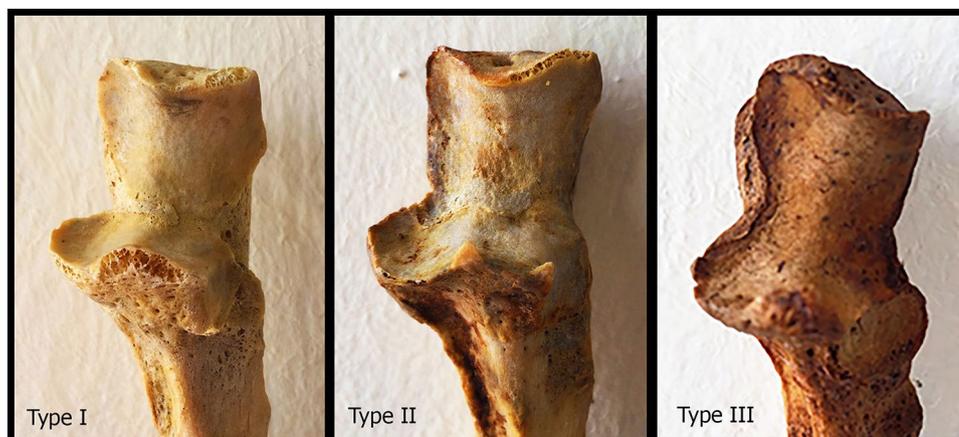
141 female and 132 male. The medical history of the donors was unknown.

Each ulna was inspected visually by the same investigator and the morphological pattern of the trochlear notch articular surface was classified into three types; bones with two completely separated facets (Type I), bones with partially fused articular facets (Type II), and bones with a single facet (absence of the transverse ridge, Type III) (Fig. 2). Pearson's χ^2 was used to test for significant differences between the two genders and the two sides of the body. A p value less than 0.05 was considered statistically significant. All analyses were conducted using SPSS for Windows (SPSS 19.0, IBM Inc, Armonk, NY, USA).

Results

The trochlear notch of 165 ulnae presented separate olecranon and coronoid facets (Type I, 60.4%). Ninety-six of them were male and 69 were female. Eighty-seven ulnae were right and 78 were left. Partial fusion of olecranon and coronoid facets was observed in 75 bones (Type II,

Fig. 2 **a** Proximal end of left ulna presenting two separate olecranon and coronoid facets (Type I); **b** proximal end of right ulna presenting partial fusion of olecranon and coronoid facets (Type II); **c** proximal end of left ulna presenting a single olecranon and coronoid facet (Type III)



27.5%). Twenty-five of them were male and 48 were female ulnae, while 33 of them were right and 42 were left. A single olecranon and coronoid facet was present in 33 out of 273 ulnae (Type III, 12.1%). Nine of them belonged to males and 24 belonged to females, while 18 of them were right and 15 were left. The completely separated type was significantly more common in males, whereas the partial fusion and the single articular surface were predominantly found in females ($p < 0.001$). There was no significant difference in the incidence of the three types between two sides ($p = 0.404$). Results are summarized in Table 1.

Discussion

The main finding of the present study is that the typical morphological pattern of the trochlear notch as it is described in the textbooks (Type I: separate olecranon and coronoid facets) was only found in 60.4% of the ulnae, whereas the remaining 39.6% of the bones appeared with partial (Type II) or complete fusion of olecranon and coronoid facets (Type III). In women, the two anatomical variations of the notch (Types II and III) were more frequent (51%) than the typical one (49%) (Type I).

Oberländer et al. in 1984 analyzed the occurrence of the three different types in 150 adult cadaveric ulnae having the articular cartilage [6]. They found separate olecranon and coronoid facets (Type I) in 97 bones (64.7%), partial fusion of olecranon and coronoid facets in 44 bones (29.3%), and a single olecranon and coronoid facet more rarely, in 9 out of 150 ulnae (6%) [6]. These findings are close to ours with regard to the Types I and II, but in the present study, more ulnae had a single, undivided facet.

Sub-analysis of the trochlear notch types distribution between genders revealed that the partial fusion (Type II) and a single facet (Type III) were more frequent (51%) than the typical completely separated one (Type I) (49%) in women. A significant difference ($p < 0.001$) was observed

with the types distribution in men, where the Type I articular surface was predominantly found (72.7%). The significant most common presence of the separate olecranon and coronoid facets (Type I) in men may be an indication that the existence of the transverse ridge is a characteristic of robustness.

