

Femoral Sulcus Angle Measurements: An Anatomical Study of Magnetic Resonance Images and Dry Bones

Khalil Awadh MURSHED¹, Aynur Emine ÇİÇEKÇİBAŞI¹,
Taner ZİLYAN¹, Aydın KARABACAKOĞLU²

¹ Department of Anatomy, Meram Faculty of Medicine, Selçuk University, Konya - Turkey

² Department of Radiology, Meram Faculty of Medicine, Selçuk University, Konya - Turkey

Received: May 27, 2003

Abstract: The sulcus angle of the femoral trochlea is particularly important for evaluating the patellofemoral joint. Our experimental study aimed to assess the osseous femoral sulcus angle radiologically in the right and left knees and osteologically in the right and left femurs in males and females. The osseous sulcus angle of 28 male right, 22 male left, 21 female right and 29 female left knees was measured on magnetic resonance images (MRIs) and by a goniometer; the angle was measured in 40 right and 40 left femurs. In MRIs, the mean sulcus angle in males and in females was $134^\circ \pm \text{SD } 5.1^\circ$ and $133.2^\circ \pm \text{SD } 6.7^\circ$, respectively. In the right and left knees it was $133.5^\circ \pm \text{SD } 5.2^\circ$ and $134.5^\circ \pm \text{SD } 6.7^\circ$ respectively. No statistically significant differences were found between right and left knees in MRIs. In dry bones, the mean sulcus angle in the right and left femurs was $142.2^\circ \pm \text{SD } 9.7^\circ$ and $141.2^\circ \pm \text{SD } 7.9^\circ$, respectively, with no significant difference. Statistical comparisons between the mean sulcus angle in MRIs and in dry femurs showed highly significant differences ($P < 0.01$). Our results suggest that there are no differences in the femoral osseous angle between men and women or between the right and left sides. Differences in the techniques and methods of angle assessments could explain the differences in their values.

Key Words: Sulcus angle, Femur, MRI, Measurement.

Introduction

The location and configuration of the intercondylar groove of the distal femur is clinically significant in the mechanics and pathomechanics of the patellofemoral articulation (1-3). The location of the femoral sulcus, the deepest depression of the intercondylar groove, relative to the condyles or its orientation relative to the anatomic and mechanical axes of the femur was defined by Walmsley (4). Eckhoff et al. (5) documented the location and orientation of the femoral sulcus, placing it lateral to the midplane between the femoral condyles and oriented between the anatomic and mechanical axes of the average femur.

The shape of the sulcus in the patellar surface of the femur is an important factor in the patellofemoral congruence (6-8). Its depth has been recorded as the osseous angle seen on axial radiographs (9,10) and in computed tomographic scans and magnetic resonance

imaging of the patellofemoral joint (7,8). In computed tomographic and ultrasonographic measurements, Martino et al. (11) reported that in normal subjects the mean sulcus angle was 132° . Others mentioned that the normal sulcus angle was 138° (12). The osseous sulcus angle was found to be inversely related to age, being flattest in young children and deepening steadily through growth (13). Many clinical investigators have related the radiological appearances of the patellofemoral joint to patellofemoral pain (14,15). An abnormally shallow sulcus has been reported to be an important factor in patellar instability both in adults and in children (9,10). The shape of the femoral sulcus discriminates between normal knee joints and joints displaying patellar instability (8,9,16,17).

The literature contains very little data on gender or bilateral comparative anatomical studies on the measurements of the sulcus angle. Therefore, in this

experimental study, we aimed to assess the osseous femoral sulcus angle radiologically in both right and left knees and osteologically in right and left femurs in males and females.

Materials and Methods

One hundred knee axial MRIs were analysed in the Radiology Department of Meram Faculty of Medicine, Selçuk University. The analysed images comprised 28 male right, 22 male left, 21 female right and 29 female left knees from subjects between 18 and 78 years old. The subjects were patients referred to the Orthopaedic Outpatient Clinic for anterior knee pain treatment. According to the radiologists' reports all cases were normal and none of the individuals showed any symptoms of pathology, and those with congenital deformities and patellar shape problems were excluded. The axial MRIs had been performed on a 1.5 Tesla superconducting unit (Picker Internationals, Highlands, Cleveland OH USA) with spin-echo sequences. The images were T1 weighted axial images (TR:674, TE:20). Slice thickness was 3.5 mm, gap 0.5 mm. Field of view was 20 cm and display matrix 160 x 256. Measurement of the sulcus angle was performed on the axial MR sequence at the level of the

deepest depression of the intercondylar groove between the ventral prominences of the condyles (Figure 1).

