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Morphological evaluation and clinical significance of the supracondylar process and supratrochlear foramen: an anatomic and radiological study

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Background: *In our literature review, we did not encounter any study examining the supracondylar process (SP) and the supratrochlear foramen (STF) with a three-dimensional (3D) reconstruction method. The present study aimed to evaluate SP and STF morphologically by employing the 3D reconstruction method and emphasize their clinical significance.*

Materials and methods: *The research was carried out on dried human humeri of unknown sex and without pathological alterations. A total of 81 humeri (42 right, 39 left) were obtained from the Departments of Anatomy of Gazi University Faculty of Medicine and Lokman Hekim University Faculty of Medicine. The morphometric measurements of SP and STF were made with a digital vernier calliper. The computed tomography images acquired for radiological evaluation were analysed with the 3D reconstruction method.*

Results: *The narrower distal medullary canal widths of humeri with STF were found to be statistically significant. No statistically significant difference was found between the transverse diameters (TD), vertical diameters (VD), the distance of the medial edge to the medial epicondyle, and the distance of the lateral edge to the lateral epicondyle of the supratrochlear foramen of the right and left humeri.*

Conclusions: *The supracondylar process is often evaluated by mistake as a pathological condition of the bone, not as a normal anatomical variation. Knowing different shapes and dimensions, e.g. the TD and VD distance in which STF emerges, can assist in avoiding the misinterpretation of radiographs.* (Folia Morphol 2023; 82, 4: 869–874)

Key words: supracondylar process, supratrochlear foramen, three-dimensional reconstruction

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INTRODUCTION

The supracondylar process (SP) of the humerus, also known as the epicondylar, supra-epitrochlear, or a supratrochlear spur, represents a hook-like, bony spine with varied dimensions, which may project distally from the anteromedial surface of the humerus [10]. The process is usually located 4 to 8 cm proximal to the medial epicondyle (ME) [5]. The SP is often evaluated by mistake as a pathological condition of the bone, not as a normal anatomical variation [24]. It can sometimes induce symptoms by compressing the brachial artery or median nerve, or both of them [26].

The olecranon and the coronoid fossa are separated by a thin bone plate, which can sometimes be perforated, causing a foramen named supratrochlear foramen (STF). STF represents a significant and comparatively frequent anatomic variation in the lower end of the humerus in people [12]. Orthopaedic surgical experience has demonstrated an association between STF and a narrow intramedullary cavity [20]. The treatment for supracondylar fractures is intramedullary nailing, which can be compromised by the mentioned aperture. While the humerus is being evaluated radiologically, the presence of STF can be misjudged as a pathological lesion or cyst [17].

MATERIALS AND METHODS

The present research was conducted on a total of 81 (42 right, 39 left) dried humeri obtained from the Departments of Anatomy of Gazi University and Lokman Hekim University, Ankara, Turkey. Only adult bones were utilized in the current study. A digital vernier calliper was used to measure the transverse (TD) and vertical (VD) diameters of STF, the distance of the lateral edge of STF to the lateral epicondyle (LE), and the distance of the medial edge of STF to the ME. The presence of an STF was detected, and its shape was observed and separated into three types (oval, round, and triangular) (Fig. 1). In bones without the foramen, the translucency of the supratrochlear septum was noted with the help of transmitted light posterior to anterior. The length of the protrusion from the surface of SP, the length and width of the base of SP, the distance of the root of SP to the upper end of the ME, and the distance of SP to the nutrient foramen were measured with a digital vernier calliper. Computed tomography (CT) was taken on humeri with STF and SP and four control humeri. Three-dimensional (3D) scientific modelling and morphometric measurements of the humeri with CT were performed from sequential serial images in the DICOM format, using a 3D reconstruction programme (Materialize Mimics 17, Leuven, Belgium) used for scientific purposes. To better evaluate the medullary canals in the acquired models in comparison with normal CT images, solid humerus models were made transparent in the digital environment. For this purpose, Cinema 4D (R25, Friedrichsdorf, Germany) 3D modelling and animation programme was used. With the help of Materialize Mimics, the proximal medullary canal width of humeri with STF and SP and four control humeri was measured 25% proximally of the humerus, the midshaft medullary canal width was measured from 50% midshaft of the humerus, and the distal medullary canal width was measured 25% distally of the humerus (Fig. 2). Furthermore, Materialize Mimics was used to measure the distance between the end of the medullary canal and STF, and the distance between the lower point of STF and the lower end of the humerus. Ethics committee approval was granted for our study by Lokman Hekim University Non-Interventional Clinical Research Ethics Committee.

