

## Morphometric analysis of the angle of the femoral trochlea

Nascimento, SRR.<sup>1\*</sup>, Pereira LA.<sup>2</sup>, Oliveira, MJ.<sup>3</sup>, Wafae, GC.<sup>4</sup>,  
Ruiz, CR.<sup>5</sup> and Wafae, N.<sup>6</sup>

<sup>1</sup>Postgraduate in Macroscopic Anatomy and Anatomy by Radiologic Imaging,  
São Camilo University Center, São Paulo, SP, Brazil

<sup>2</sup>Laboratory of Human Anatomy, São Camilo University Center, São Paulo, SP, Brazil

<sup>3</sup>Assistant Professor of Anatomy, University of Oeste Paulista – UNOESTE, São Paulo, SP, Brazil

<sup>4</sup>Medical Student, Nove de Julho University, São Paulo, SP, Brazil

<sup>5</sup>PhD, Professor of the Discipline of Human Anatomy and Anatomy by Radiologic Imaging,  
in the Technology and Medicine courses, coordinator of the postgraduate course in Macroscopic  
and Radiologic Imaging Anatomy, and the course of Computed Tomography and Magnetic Resonance,  
São Camilo University Center, São Paulo, SP, Brazil

<sup>6</sup>PhD, Specialist by the Paulista School of Medicine, Doctor by the Paulista School of Medicine,  
Associate Professor, Federal University of São Paulo – UNIFESP, São Paulo, SP, Brazil

\*E-mail: riosnascimento@uol.com.br

### Abstract

The possible association between disorders of the femoropatellar joint and geometrical anatomical variations in the patellar facet and femoral sulcus motivated us to conduct a morphometric study on the angle of the femoral sulcus and to correlate this with possible variation factors, such as: length, width at the midpoint of the femur, femur inclination angle, distance between condyles and depth of the patellar facet. The material consisted of 56 dry femurs of both sexes and various ages: 24 from the right side and 32 from the left side. The patellar facets were photographed at three positions: a) start level; b) middle level; and c) end level. The angle formed in each of these positions was measured using graphical tools in CorelDraw X4. To analyze the results, the statistical tests used were chi-square and Student's *t*-test for correlations. The results obtained were: a) angle of the patellar facet: mean for start level of the patellar facet = 129°01; mean for middle level = 131°35 and mean for end level = 132°14; b) mean distance between condyles = 50.29 mm; c) mean depth of the patellar facet = 9.55 mm; d) mean for Ficat and Bizou's condylar depth index = 5.45. We concluded that the angle of the femoral sulcus increased from the start of the patellar facet to its end, and that its variability was weakly influenced by the length, width, femur inclination angle and side, according to the *t*-test (significance of 5%) for the correlation coefficients found.

**Keywords:** anatomy, anthropometry, femur, knee, radiography, radiology, lower extremity, orthopedics, joint disorders, joint instability, knee joint.

### 1 Introduction

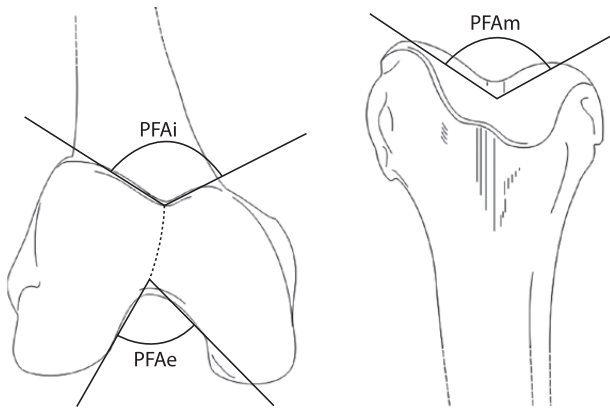
Disorders of the femoropatellar joint have frequently been reported. Among these are patellar dysplasia (TARDIEU and DUPONT, 2001), patellar instability (MCCONNELL, 2007), osteoarthritis (TEICHTAHL, PARKINS, HANNA et al., 2007) and subluxation of the patella (JAFARIL, FARAHMAND and MEGHDARI, 2008). According to some investigators, these problems may be associated with geometrical anatomical variations in the patellar facet (FUCENTESE, VON ROLL, KOCH et al., 2006), while others have correlated these problems with the depth of the angle of the femoral sulcus (DAVIES-TUCK, TEICHTAHL, WLUKA et al., 2008).

