Anatomic Study of Femoral Patellar Groove in Fetus

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Abstract: The authors performed a biometric analysis of the femoral patellar groove in fetus and compared their findings with those observed in adults. Forty-four formalin-preserved fetuses were studied (13–38 weeks). Digitalized images were used to obtain measurements (α angle of the groove, trochlear slopes θL and θM). A comparison of means of independent samples between our series and adults was performed. For each angle of the distal epiphysis (α, θL, θM) there was no significant difference between this fetal series and adults. This is the first biometry of the fetal patellar groove. The morphology of the lower femur appears to be the same in fetus and adults. The results of this study suggest that the anatomic characteristics of the patellar groove could have been integrated into the genome during the course of evolution. This would be in favor of a genetic origin of patellar groove dysplasia.

Key Words: femoral patellar groove, biometry, fetus

(*J Pediatr Orthop* 2005;25:305–308)

The lower extremity of the femur has a specific shape in humans compared with other species. It is characterized by an anterior groove in which patella is held during motion. This groove separates the two lips of the trochlea (medial and lateral), prolongation of the two condyles. In humans the lateral trochlear lip is more developed than the medial one, creating an asymmetric groove that is also specific to the human body.

Because of femoral obliquity, contraction of quadriceps leads to a lateral dislocation stress on the patella, and the more elevated lateral side of the patellar groove helps the patella stay in its correct place, acting as a wall against lateral dislocation. This specific shape fits to an oblique femur. It is known that femoral obliquity is not genetically determined but comes with orthostatism and biped walking.[1–3]

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Study conducted at the Unité d'anthropologie, Adaptabilité Biologique et Culturelle, CNRS-Université de la Méditerranée, Faculté de médecine Timone, France.

None of the authors received financial support for this study.

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Previous studies have suggested that the shape of the lower extremity of the femur is determined early in development, long before standing and walking,[4–6] but a biometric study has never been done. Our aim was to show that in the early stage of development this groove exists, determining a shape of the femoropatellar joint that could be similar in both fetus and adults, suggesting the hypothesis of a genetically determined shape of the femoral trochlea. We performed a biometric study of the anterior patellar groove of the distal femur epiphysis in fetus.

MATERIALS AND METHODS

The anatomic work was performed on formalin-preserved fetuses that had first been examined to determine the cause of death. Criteria for inclusion were absence of external malformation, absence of malformation of the viscera, absence of bone abnormality on entire body radiographic examination (including no delay in skeletal ossification), a normal karyotype, absence of maternal or family history of congenital disease, and absence of maternal pathology such as diabetes or high blood pressure. Fetal age was assessed using both last menstrual date and early ultrasonography. When data were not consistent, the age was not mentioned (three cases). Age was expressed in weeks after conception. Forty-four fetuses were included, all considered free of disease or malformation, ranging from 13 to 38 weeks. There were 16 females and 28 males.

For each fetus, the two femurs were fully dissected and removed. One picture of each femur was taken, according to the method described by Wanner.[7] The femur is placed on a hard desk, the lower epiphysis lying on the posterior side of the condyles and the upper extremity lying on the intertrochanteric crest. The picture is taken perpendicularly to the plane on which the femur lies, with the distal epiphysis in the middle of the screen. The camera used was an Olympus E-10 4 Mega pixel CCD.

One femur (left side) was damaged during the dissection, so the survey was achieved on 43 left femurs and 44 right femurs. Biometry was performed as follows (Fig. 1):

A: maximum altitude of the lateral margin of the patellar groove (mm)
B: minimum altitude of the lowest point of the groove (mm)
C: maximum altitude of the medial margin of the patellar groove (mm)
D: width of the lateral side of the patellar groove (mm)
E: width of the medial side of the patellar groove (mm)
θL: angle formed between a line passing through the point of maximum altitude of the lateral margin and the lowest