Comparing the morphology of the articular surface between two sides of the body, no significant difference was found. It is important to note that our samples were unpaired. Oberländer et al. reported on the symmetry of the variations on a paired sample. Separate olecranon and coronoid facets (Type I) were present bilaterally in 34 out of 67 pairs and in one side in 18 pairs. A single olecranon and coronoid facet (Type III) was found in both ulnae of two pairs (four bones) and in two other pairs unilateral [6].

The existence of other than the completely separated trochlear notch articular surface may have clinical relevance for the orthopedic surgeon performing an olecranon osteotomy. Considering that the transverse ridge is present, the cartilage-free area is often used as the target point to perform an olecranon osteotomy [1, 7, 13]. In elbows with no transverse ridge, which according to the present study represent the 40% of cases, an olecranon osteotomy may harm the articular cartilage that may lead to secondary osteoarthritis. Moreover, anatomical landmarks, such as the transverse ridge, are helpful during arthroscopy for orientation of the surgeon. Absence of the ridge in a Type III trochlear notch may confuse the surgeon during elbow arthroscopy. Variations of the trochlear notch may be taken into consideration for the design of anatomical prostheses for elbow arthroplasty.

It is well known that knowledge of the normal variants of any part of the human body is useful to avoid misinterpretation of radiologic studies [3]. The transverse ridge of the trochlear notch is apparent in imaging studies, such as CT and MRI scans, in which it may be mistaken for a fracture or a post-traumatic intraarticular osteophyte [4, 9]. Canale et al. mentioned that the proximal ulna epiphysis fuses to the

Table 1 Proximal ulna articular surface morphology

		Articular surface morphology of the trochlear notch						<i>p</i>
		Separate olecranon and coronoid facets (Type I)		Partial fusion of olecranon and coronoid facets (Type II)		Single olecranon and coronoid facet (Type III)		
		No. of bones	Percent (%)	No. of bones	Percent (%)	No. of bones	Percent (%)	
Gender	Male	96	72.7	27	20.5	9	6.8	0.000
	Female	69	48.9	48	34.0	24	17.0	
	Total	165	60.4	75	27.5	33	12.1	
Side	Right	87	63.0	33	23.9	18	13.0	0.404
	Left	78	57.8	42	31.1	15	11.1	
	Total	165	60.4	75	27.5	33	12.1	

Distribution of morphological types by gender and side

metaphysis at 14 years old. A sclerotic margin at the site of fusion may persist through adulthood and may be mistaken for a fracture [2].

The three morphologic types of the trochlear notch may be explained embryologically. The complex development of the proximal ulna is the major contributor to the morphology of its articular surface. The fusion of the proximal ulnar growth plate between the two secondary ossification centers (olecranon and coronoid process) leads to the formation of the non-articular transverse ridge [4, 11]. Variations in the development of this growth plate may lead to the different anatomical patterns in the articular surface.

In the literature, there is no official terminology to describe the three morphological patterns and the transverse non-cartilaginous strip of the trochlear notch. We suggest the term “transverse ridge of the trochlear notch” of ulna and the following terminology for the three types: Type I: separate olecranon and coronoid facets; Type II: partial fusion of olecranon and coronoid facets; Type III: a single olecranon and coronoid facet.

The present study has certain limitations. The ulnae we studied were unpaired, thus the comparison of the morphology in the same individual was impossible. Moreover, there was no clinical data about the specimens and no cadaveric specimens to correlate our findings with biomechanical data for each trochlear notch type.

Conclusion

The most common pattern of the proximal ulna articular surface was the existence of olecranon and coronoid facets separated by the transverse ridge of the trochlear notch, which is considered as the typical anatomical pattern. In 40% of the cases, the morphology of the articular surface does not match the typical anatomical pattern. Partial fusion of olecranon and coronoid facets was the second most common pattern (27.5%) and the single olecranon and coronoid facet with no transverse ridge present was the rarest one (12.1%). These variations affect the area covered by cartilage within the articular surface; they are noticeable in an elbow MRI and may have implications on elbow arthroscopy and olecranon osteotomies.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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