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ORIGINAL ARTICLE

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Stage-I osteochondritis dissecans versus normal variants of ossification in the knee in children

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Abstract ***Background***: Juvenile osteochondritis dissecans (OCD) has a better prognosis than the adult type. ***Objective***: We postulated that the excellent prognosis of juvenile OCD could be explained, at least in part, by the erroneous diagnosis of some developmental variants of ossification as stage-I OCD. ***Materials and methods***: Knee MRIs of 38 children, ages 7.5–17.7 years (mean and median age 13 years), were retrospectively reviewed to look for features that might separate normal variants of ossification from stage-I OCD. These included age, gender, site, configuration of the lesion, residual cartilaginous model and presence of edema. ***Results***: Twenty-three patients (32 condyles) had ossification defects with intact articular cartilage suggestive of stage-I lesions. No stage-II lesions were seen in the posterior femoral condyles. Accessory ossification centers were seen in 11/16 posterior condyles and 3/16 central condyles. Spiculation of existing ossification was seen in 12/16 posterior condylar lesions and 1/16 central condyles. There was a predominance of accessory ossifications and spiculations in the patients with 10% or greater residual cartilaginous model. No edema signal greater than diaphyseal red-marrow signal was seen in the posterior condyles. Clinical follow-up ranged from 0.5 to 38 months, with clinical improvement in 22 out of 23 patients. ***Conclusion***: Inclusion of normal variants in the stage-I OCD category might explain, in part, the marked difference in published outcome between the juvenile and adult forms of OCD. Ossification defects in the posterior femoral condyles with intact overlying articular cartilage, accessory ossification centers, spiculation, residual cartilaginous model, and lack of bone-marrow edema are features of developmental variants rather than OCD.

Keywords Knee · MRI · Juvenile osteochondritis dissecans · Developmental variants

Introduction

The clinical outcome of osteochondritis dissecans (OCD) in children is markedly better than it is in adults [1–3]. We postulated that the excellent prognosis of juvenile OCD could be explained, at least in part, by the erroneous diagnosis of some developmental variants of ossification as stage-I OCD. Because grade-I OCD has a defect in subchondral bone without articular cartilage interruption, it could be confused with variants of ossification during normal development of the knee. We retrospectively reviewed knee MRIs performed from 1995 to 2003 to find patients with criteria of stage-I OCD to look for developmental features, symmetry, lack of tissue reaction, age, gender, and other features that might separate developmental variants from stage-I

OCD. Because the generally accepted treatment of stage-I juvenile OCD is restriction of activity, this has a significant effect on patient lifestyle.

Materials and methods

The study was approved by our Institutional Review Board. All pediatric radiology reports from 1995 to 2003 were word-searched for the term ''osteochondritis dissecans'' using our institution's database. This search returned 54 patients. Thirty-eight of these 54 patients had knee MRIs performed at our institution.

MRI was performed on a 1.5-T unit (General Electric Medical Systems, Milwaukee, Wis.) using a dedicated extremity coil. Axial T1-weighted localizer (T1), sagittal proton density-weighted (PD), and axial and coronal heavily T2-weighted PD fat-saturated (T2) acquisitions were obtained on all patients. 3D T2-weighted gradient echo sequences (GRASS: flip angle 30, matrix at least 256×224) were obtained in 22 of the 38 patients. No IV contrast medium was used. Only symptomatic knees were imaged. Only two patients had complaints in both knees and had bilateral knee MRIs. No contralateral asymptomatic knees were scanned for comparison.