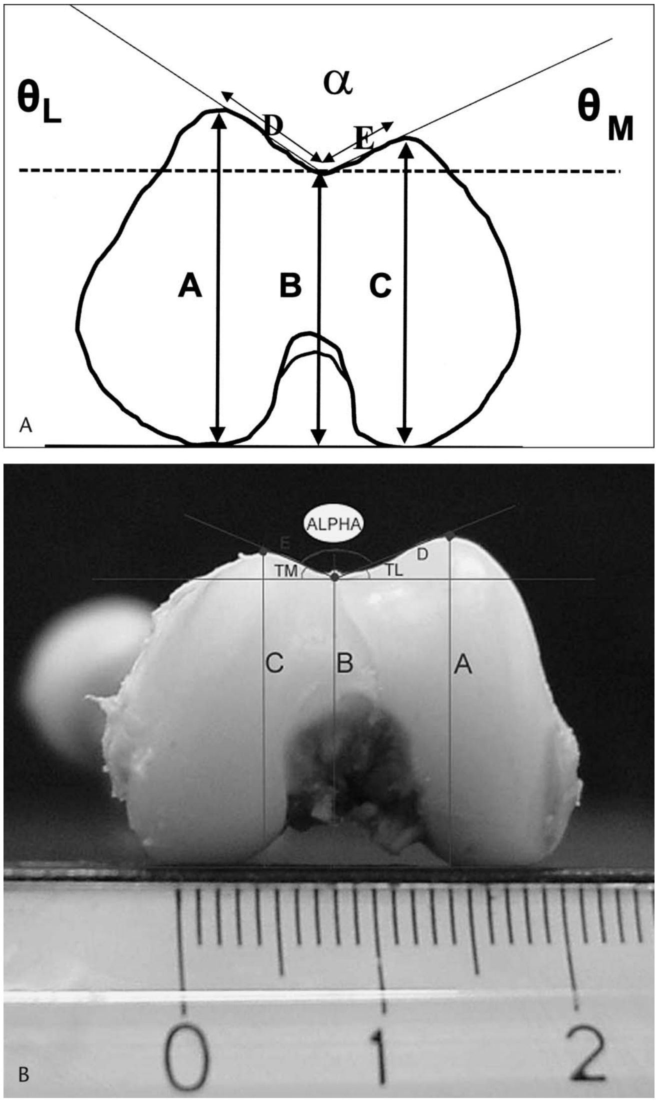

FIGURE 1. Inferior view of the lower femoral epiphysis. A, Maximum altitude of the lateral margin of the patellar groove (mm). B, Minimum altitude of the lowest point of the groove (mm). C, Maximum altitude of the medial margin of the patellar groove (mm). D, Width of the lateral side of the patellar groove (mm). E, Width of the medial side of the patellar groove (mm). θL: Angle formed between a line passing through the point of maximum altitude of the lateral margin and the lowest point of the groove and a horizontal line passing the lowest point of the groove (degrees). θM: Angle formed between a line passing through the point of maximum altitude of the medial margin and the lowest point of the groove and a horizontal line passing the lowest point of the groove (degrees). α: Angle of patellar groove enclosed by the medial and the lateral aspect (degrees).

point of the groove and a horizontal line passing the lowest point of the groove (degrees)

θM: angle formed between a line passing through the point of maximum altitude of the medial margin and the lowest point of the groove and a horizontal line passing the lowest point of the groove (degrees)

α: angle of patellar groove enclosed by the medial and the lateral aspect (degrees)

Statistical analysis was performed using SPSS 11.0 software. For each item we calculated mean (m_F) and variance (s^2_F). For each item, a Pearson correlation test was performed (each item was matched with other items and age and sex). A test comparing angle α between our series and that of Wanner[7] was performed. We used the mean comparison test of independent samples with known variances. Wanner worked on right femurs only, so the comparison was performed considering only the right side. The test was constructed as follow:

μ_A is the angle α mean in general adult population (unknown).
μ_F is the angle α mean in general fetal population (unknown).
m_A is the observed angle α mean in Wanner's adult sample.[7]
m_F is the observed angle α mean in our fetal sample.
s^2_A is the observed angle α variance in Wanner's adult sample.[7]
s^2_F is the observed angle α variance in our fetal sample.
n_A is the size of Wanner's adult sample.[7]
n_F is the size of our fetal sample.