In addition to the above-mentioned samples studied by MRI measurements, the osseous angle of the trochlear groove was measured in 80 (40 right and 40 left) intact human adult dry femurs, which were obtained from the teaching skeletal collections at the Anatomy Department of the Medical Faculty, Selçuk University. For measuring the sulcus angles, these femora were placed in a supine position on a flat table and, with a goniometer (Figure 2), the measurement of the sulcus angles was performed at 30° opposite and below the longitudinal axis of the femur (Merchant radiological view) (10) (Figure 3). To avoid mismeasurement and to reduce the rate of error, all MRIs and dry bone measurements were performed by the same researcher. Due to the difficulty in the determination of the sex of an individual from a single femur (18), we restricted our study to the assessment of the sulcus angle in the right and left bones.

The data obtained were summarised as means \pm standard deviations. SPSS for Windows 10.0 was used for the statistical analysis. Student's t test was used to compare male-female, right-left and MRI-dry bone measurements.



Figure 1. Femoral sulcus angle measurement on MRI.

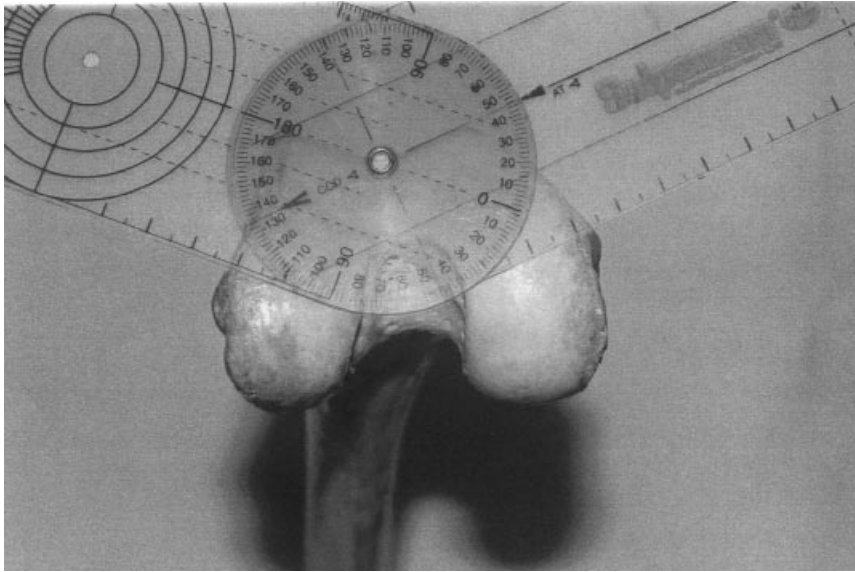


Figure 2. Femoral sulcus angle measurement on dry femur.

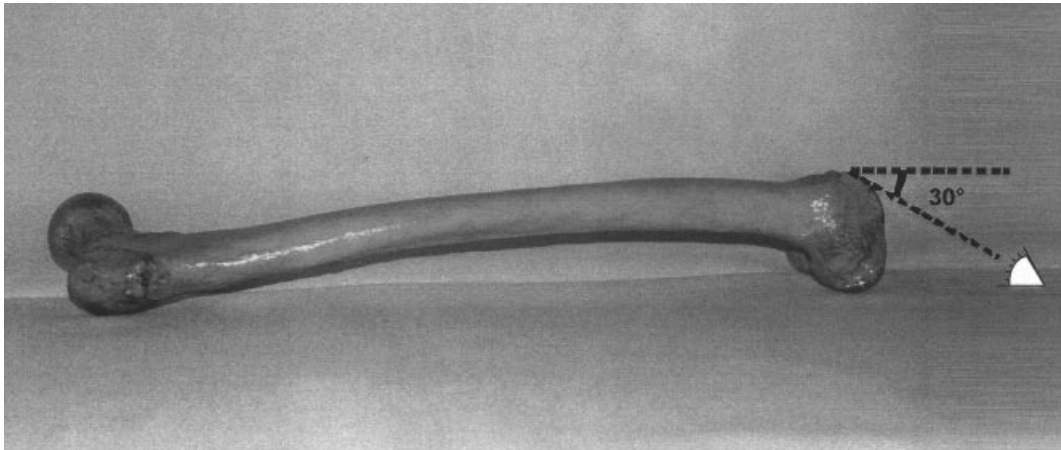


Figure 3. Femoral sulcus angle measurement on dry femur.