The MR imaging studies were evaluated by two pediatric radiologists, one of them blinded to final outcomes and symptomatology. Stage-I OCD was defined by Bohndorf's classification [4], as subchondral defects of low intensity on T1, heterogeneous signal on T2, intact articular cartilage, no cystic area greater than 5 mm on T2, and no fluid rim at the interface. We excluded stage-II lesions with cartilaginous defects partly or fully detached, subchondral cystic areas greater than 5 mm on T2 and osteochondral fractures. Lesion sites were classified as to right or left knee, medial or lateral, intercondylar or inferocentral femoral condyle in accordance with Cahill et al. [5], and anterior/central / posterior condyle in accordance with Harding [6] and Hughston et al. [7] (Fig. 1). The osseous defect configurations were categorized as puzzle piece, incomplete puzzle piece, spiculated and/or accessory ossification centers (Fig. 2). Puzzle piece referred to an osseous defect filled with an ossification that fit the defect; incomplete puzzle piece, a defect with incomplete or no ossification filling the defect. A rough estimate of non-ossified epiphyseal cartilaginous model was made by visual comparison with a standard set of concentric circles representing area differences of 10, 20, 30, 40, and 50%. Surrounding edema was graded, greater than (+) or less than (−) femoral diaphyseal red-marrow signal on T2-weighted fat-saturated sequences by scrolling through the images.

All stage-I OCD cases were treated with restriction of activity. The degree of compliance was unknown. Follow-up radiographic studies were assessed for change in size or disappearance of the lesion. The medical records were reviewed for final outcomes, as reflected by symptoms, surgeries, and follow-up radiological studies.

Results

Of the 38 patients with a diagnosis of OCD on knee MRIs at our institution, 15 patients were excluded from the study after we noted the location of the lesions, because they had condylar cartilage disruptions consistent with stage-II OCD or osteochondral fractures. Twenty-three patients (25 knees, 32 condyles) had findings consistent with stage-I disease as defined by Bohndorf [4].

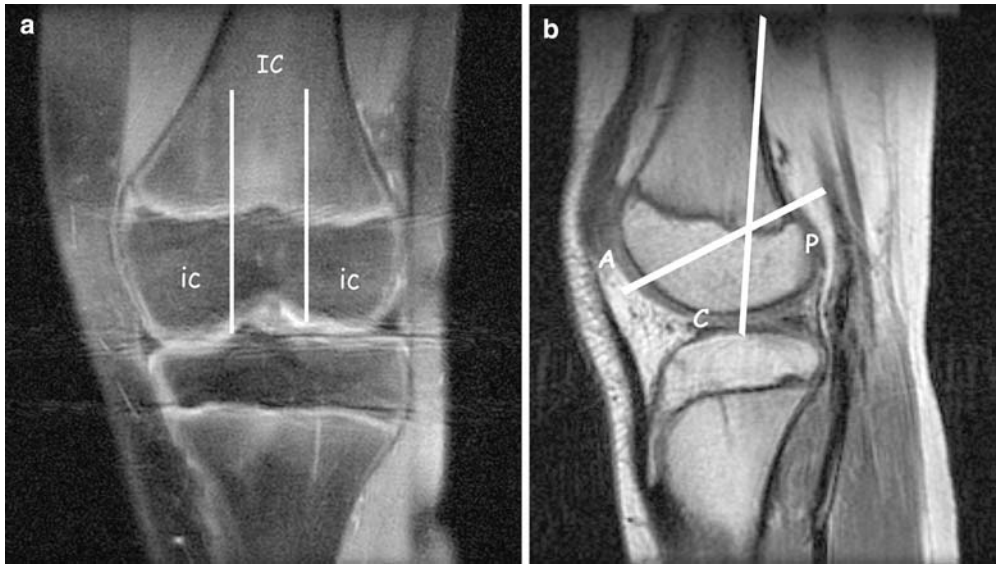

Fig. 1 MR image. **a** Coronally, lesion sites were classified as intercondylar (*IC*; lateral surface of medial condyle and medial surface of lateral condyle) or inferocentral (*ic*; the rest of the condylar surface), as illustrated on this T2-weighted fat-suppressed coronal image. **b** Sagittally, lesion sites were classified as anterior (*A*), central (*C*), or posterior (*P*) in relation to extension of the posterior femoral diaphyseal cortical line distally and a line extending anteriorly from the roof at the intercondylar notch estimated by scrolling through the sagittal images, shown here on a sagittal PD image