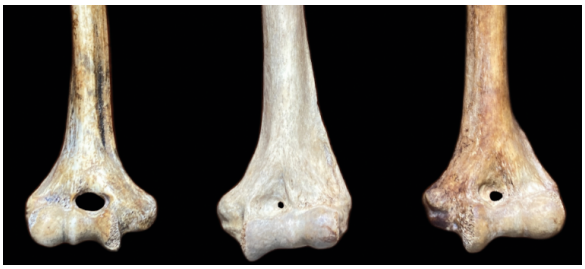

Figure 1. Different shapes of the supratrochlear foramen.

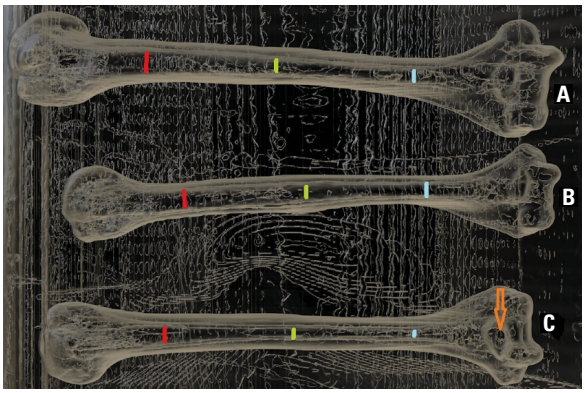

Figure 2. Transparentised image of the three-dimensional reconstructed humeri with computed tomography; **A.** Control humerus; **B.** Supracondylar process; **C.** Supratrochlear foramen (red line: proximal medullary canal width, green line: midshaft medullary canal width, blue line: distal medullary canal width, orange arrow head: supratrochlear foramen).

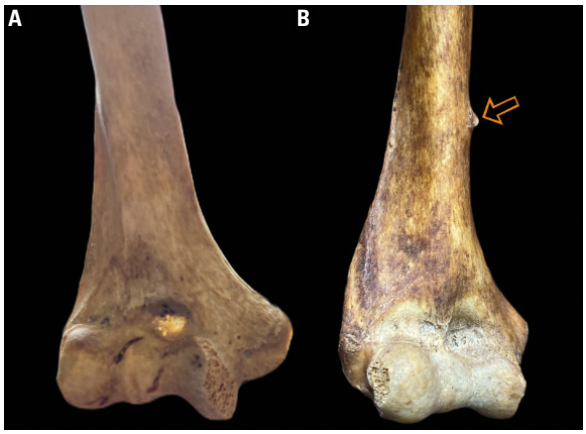

Figure 3. Translucent septum (**A**) and supracondylar process (**B**); arrow: supracondylar process.

Table 1. Incidence of different shapes of the supratrochlear foramen

Variables	Right side	Left side	Total
Oval shape	3 (23.07%*)	7 (53.84%*)	10 (76.92%*)
Round shape	1 (7.69%*)	1 (7.69%*)	2 (15.38%*)
Triangular shape	–	1 (7.69%*)	1 (7.69%*)

*The percentage in bones with supratrochlear foramen

Statistical analysis

Statistical Package for the Social Sciences v23.0 (SPSS Inc, Chicago, IL) was used for statistical analysis. The normality distribution of continuous variables was assessed with the Kolmogorov-Smirnov, histogram and Q–Q plot tests. Categorical variables are presented with numbers and percentages, while continuous variables are shown in tables with mean and standard deviation, median and minimum–maximum values. The Mann-Whitney U test was conducted to compare continuous variables that were not normally distributed. $P < 0.05$ was considered statistically significant.

RESULTS

Of the 81 humeri we examined, only 1 (1.23%) SP was detected on the anteromedial aspect of the right humerus (Fig. 3). The protrusion of SP from the surface was 35 mm, its base was vertically 6 mm long and 2.5 mm wide, the distance from the root of the protrusion to the upper end of the ME was 53 mm, and the distance of SP to the nutrient foramen was 30 mm. The direction of SP was anteriorly, inwardly, and distally oriented. The lengths of the proximal, midshaft, and distal medullary canal widths of the humerus with SP were determined as 14 mm, 12 mm, and 18 mm, respectively (Fig. 2).

The STF was detected in 13 (16.04%) bones in total. Of the humeri with STF, 4 (9.52%) were right, and 9 (23.07%) were left. In the present study, we found STF more on the left side. Most STF had an oval shape in 76.92%, which was followed by a round shape in 15.38% and a triangular shape in 7.69% (Table 1, Fig. 1). No statistically significant difference was found between the TD, VD, ME, and LE of STF of the right and left humeri (Table 2).