Results

In MRI measurements, the sulcus angle in males and females was 123°-144° (mean 134° ± SD 5.1°) and 119°-150° (mean 133.2° ± SD 6.7°), respectively (Table 1). In the right and left knees, the sulcus angles in MRIs were 124°-143° (mean 133.5° ± SD 5.2°) and 119°-150° (mean 134.5° ± SD 6.7°), respectively (Table 1). In MRI measurements no statistically significant differences were found between males and females or between right and left knees ($P > 0.05$) (Table 1).

The sulcus angles in the right and left dry bones were 125°-158° (mean 141.2° ± SD 7.9°) and 124°-162°

Table 1. Femoral sulcus angle measurements - Gender comparative results of the MRIs. (Maximum and minimum values, means and SD).

	Min.	Max.	Mean	SD	t	P
Male	123°	144°	134°	5.1°	1.305	0.195
Female	119°	150°	133.2°	6.7°		
Right	124°	143°	133.5°	5.2°	0.836	0.407
Left	119°	150°	134.5°	6.7°		

(mean $142.2^\circ \pm$ SD 9.7°), respectively (Table 2). In the dry bones measurements, no statistically significant differences were found between the right and left angles ($P > 0.05$) (Table 2).

General statistical comparisons between the sulcus angle in MRIs and in dry bones showed highly significant differences ($P < 0.01$) (Table 3).

Table 2. Femoral sulcus angle measurements - Bilateral comparative results of the dry femora. (Maximum and minimum values, means and SD).

	Min.	Max.	Mean	SD	t	P
Right	125°	158°	142.2°	9.7°	0.517	0.607
Left	124°	162°	141.2°	7.9°		

Table 3. Mean, standard deviations, t and P values of the sulcus angle measurements – Comparative results between MRIs and dry bones.

	Mean	SD	t	P
MRIs	134.0°	5.99°	6.916	0.000
Dry femora	141.7°	8.83°		

Discussion

In our study we found no significant difference between males and females or between right and left sides in either MRI or dry femur measurements. In a study of 100 knees of 25 boys and 25 girls, Nietosvaara (13) reported that no statistically significant differences were found between the left and the right knees or between the boys and girls. These results are in

agreement with those found in our study. According to Brattström (9), the mean osseous intercondylar angle was 142° in normal knees. Merchant (12) mentioned that the normal sulcus angle has been defined as 138° . In 100 human adult cadaver knees, the mean femoral sulcus angle was 144° (19). In our results, if the right and left dry femurs are considered together, the mean sulcus angle is 141.7° . Thus, our results are in agreement with those obtained by Brattström (9) and, compared with those of Merchant (12), our results were several degrees larger. In the ultrasonographic and computed tomographic measurements of the right knees of 11 normal subjects, Martino et al. (11) reported the mean sulcus angle to be 132° . This result is similar to our finding in the MRI measurements of the right and left knees. Regarding the consistency of the femoral sulcus angle measurement, Mulligan and Jones (20) applied 3 methods of radiographic projections to 74 cadaveric knees, and the mean sulcus angle was 138.6° , 141.6° and 137.4° , respectively. In addition to the above-mentioned data collected by other authors, our results indicate that differences in the techniques used in the assessment of the femoral sulcus angle could cause differences in its values. Our results suggest that there are no differences in the femoral osseous angle between men and women or between the right and left sides. These results could be useful for clinicians dealing with cases of pathologic alterations in the sulcus angle and malalignment of the patellofemoral joint.

Corresponding author:

Aynur Emine ÇİÇEKÇİBAŞI

Selçuk University, Meram Faculty of Medicine,

Department of Anatomy, 42080, Konya - Turkey

e-mail: cicekbasi@hotmail.com

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