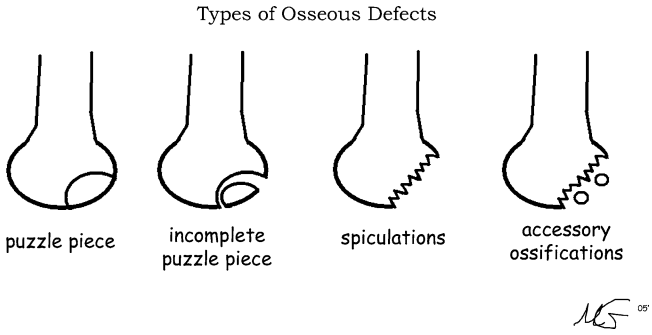

Fig. 2 MR configuration of osseous defects in distal femoral epiphyses. Puzzle piece refers to an osseous defect filled with an ossification that fits the defect; incomplete puzzle piece refers to incomplete or no ossification filling the defect

There were 16 boys and 7 girls. Ages ranged from 7.5 to 17.7 years (mean and median 13 years). The physes were open in all but one patient, who was 17 years old. Residual non-ossified cartilaginous model of the epiphysis ranged from 0 to 50% (Fig. 3), corresponding roughly to age and sex as expected from developmental standards [8].

Of the 38 patients with MRI diagnosis of OCD in our study, no stage-II lesions were located in the posterior femoral condyles. Sites of the stage-I lesions are presented in Table 1. The lesions were fairly evenly distributed between medial and lateral condyles (17:15) and between central and posterior location (16:16). Seven knees had involvement of both medial and lateral condyles, including three out the four knees of the two patients who had lesions in both knees. Five of these seven knees had involvement of the posterior condyle. There were only three intercondylar lesions, all of which were central in location.

Lesion configuration is presented in Table 2. Accessory ossification centers (Fig. 3), as described in the literature [9–11], were seen in 11/16 posterior and 3/16 central condyles. The spiculated configuration (Fig. 3), which resembled the rapid growth phase described by Ribbing, Sontag and Pyle, and Caffey et al. [9–11] in younger patients, was seen in 12 out of 16 posterior condylar lesions with an even distribution between medial and lateral condyles and in only 1 out of 16 central lesions. Puzzle piece or incomplete puzzle-piece configuration (Figs. 4, 5) were seen fairly uniformly distributed over the entire group. There was a predominance of accessory ossifications and spiculations in the 12 patients with 10–50% model as compared to the 11 patients with less than 10% model (Table 3). Edema signal greater than red-marrow signal was seen associated with five central lesions only (Table 2).

Thirteen of 23 patients (14 knees) had MR or radiographic follow-up, with evidence of healing in 7 patients (eight knees) and no change in 5 patients. One lesion was less distinct but larger 4 months after diagnosis, but was not clinically symptomatic at 5 months (Fig. 5). No condylar articular cartilage defects were