The null hypothesis was $\mu_A = \mu_F$. If the null hypothesis is true, the law of large numbers allows to suppose that $Z_\alpha = m_A - m_F / \sqrt{s_A/n_A + s_F/n_F}$ has a standardized normal distribution.

α risk was chosen at 0.05.

For θL and θM angles, in the same way, $Z_{\theta L}$ and $Z_{\theta M}$ were determined to make a mean comparison test between our series and Wanner's.

RESULTS

Results are summarized in Table 1. All the observed femurs showed an anterior groove. Biometry was possible in all cases.

The Pearson correlation test showed that angles α, θL, and θM were not correlated with age or sex and lengths A, B, C, D, and E were not correlated with sex. There was a correlation between these five items and age ($P < 0.05$).

TABLE 1. Summary of Results

	Mean	Variance	n
AGE	22.61	26.84	41
α_R	148.80	24.70	44
α_L	145.92	35.61	43
θL_R	18.09	13.75	44
θL_L	20.95	15.48	43
θM_R	13.44	26.34	44
θM_L	13.13	29.70	43
A_R	9	5.15	44
A_L	9.21	6.55	43
B_R	8.06	4.08	44
B_L	8.11	5.15	43
C_R	8.42	5.95	44
C_L	8.64	6.15	43
D_R	3.06	0.98	44
D_L	3.06	1.14	43
E_R	2.38	0.76	44
E_L	2.36	0.56	43

When we compared our data with that of Wanner,[7] the mean comparison test of independent samples with known variances showed (Table 2) that for angles α, $Z_{\alpha} = 0.50$. The null hypothesis was not rejected with α risk at 0.05. There was no significant difference in the measurement of angle α between our series and Wanner's. For angle θL, $Z_{\theta L} = 0.78$. The null hypothesis was not rejected with α risk at 0.05. There was no significant difference in the measurement of angle θL between our series and Wanner's. For angle θM, $Z_{\theta M} = 1.03$. The null hypothesis was not rejected with α risk at 0.05. There was no significant difference in the measurement of angle θL between our series and Wanner's. For each of these three angles, no significant difference was shown between our fetal sample and Wanner's adult sample.

DISCUSSION

The literature is poor regarding the femoral patellar groove before birth. Bernays[8] in 1878 described the knee in embryo and showed that the knee starts its development before first muscular contractions. Vries[9] in 1908 described the fetal patella and showed that its morphology is comparable to that of adults from 16 weeks. Walmsley[6] in 1940 described a patellar groove in an embryo of 9 weeks with the lateral lip more elevated than the medial one. Gray and Gardner[5] in 1950 showed that the joint surfaces of the femoropatellar articulation are well shaped before both parts are properly fixed together. Doskocil[4] in 1985 published the first series concerning the anatomy of the patellar groove in embryo. There were 14 joints from formalin-preserved embryos ranging from 4 to 10 weeks of age. He established that from the earliest stage, the patellar groove is asymmetric, with a lateral lip bigger and wider than the medial one, but it was a subjective and visual observation, without any biometry or measurement. He pointed out that during development there is a distal migration of the patella to its final place, directly in front of the anterior patellar groove of the femur, and this occurs within the third month of intrauterine life. He insisted on variation of the patellar tendon orientation, in direct continuity with the rectus femoris muscle. This variation modifies the position of the patella in its femoral groove and could be responsible for joint surfaces mechanical remodeling. Doskocil[5] deduced an initially genetically determined shape of the femoropatellar joint, followed by a possible remodeling under mechanical effects during in utero life. Clavert[10] in 1991, Larsen[11] in 1993, and Mallet[12] in 1994 insisted on the rotation of the lower limb during embryogenesis, the myotome development, and the stabilization role of the vastus medialis muscle for the patella.