The narrower distal medullary canal widths of humeri with STF than the distal medullary canal widths of the control humeri were found to be statistically significant ($p = 0.045$). There was no statistically significant difference in terms of the proximal and midshaft medullary canal widths (Table 3, Fig. 2). The narrower distal medullary canal widths of the right humeri with STF than the distal medullary canal widths of the left humeri with STF were found to be statistically significant ($p = 0.006$). No statistically significant difference was found between the right and left humeri with STF in terms of proximal and midshaft medullary canal widths, the distance between the end of the medullary canal and STF, and the distance between the lower point of STF and the lower end of the bone (Table 4).

Table 2. The different measurements in supratrochlear foramen

Measurements	Right side [mm]		Left side [mm]		P
	Median	Min–Max	Median	Min–Max	
TD	5.75	3.00–12.00	4.10	2.00–10.00	0.439
VD	2.75	2.50–7.50	3.50	2.00–7.00	0.938
ME	24.50	21.00–26.50	24.00	20.00–31.50	0.877
LE	25.25	20.00–28.50	26.50	20.00–30.00	0.353

Min–Max — minimum–maximum; TD — transvers diameter; VD — vertical diameter; ME — the distance from the medial edge of the supratrochlear foramen to the medial epicondyle; LE — the distance from the lateral edge of the supratrochlear foramen to the lateral epicondyle

Table 3. Comparison of the proximal, midshaft, and distal medullary canal widths of humeri with the supratrochlear foramen and control humeri

Measurements	Supratrochlear foramen [mm]		Control humerus [mm]		P
	Median	Min–Max	Median	Min–Max	
PMCW	14.0	11.0–18.0	15.5	14.0–17.0	0.169
MMCW	9.0	6.0–15.0	12.5	12.0–14.0	0.068
DMCW	12.0	9.0–18.0	14.5	14.0–16.0	**0.045**

Min–Max — minimum–maximum; PMCW — proximal medullary canal width; MMKW — midshaft medullary canal width; DMKW — distal medullary canal width

Table 4. Comparison of medullary canal widths of right and left humerus with supratrochlear foramen

Measurements	Right side [mm]		Left side [mm]		P
	Median	Min–Max	Median	Min–Max	
PMCW	12.0	11.0–18.0	14.0	12.0–16.0	0.260
MMCW	9.5	7.0–13.0	9.0	6.0–15.0	0.825
DMCW	9.0	9.0–11.0	12.0	11.0–18.0	**0.006**
MSF	9.5	6.0–11.0	10.0	9.0–12.0	0.330
SFLEB	12.0	11.0–14.0	12.0	11.0–17.0	0.604

Min–Max — minimum–maximum; PMCW — proximal medullary canal width; MMCW — midshaft medullary canal width; DMCW — distal medullary canal width; MSF — the distance between the end of the medullary canal and the supratrochlear foramen; SFLEB — the distance between the lower point of the supratrochlear foramen and the lower end of the bone

Table 5. Measurements of supracondylar process (SP) as reported by different authors

Measurement of SP	Gupta and Mehta, 2008	Ravi and Patil, 2014	Uyaroglu et al., 2005	Present study Coskun et al., 2022
Length of spine	3 mm	8 mm	10.6 mm	3.5 mm
Breadth at the base of spine	11 mm	12 mm	–	2.5 mm
Distance of spine from medial epicondyle	65 mm	53 mm	37 mm	53 mm
Distance of spine from nutrient foramen	–	38 mm	–	30 mm

The translucent septum was detected in 37 (45.67%) humeri. The translucent septum was observed at similar rates on both sides (right 45.23%, left 46.15%) (Fig. 3).

DISCUSSION

The SP of the humerus has a very low incidence. The incidence of SP was found to be 1.3% in Caucasians [14], 2.5% in Nigerians [18], 0.7% in Japanese (Kyoto) [1], and 1.25% in Indians (Assam) [21]. Uyaroglu et al. [27] found the incidence of SP as 1.44% in their study on the Turkish population. This rate is very similar to our study.

Our study is compatible with the study by Gupta and Mehta [11] in terms of length of the spine and with the study by Ravi and Patil [22] in terms of distance of the spine from the ME and distance of the spine from the nutrient foramen. In their study, Uyaroglu et al. [27] found the length of SP to be longer than that in our study and the distance of SP to the ME shorter than that in our study (Table 5).