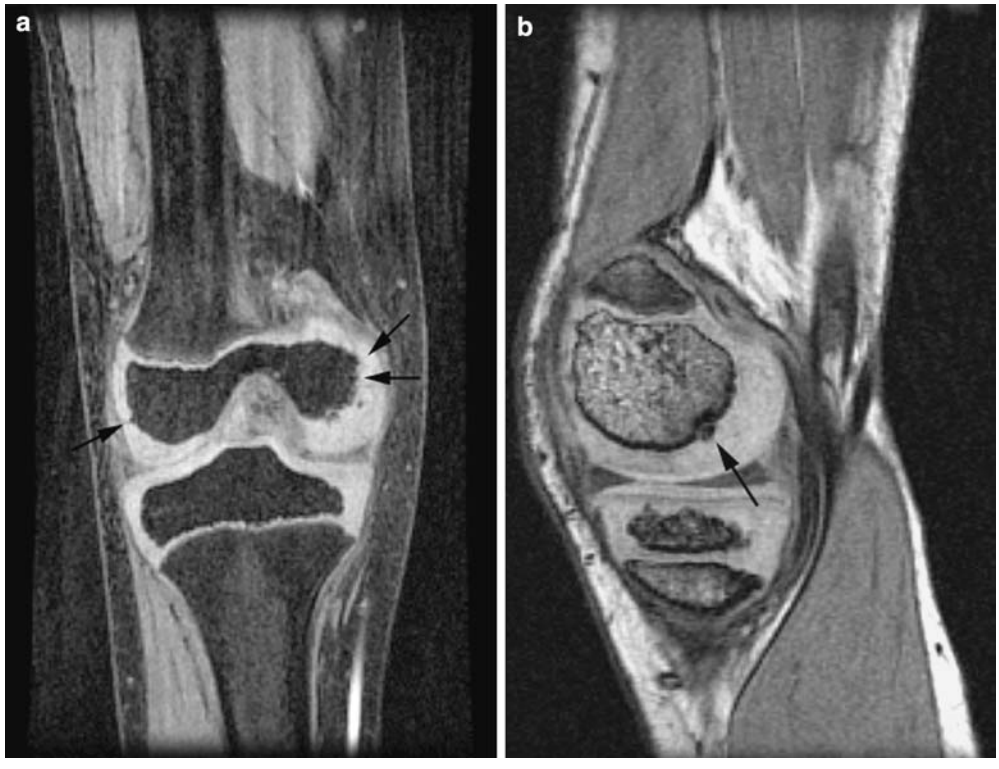

Fig. 3 Normal variant simulating stage-I OCD. A 7-year-old boy soccer player presented with knee pain with no discrete injury. No knee complaints on 3.5-year clinical follow-up. **a** On T2-weighted sequence, 50% cartilaginous model is seen in the distal femoral epiphysis with spiculations (*arrows*) and small accessory ossifications in both medial and lateral condyles. **b** The small accessory ossification (*arrow*) in the posterior medial condyle has an OCD-like appearance on GRASS sequence

Table 1 Sites of OCD-like lesions of the femoral condyles on coronal and sagittal MR imaging (after Yoshida et al. [3])

Site of lesion	Intercondylar			Inferocentral			Total
	Anterior	Central	Posterior	Anterior	Central	Posterior	
Medial condyle		1			7	9	17
Lateral condyle		2			6	7	15
Total		3			13	16	32

Table 2 Configuration and location of OCD-like femoral lesions on MR imaging

	Puzzle piece	Incomplete puzzle piece	Spiculations	Accessory ossifications	Edema
Posterior condyle	5	9	12	11	0
Central condyle	6	9	1	3	5

seen in the three patients who had arthroscopies (performed for other problems: meniscal tear, anterior cruciate tear and patellar dislocation). All 23 patients had clinical follow-up ranging from 0.5 to 38 months (mean 17 months, median 13 months). All but one patient had decreased pain or resolution of pain. The exception had only 2 weeks of follow-up.

Discussion

OCD is a localized condition of subchondral bone and overlying articular cartilage most commonly occurring in the knee. The etiology is controversial, but appears to include mechanical and traumatic factors as well as a familial predisposition [1, 2, 4, 12]. The literature has been confused with other osteochondral abnormalities including osteochondral fractures, osteonecrosis, epiphyseal dysplasias, and accessory ossification centers [1, 2]. Although osteochondral fractures [1] have disruption of the articular cartilage and therefore should not be confused with stage-I OCD, such disruptions can be very subtle. Osteonecrosis and epiphyseal dysplasias are usually differentiated from OCD by clinical history and involvement of additional joints. Although the diagnosis can usually be made on radiography, MRI has been

Table 3 Frequencies of configurations in distal femoral epiphyses with residual cartilaginous model

Model	Puzzle piece	Incomplete puzzle piece	Spiculations	Accessory ossifications	Number of patients
< 10%	5	7	0	1	11
10–50%	6	11	13	13	12