This important attribute of the patellar facet and femoral sulcus motivated us to conduct a morphometric study on the angle of the femoral sulcus (or trochlea), with the aim of measuring the angle formed by the patellar facet in relation to the length, width at the midpoint of the femur, femur inclination angle, distance between condyles and depth of the patellar facet.

### 2 Material and methods

The material consisted of 56 dry femurs of both sexes and various ages: 24 from the right side and 32 from the left side. They came from the anatomy laboratories of São Camilo University Center and the Federal University of São Paulo. Completely preserved femurs were selected, in order to rule out the possibility of interference due to wear or tear that could affect the measurements.

The patellar facets were photographed at three positions: a) start level; b) middle level; and c) end level. For the start level, the camera were centered on the anterior start of the patellar facet (Figure 1); for the middle level, we focused on the midpoint between the start and end points of the patellar facet (Figure 1); and for the end level, we centered on the transition between the patellar facet and the intercondylar notch, at the last point of the patellar facet that was still visible (Figure 1). The angle formed at each of these positions was measured using graphical tools in CorelDraw X4. The camera was placed at a distance of 10 cm from the trochlea and centered perpendicularly to the femoral sulcus.



**Figure 1.** Planning: **PFAs** – Angle at the start of the patellar facet. **PFAm** – Angle at the midpoint of the patellar facet. **PFAe** – Angle at the end of the patellar facet.

Firstly, using eight specimens, the results obtained from the photographs were compared with those obtained directly using a goniometer. Since no differences could be seen, we proceeded with the photography.

To obtain femur measurements, we took the following reference points: length, from the apex of the greater trochanter to the start of the patellar facet; width, from the midpoint of the length; inclination angle, formed by the meeting point between straight lines traced out from the center of the body of the bone and the center of the anatomical neck; distance between condyles, between the lowest points on each condyle; depth of the patellar facet, distance from the femoral sulcus perpendicularly to the straight line of the distance between the condyles (Figure 2); Ficat and Bizou's condylar depth index, ratio of the distance between the condyles divided by the depth of the patellar facet at the midpoint considered. These measurements were made as follows: femur length, using a ruler graduated in millimeters; width, using a Digimess digital pachymeter; and the inclination angle, distance between condyles and depth of the patellar facet, using CorelDraw X4.

### 3 Results

Firstly, the angles of the patellar facet at the three levels that had been defined were measured. It was seen that there were no significant differences between the sides, and therefore we moved on to consider the whole sample. The following values were obtained:

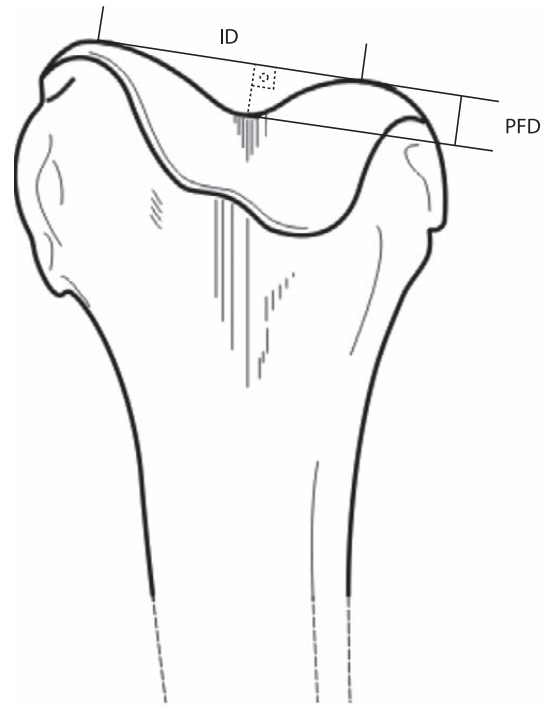
**Angle of the patellar facet** (Figure 3): mean for the start of the patellar facet = 129.01 degrees (extreme values: 113.55 and 146.63 degrees); mean for the middle level of the patellar facet = 131.35 degrees (extremes: 115.93 and 146.44 degrees); and end of the patellar facet = 132.14 degrees (extremes: 106.18 and 144.96 degrees).