TABLE 2. Comparison of Fetus vs. Adult

	Fetus	Adults (Wanner)[7]
Mean angle α right	148.80	147.93
Variance angle α right	24.70	80.46
Mean angle θL right	18.09	17.33
Variance angle θL right	13.75	21.16
Mean angle θM right	13.44	14.78
Variance angle θM right	26.34	35.16
Number of subjects	44	32

There are more works in the literature concerning the femoropatellar groove and femoropatellar pathology in children and adults.[13–16] Only one series (Wanner's) contains a biometric evaluation of the patellar groove in adults.[7] This series comprised 32 right femurs from the Colorado University Anthropology Laboratory. The biometry was achieved according a strict protocol: the femur is placed on a hard desk, with its lower extremity lying on the condyle posterior side and its upper extremity lying on the intertrochanteric line. Each anatomic piece was shot with the camera placed facing the lower epiphysis. The same protocol was used in our survey. Wanner pointed out that the lateral side of the patellar groove is more elevated than the medial one, and that the lateral side of the patellar groove is about twice as wide as the medial one. He also showed that these parameters are very variable, but α, θL, and θM angles had a remarkable stability through his series.

More recently, Nietosvaara[16] published a series of knees of 50 normal children aged from birth to 18 years examined by ultrasonography to measure the angles of the bony intercondylar and the cartilaginous femoral patellar groove. At all ages, the angle of the cartilaginous groove was 134 to 155 degrees, although the osseous angle was found to be inversely related to the child's age. The authors suggested that the configuration of the patellar groove is already well developed at birth.

Our aim was to fill in the blank between Doskocil[4] and Wanner[7] by performing biometry of the patellar groove in fetuses. We chose to use the anatomic method described by Wanner to compare our results to Wanner's. The statistical comparison showed no difference between Wanner's results and our series concerning angles α, θL, and θM. These results strengthen Gray and Gardner's[5] and Doskocil's outcome,[4] which noted that the joint surfaces morphology of the knee is determined early during in utero life, implying a genetically determined shape of the femoropatellar joint.

An asymmetric patellar groove with a lateral side that sticks out, associated with an oblique femur, is a specific mark of biped walk for many authors.[17–20] These authors have published series comparing femurs in apes and humans. Apes present a wide and symmetrical groove on their distal femur, associated with a flat patella. In apes, the femoral shaft is vertical, showing no obliquity (Fig. 2). Moreover, apes, when they are occasionally bipedal during walking, cannot extend their knee joint. This explains why there is no lateral dislocation stress that is applied on the patella during contraction of the quadriceps. Under such mechanical conditions, there is no need for patellar containment in a deep groove and no need for special lateral strengthening of the container.

Tardieu[18,19] pointed out that femoral obliquity is acquired and has no genetic determinism. It is an epigenetic feature. During hominid evolution, the protrusion of the lateral trochlear lip was probably first acquired in response to femoral obliquity, containing the patella during the increasing practice of full knee extension, improving the efficiency of bipedal walking and the performances of early hominids. We can believe it was selected and genetically assimilated, explaining why we find this typical modern morphology in human fetus early in development, long before walking. This hypothesis of

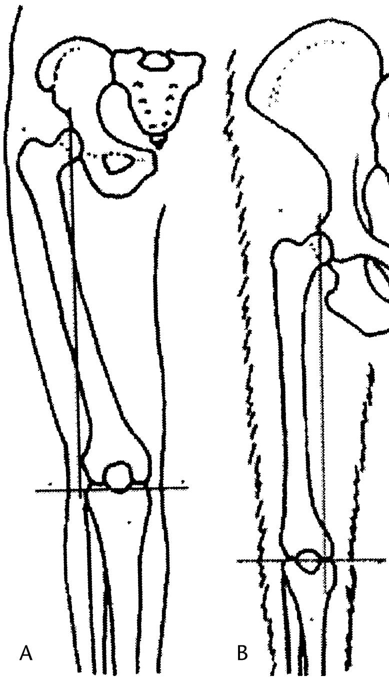

FIGURE 2. The femoral shaft is oblique in humans (A) and vertical in apes (B).

a genetic assimilation of progressive anatomic features concerning the anterior femoral patellar groove in human evolution must be scientifically assessed.

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