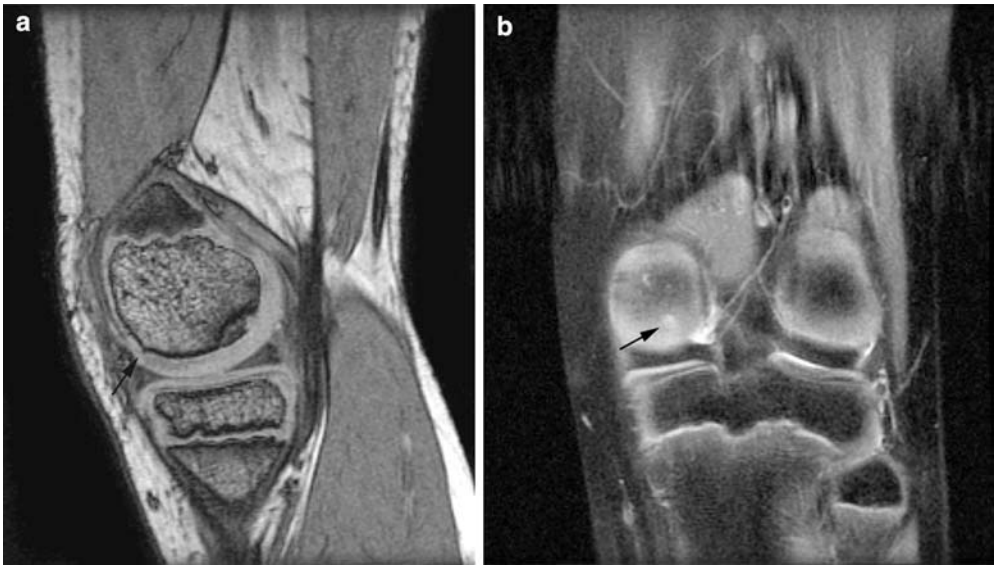

Fig. 4 Probable normal variant simulating stage-I OCD. A 12-year-old boy presented with a 3-month history of knee pain and acute exacerbation after jumping on a trampoline. No knee complaints at the 12-month clinical follow-up. **a** Posterior ossification defect in the medial femoral condyle has ossification partly filling the defect like an incomplete puzzle piece on GRASS sequence. Small spiculation (*arrow*) is seen. **b** Signal on T2-weighted sequence in the region of the lesion (*arrow*) was less than that of red marrow (assessed by scrolling through the entire sequence)