**Distance between condyles:** mean = 50.29 mm (extremes: 26.20 and 89.66 mm).

**Depth of the patellar facet:** mean = 9.55 mm (extremes: 5 and 19 mm).

**Ficat and Bizou's condylar depth index:** mean = 5.45 (extremes: 3.87 and 8.65).

**Length:** mean = 40.16 cm (extremes: 34.80 and 45 cm).



**Figure 2.** **DC** – Distance between condyles, measured between the lowest points on each condyle. **DPF** – Depth of the patellar facet, measured as the straight line obtained between the deepest point of the patellar facet and the point at which the straight line intersects perpendicularly with the straight line tangential to the femoral condyles.

**Width at midpoint:** mean = 2.63 cm (extremes: 2.00 and 3.10 cm).

**Inclination angle:** mean = 128.98 degrees (extremes: 117.37 and 144.66 degrees).

For all graphs,  $\chi^2$  tests were performed to evaluate the linearity of the data around the straight line of the regression. The results were satisfactory at the significance level of 5%, i.e. the relationship was found to be linear.

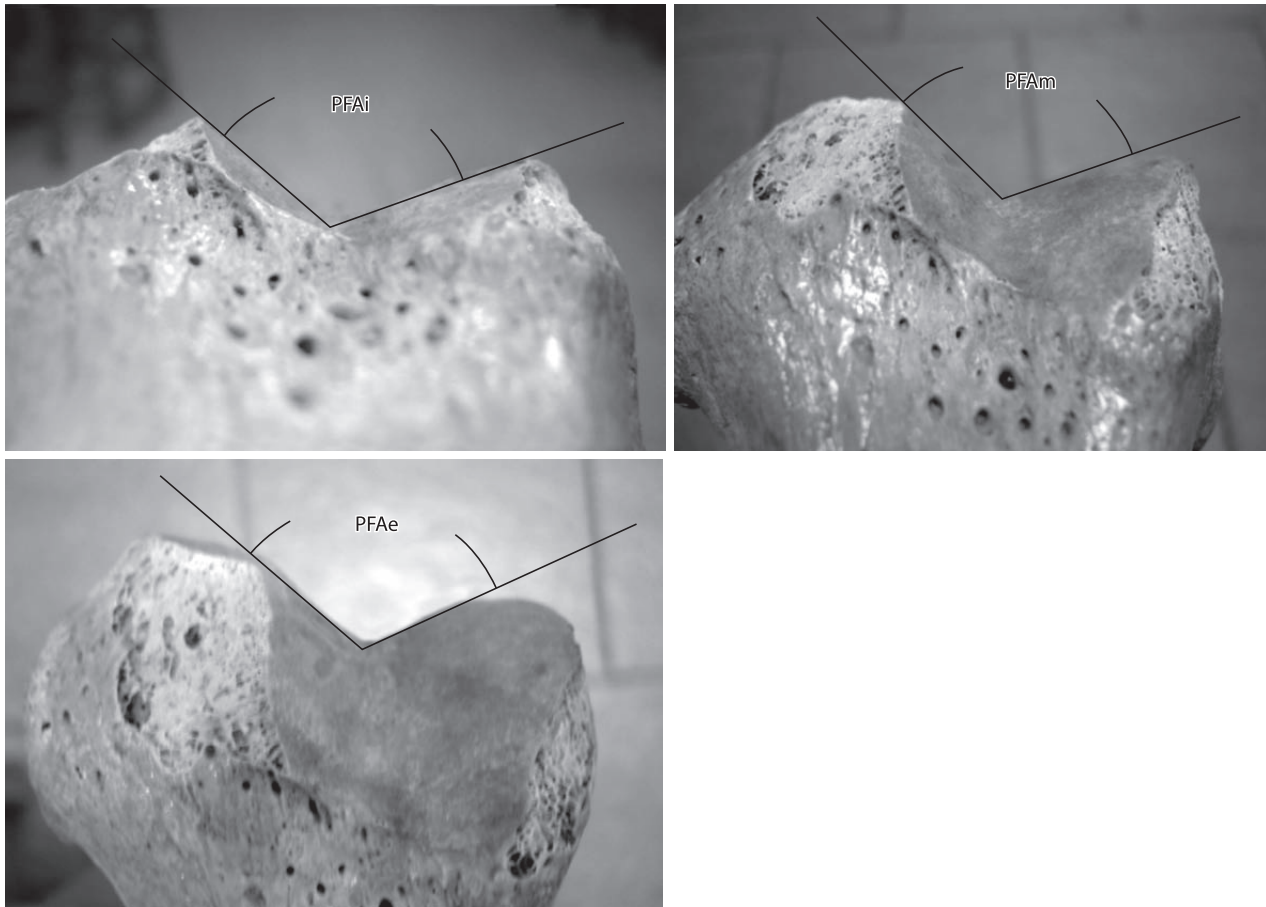
### 4 Discussion

The bone structures at the lower extremity of the femur that are most cited in the literature that we consulted are the sulcus of the patella facet or trochlea (BRATTSTRÖM, 1960; BUARD, BENOIT, LORTAT-JACOB et al., 1981; HEPP, 1982; TARDIEU and DUPONT, 2001; TEICHTAHL, PARKINS, HANNA et al., 2007; DAVIES-TUCK, TEICHTAHL, WLUKA et al., 2008; JAFARIL, FARAHMAND and MEGHDARI, 2008) and the intercondylar notch (FICAT, 1970; GOOD, ODENSTEN and GILLQYUIST, 1991; LUND-HANSEN, GANNON, ENGBRETSEN et al., 1994; WADA, TATSUO, BABA, 1999; HERNIGOU and GARABEDIAN, 2002; ÂNGELO, COSTA, GALINDO et al., 2007; BERG, TA'ALA, KONTANIS et al., 2007). All of these studies reported that morphometric abnormalities at these levels might be associated with knee disorders.

The depth of the patellar facet and the distance between the condyles were the measurements with the largest dispersion in relation to their mean values. This suggested