Studies on the proximal, midshaft, and distal medullary canals in the literature reviews have been conducted directly on the bone or conventional radiographs [16, 20]. However, no studies have been encountered on the 3D humerus models created from CT images by employing the digital transparentising method. The proximal and midshaft medullary canal width of the humerus with SP was found to be smaller than the mean medullary canal width of the control group humeri, whereas the distal medullary canal width was revealed to be more than the mean medullary canal width of the control group humeri. The mean proximal, midshaft, and distal medullary canal widths of the humeri in the control group were detected to be 15.5 mm, 12.7 mm, and 14.7 mm, respectively. Since the number of SP was 1, a statistical evaluation could not be carried out.

It is necessary to differentiate the SP from osteochondroma in pathological terms. The SP is distally oriented, toward the elbow without discontinuities in the cortex of the humerus. An osteochondroma points away from the joint. The X-ray of SP demonstrates that an underlying humeral cortex is intact, while the cortex of the tumour is continuous with the humeral cortex in an osteochondroma. A SP can also be mimicked by heterotopic bone, e.g. myositis ossificans [24].

The incidence of STF in people ranges from 0.3% to nearly 60% around the world. The incidence of STF was found to be 0.304% in Greeks [19], 57% in Libyans [13], 47.0% in Africans [9], 30.5% [4] and 31.3% [2] in Indians, 6.9% in Americans [3], and 6.0% in Europeans [9]. The two studies on the Turkish population found the incidence of STF as 10.8% [8] and 12.0% [7], respectively. In the current study, we found the incidence of STF as 16.04%. This rate we found is close to the incidence percentages determined in the Turkish population. Indians and Africans have been stated to have a higher prevalence of STF in comparison with Europeans and Turks.

In the current research, the prevalence of STF was determined to be higher on the left side compared to the right side. Our findings also support previous reports [2, 4]. On the contrary, Nayak et al. [15] found STF more frequently on the right side in their study. They detected 73 STF on the right side and 59 STF on the left side.

Studies have shown that STF is mostly oval-shaped [2, 4, 6]. In our study, the shape of STF was oval in 76.92%, round in 15.38%, and triangular in 7.69% of 13 samples (Table 1). Shivaleela et al. [23] encountered mostly round-shaped STF in their study, which was followed by round-shaped STF and oval-shaped STF. They revealed that 47.37% of STF had a round shape and 42.11% had an oval shape [23].

In our study, no statistically significant difference was revealed between the TD, VD, ME, and LE of STF of the right and left humeri (Table 2). In most studies, no statistical significance was determined between the transverse and VD of the right and left STF [6, 15, 23, 25]. Erdogmus et al. [8] found the TD of STF to be wider on the left side and STF to be closer to the ME on the left side.

The narrower distal medullary canal widths of the humeri with STF than distal medullary canal widths of the control humeri in our study were found to be statistically significant. No statistically significant difference was revealed in terms of the proximal and midshaft medullary canal widths (Table 3). Paraskevas et al. [20] found the width of the medullary canal narrower in the distal of humeri with STF. In our study, it was determined to be statistically significant that the distal medullary canal widths of the right humeri with STF were narrower than the distal medullary canal widths of the left humeri with STF ($p = 0.006$). No statistically significant difference was detected between the right and left humeri with STF in terms of proximal and midshaft medullary canal widths, the distance between the end of the medullary canal and STF, and the distance between the lower point of STF and the lower end of the bone (Table 4). Ndou et al. [16] found no significant difference in the distal medullary canal widths of bones with STF.

Since STF is directly related to the size of the intramedullary canal, it may play a key role in the preoperative planning of intramedullary nailing [6]. In humeral fractures of STF, surgeons should remember antegrade medullary nailing is better compared to retrograde nailing because a secondary fracture is more likely to occur since the canal at the distal portion of humeri with STF is extremely narrow [20].

In our study, the incidence of the translucent septum was 45.67%. In the studies by Nayak et al. [15] and Shivaleela et al. [23], the incidence of the translucent septum was 56.7% and 47.89%, respectively.

CONCLUSIONS

The incidence of the SP in the Turkish population was determined as 1.23%. The SP is often evaluated by mistake as a pathological condition of the bone instead of a normal anatomical variation. Knowing the mentioned variation and its prevalence may reduce misdiagnosis in radiographic images. We determined the incidence of STF in the Turkish population to be 16.04%, mostly on the left side. Having knowledge of the anatomy of STF may play a key role in the preoperative planning of intramedullary nailing since there may be variations in the width of the medullary canal of the humerus with STF. It is also essential for anatomists and radiologists to have knowledge of the anatomy of STF. We think that this study, in which we employed the 3D reconstruction method, will contribute to the literature.

Conflict of interest: None declared

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