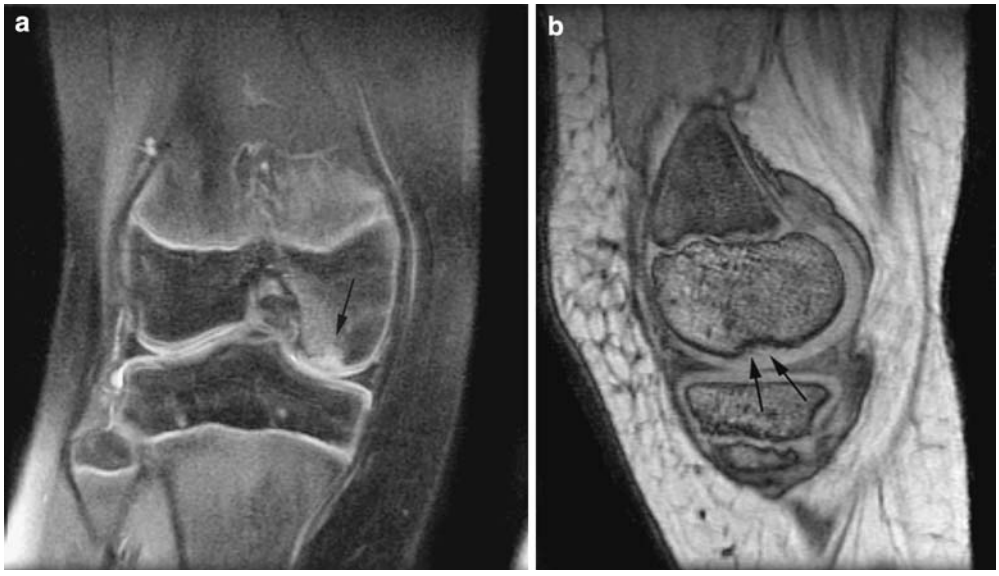

Fig. 5 Indeterminate lesion with features of both normal variant and OCD. A 9-year-old girl had intermittent knee pain for 6 months after a week of intensive snowboarding. Radiograph at the 4-month follow-up showed a larger, less distinct lesion. There were no knee complaints at the 5-month clinical follow-up. **a** T2-weighted sequence shows the inferocentral lesion in the medial femoral condyle with T2 signal higher than red marrow consistent with bone edema (*arrow*). **b** GRASS sequence demonstrates intact articular cartilage with an ossification defect of the incomplete puzzle piece type (*arrows*) in the central portion of the condyle. Small spiculations and accessory ossification centers are seen

shown to be useful in the assessment of the status of the overlying cartilage and the stability of the fragment [4, 13–16]. These, in turn, determine treatment [2, 17].

It is generally accepted that juvenile OCD, presenting with variable pain and/or mechanical symptoms before fusion of the physes, is a separate type from the adult form. The prognosis of juvenile OCD is much better as 80–90% resolve with activity restriction alone [1, 3, 18]. A much higher percentage of children present in stage I compared to adults [1, 3, 13, 15, 16, 19–21] and stage-I OCD has an excellent prognosis [3, 5, 17, 19, 20]. Bilaterality is more common in the juvenile form, up to 30% of cases, as compared to 3% of cases in adults [3, 13, 15, 19, 21]. Gender distribution is more even in the juvenile form [17, 19–22].

The frequency of lateral condylar involvement is much higher in juvenile OCD than in the adult form, at least in more current studies. Our study and that of Yoshida et al. [3] had medial to lateral condylar involvement ratios of 1.1:1 and 0.7:1, respectively. Earlier studies of Mubarak and Carroll [21] in 1981, Linden [23] in 1977, and Green and Banks [19] in 1953 had ratios of 2.8:1, 4:1, and 4.2:1, which were more like the adult form, where the medial femoral intercondylar lesions predominate with ratios around 4:1. The recent increase in MR imaging of children's knees with possible misdiagnosis of normal variants as stage-I OCD could explain this shift because normal variants predominate in the lateral condyle [11].

The puzzle and incomplete puzzle configurations were evenly distributed over the condyles and, therefore, were not distinguishing features. Multiple ossification centers, spiculated margins of ossification, and separate calcifications have been described in the process of ossification of the cartilaginous model of the distal femur during normal skeletal maturation with a high rate of bilaterality [9–11, 18]. Nawata et al. [24] described a series of four patients aged 8, 10, 11, and 11 years, with MRIs of both symptomatic and contralateral knees that showed bilateral spiculations and accessory ossifications in the posterior lateral femoral condyles. Accessory ossification centers were primarily seen posteriorly and inferocentrally by Sontag and Pyle [10] and Mubarak and Carroll [21] in studies of developmental changes. There was a predominance of the accessory ossifications (11/14) and spiculations (12/13) in the posterior condyles in our study, especially in those with 10% or greater cartilaginous model. We believe that the spiculations and accessory ossifications seen, at least in the posterior condyles, are developmental variation rather than true OCD lesions. This would account, in part, for the difference in the site of the ossification defects in the juvenile versus adult knee. It would also be consistent with the higher rate of bilaterality and more even gender distribution seen in the juvenile-type OCD because developmental variants are often bilateral with no gender bias. As expected, more developmental variants are seen in patients with more residual cartilaginous model, i.e., those in an earlier stage of development. Some authors [9, 11, 22] have suggested that accessory ossification centers predispose to OCD. We disagree. If this were true, we would expect to see a higher frequency of