that they are measurements that vary greatly between individuals. Consequently, they make give rise to significant variation in Ficat and Bizou's condylar depth index, since they are incorporated in this index. However, the angles of the patellar facet present small dispersion in relation to their mean values, thus suggesting that these angles are less variable in relation to their mean values than are the measurements of the depth of the patellar facet and the distance between the condyles (Table 1).

The mean angle of the patellar facet presented a reasonable negative association with the depth of the patellar facet. In other words, the mean angle of the patellar facet was smaller when the patellar facet was deeper, and the angle increased as the patellar facet became shallower (Table 2 and Figure 4), according to the *t*-test (significance level of 5%) for the correlations (Table 3). The mean angle of the patellar facet also presented a considerable positive association with Ficat and Bizou's index (Table 2 and Figure 5), also according



**Figure 3.** PFAs – Angle at the start of the patellar facet. PFAm - Angle at the midpoint of the patellar facet. PFAe - Angle at the end of the patellar facet.

**Table 1.** Femur measurement values.

Morphometry of the lower extremity of the femur		
	Mean value ± standard deviation	CV* (%)
Angle at the start of the patellar facet (degrees)	129.01 ± 6.46	5.01
Angle at the midpoint of the patellar facet (degrees)	131.35 ± 7.28	5.54
Angle at the end of the patellar facet (degrees)	132.14 ± 7.57	5.73
Mean angle of the patellar facet (degrees)	130.83 ± 5.98	4.57
Distance between condyles (mm)	50.29 ± 13.43	26.70
Depth of the patellar facet (mm)	9.55 ± 3.22	33.74
Ficat and Bizou	5.45 ± 1	18.29
Length (cm)	40.16 ± 2.54	6.33
Width at the midpoint (cm)	2.63 ± 0.22	8.20
Inclination angle	128.98 ± 5.99	4.64

