THE FEMORAL SULCUS IN CHILDREN

AN ULTRASONOGRAPHIC STUDY

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Both knees of 50 normal children aged from birth to 18 years were examined by ultrasonography to measure the angles of the bony intercondylar and the cartilaginous sulcus on the patellar surface of the femur. The osseous angle was inversely related to the age of the child and was completely flat in the youngest children. During growth it gradually gained depth to assume the shape of the overlying articular cartilage by adolescence. At all ages, however, the angle of the cartilaginous sulcus was between 134° and 155°. This suggests that the configuration of the patellar articulation is already well developed at birth.

J Bone Joint Surg [Br] 1994; 76-B:807-9.

Received 15 February 1994; Accepted 29 March 1994

The shape of the sulcus in the patellar surface of the femur is an important factor in patellofemoral congruence (Laurin et al 1978; Schutzer, Ramsby and Fulkerson 1986; Kujala et al 1989). Its depth has been recorded as the osseous angle seen on axial radiographs (Brattström 1964; Merchant et al 1974) and in CT scans and MRI of the patellofemoral joint (Schutzer et al 1986; Kujala et al 1989).

Axial radiographs do not show cartilaginous structures and therefore give little information on the patellofemoral articulation in children. Contrast methods are invasive and cumbersome, while CT or MRI of small children necessitates sedation or anaesthesia. Ultrasound has been used to help to locate an unossified congenitally dislocated patella (Walker, Rang and Daneman 1991) and to measure the sulcus angle and patellar tracking during flexion of the knee in children (Nietosvaara and Aalto 1993). Since cartilaginous and bony outlines can be viewed simultaneously, the thickness of the articular cartilage can also be measured (Rushfeldt, Mann and Harris 1981).

We used ultrasound to define the configuration of

both the osseous and cartilaginous femoral sulcus during different phases of growth.

SUBJECTS AND METHODS

One hundred knees of 25 boys and 25 girls aged from birth to 18 years and without knee problems were examined. The child sat with both legs supported and the knees at 90° flexion. A coupling gel (Ultrageeli, Christian Nissen, Berner, Helsinki, Finland) was used. The linear-array probe of a real-time ultrasound scanner (Acuson 128XP/10M [Computed Sonography, Mountain View, California] 7 MHz or Aloka SSD-630 [Aloka Co, Tokyo, Japan] 7.5 MHz) was held in the transverse plane for recording sulcus angles. The osseous and cartilaginous sulcus angles were measured at the level of the most ventral point on the lateral patellar facet of the femur (Fig. 1). The thickness of the articular cartilage was measured from the ultrasonogram at three points: medial and lateral walls, and deepest point of the sulcus.

RESULTS

The osseous sulcus angle was inversely related to age (correlation coefficient -0.92 , $p < 0.001$), being flattest in the youngest children and deepening steadily through growth. By adolescence it had become the same as the cartilaginous sulcus angle (Figs 2 and 3). By contrast, the cartilaginous sulcus angle stayed virtually constant from birth to adolescence with a mean value of $146^\circ \pm 3.7^\circ$ (134 to 155). There was a trend to slight narrowing of the cartilaginous angle during growth (correlation coefficient -0.21 , $p < 0.05$). No statistically significant differences were found between left and right knees or between boys and girls.

The thickest cartilage, up to 8 mm, was seen on the lateral facet in small children, but during growth this difference gradually diminished and the cartilage became thinner on both sides of the sulcus. By adolescence the cartilage layer was thickest at the deepest point of the sulcus (Fig. 4).

DISCUSSION

Although cartilage is visualised in CT scans and MRI of the patellofemoral joint, only the osseous angle has been

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0301-620X/94/5856 \$2.00

Fig. 1

The linear-array probe is placed transversely over the most anterior point on the lateral patellar facet of the femur (v), just distal to the distal epiphyseal line (el). The transverse sonogram at this point shows the lateral (lc) and the medial facets of the patellar sulcus (mc). Lines are constructed to give the cartilaginous sulcus angle (CSA) with its apex at the deepest point. The osseous sulcus angle (osa) is measured in a similar way. Cartilage thickness can also be measured.

Fig. 2

Typical transverse sonograms in children aged 1, 4, 8, 11 and 14 years (A, B, C, D and E, respectively). The white osseous outline and the overlying black articular cartilage are clearly visible.

Fig. 3

The osseous (OSA) and the cartilaginous sulcus angles (CSA) related to age in 100 knees.

Fig. 4

Thickness of the articular cartilage on the lateral (lc), and the medial patellar facets of the femur (mc) and at the apex of the sulcus (s). Regression lines, estimated by the least-squares method, are shown. There is a highly significant inverse correlation ($p < 0.001$) with age for all three measurements (correlation coefficients, -0.87 for lc, -0.89 for mc and -0.45 for s).

recorded (Schutzer et al 1986; Kujala et al 1989). Furthermore, both methods provide images at the level of the centre of the patellar articular cartilage. This makes it difficult to compare measurements of the femoral sulcus, because the vertical position of the patella varies between individuals.

The ultrasonographic technique now described allows for measurement of both osseous and cartilaginous sulci at a constant and reproducible point of reference, the most anterior part of the lateral patellar facet of the femur. The accuracy and validity of this technique have been documented (Modest, Murphy and Mann 1989; Nietosvaara and Aalto 1993).

In 100 human adult cadaver knees the mean femoral sulcus angle has been reported to be 144° (Buard et al 1981), and the present findings for the mean cartilaginous angle were much the same, averaging 146°. This accords with the finding of Walmsley (1939), that the cartilaginous sulcus is already in adult form in embryos and is well developed at birth. The bony outline, however, gains depth during growth.

In adults, the cartilage layer appears to be thickest,

up to 4 mm, in the intercondylar notch, with thinning towards the margins of the sulcus (Ateshian, Soslowsky and Mow 1991). The present study confirmed that cartilage thickness medially and laterally diminished during growth.

An abnormally shallow sulcus has been reported to be an important factor in patellar instability both in adults and in children (Brattström 1964; Merchant et al 1974; Rünöw 1983; Dowd and Bentley 1986; Schutzer et al 1986; Kujala et al 1989; Nietosvaara and Aalto 1993; Nietosvaara, Aalto and Kallio 1994). The cause of this dysplasia may be developmental or a consequence of false tracking of the patella during childhood. Ultrasonography allows the configuration of the cartilaginous sulcus to be displayed; and abnormalities detected at all stages of growth.

This study has been supported by grants from the Foundation of Orthopaedics and Traumatology in Finland, the Orion Corporation Research Foundation and the Medical Society of Finland.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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