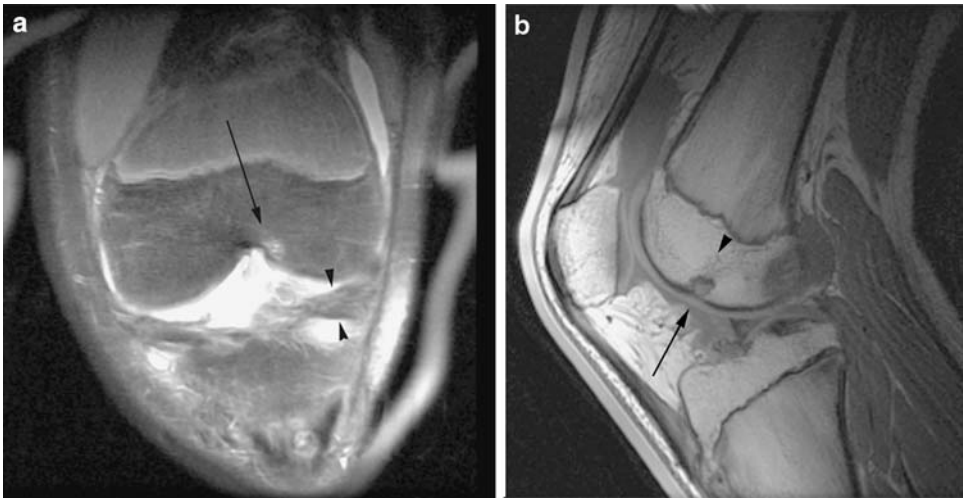

Fig. 6 Osteochondritis dissecans. A 15-year-old boy with a hockey injury and flipped bucket-handle tear of the posterior horn of the lateral meniscus (*arrowheads* show the increased thickness of the meniscus from superimposition of the flipped posterior horn on the anterior horn). Examination at the time of surgical repair of the meniscus revealed no softening or break of the condylar articular cartilage. He was clinically asymptomatic at the 20-month follow-up. **a** T2-weighted sequence shows the left femoral intercondylar lesion with a small amount of surrounding bone edema (*arrow*). **b** GRASS sequence demonstrates intact articular cartilage with an incomplete puzzle-piece-type ossification defect (*arrow*) and bone edema (*arrowhead*) in the central portion of the condyle

lateral condylar OCD in adults than is described in the literature because more accessory ossification centers are located laterally [11].

Outerbridge [25] describes a series of 14 patients with the rare occurrence of OCD of the posterior weight-bearing surface of the posterior femoral condyles in which nine patients had detached fragments; however, the images provided in that report show involvement of the central condyle, as well. None of our stage-II lesions occurred in the posterior femoral condyles. No bone-marrow edema to suggest a pathologic process was seen surrounding posterior femoral defects.

Four major constellations of findings were identified and are illustrated in Figs. 3, 4, 5, and 6. Accessory ossifications and spiculations in the posterior inferocentral condyles with a large amount of residual cartilaginous model and no associated edema, possibly bicondylar or bilateral, represent normal variants of ossification (Fig. 3). Posterior inferocentral condylar lesions with puzzle or incomplete puzzle-piece configuration and some residual cartilaginous model probably also represent normal variants (Fig. 4). Central inferocentral condylar lesions of any configuration with or without edema fall in the indeterminate range (Fig. 5). Central intracondylar lesions with surrounding edema and puzzle/ incomplete puzzle configuration fit every definition of OCD (Fig. 6).

Our study has several limitations. No pathologic material can be obtained from stage-I OCD. Clinical outcome cannot be used to support or refute our hypothesis, as the outcome was essentially the same for all our patients. The series is not large enough to do a meaningful statistical analysis of the location and characteristics of the lesions. All MRIs were of symptomatic knees. No contralateral asymptomatic knees were scanned.

Normal variation in the ossification patterns of the femoral condyle can mimic stage-I OCD. Inclusion of normal variants in the stage-I OCD category might explain, in part, the marked difference in published outcome between the juvenile and adult forms of OCD. We found several features that are helpful in distinguishing normal variants from OCD. Location in the inferocentral posterior femoral condyles with intact overlying articular cartilage, accessory ossification centers, spiculations, residual cartilaginous model, and lack of bone-marrow edema are features of normal variants, not OCD.

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