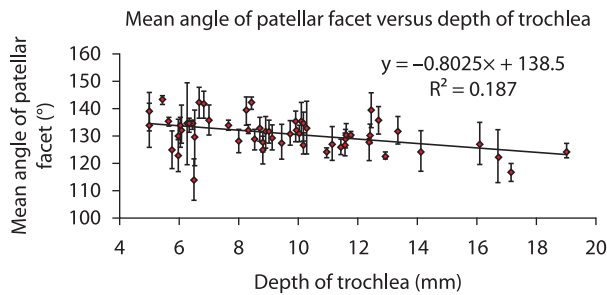
\*CV – coefficient of variation.

**Table 2.** Correlations between femur measurements.

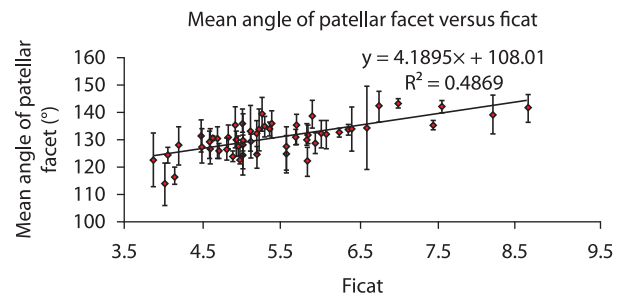
	Correlations between measurements					
	Mean angle of patellar facet	Length	Width	Inclination angle	Width of trochlea	Depth of trochlea
Mean angle of patellar facet	1	0.100	0.025	-0.057	-0.095	-0.432
Length	-	1	0.419	-0.073	0.182	0.070
Width	-	-	1	-0.259	0.156	0.087
Inclination angle	-	-	-	1	-0.052	-0.108
Distance between condyles	-	-	-	-	1	0.859
Depth of patellar facet	-	-	-	-	-	1

**Table 3.** Student's *t*-test for correlations (significance level of 5%;  $\alpha = 1.98$ ).

	Table of Student's <i>t</i> -test for correlations					
	Mean angle of patellar facet	Length	Width	Inclination angle	Width of trochlea	Depth of trochlea
Mean angle of patellar facet	-	0.738	0.187	0.421	0.70	3.52
Length	-	-	3.392	0.539	1.36	0.52
Width	-	-	-	1.968	1.16	0.64
Inclination angle	-	-	-	-	0.38	0.80
Distance between condyles	-	-	-	-	-	12.33
Depth of patellar facet	-	-	-	-	-	-



**Figure 4.** Correlation between mean angle of patellar facet and depth of trochlea.



**Figure 5.** Correlation between mean angle of patellar facet and Ficat and Bizou's index.

to the *t*-test (significance level of 5%) for the correlations (Table 3). Furthermore, it was noted that there was a strong positive correlation between the measurement of the distance between the condyles and the depth of the patellar facet, and a significant positive correlation between the measurements of length and width at the midpoint of the femur (Table 2).

Our results demonstrated that the morphometry of the lower extremity of the femur varies greatly, according to the level at which the measurements are made. Thus, numerical data such as Ficat and Bizou's index, Brattström's angle and the intercondylar width index (IWI) are relative and must be regarded as references at the points at which the measurements are made. They do not extend to the whole patellar facet and intercondylar notch. Agreeing with Ângelo, Costa, Galindo et al. (2007), we confirm that in most cases, the methodology used did not specify the level, which makes it impossible to compare values. The angle cited by Brattström (1960), which received his name, was obtained from radiographs on the knee and the level of the patellar facet at which it was measured is insufficiently clear.

## 5 Conclusion

The angle of the femoral sulcus on the patellar facet increases from the start of the patellar facet towards its end. It is variable, but this variability is weakly associated with length, width, inclination angle of the femur and the side, according to the *t*-test (significance level of 5%) for the correlation coefficients that were found.

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