Knee osteochondral fractures in skeletally immature patients: French multicenter study

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Introduction: Femoral or patellar osteochondral fractures complicating patellar dislocation are more frequently observed in adolescents than in adults. These incidental lesions of vulnerable joint cartilage are often neglected in the initial phase, which is regrettable given their good capacity for healing after repositioning. The objective of this study was to investigate the characteristics and analyze the results of repositioning these fractures in skeletally immature patients.

Material and methods: This retrospective multicenter study grouped 14 patients and knees (seven females). The mean age at the time of the accident was 12.9 years (range, 11.2–14.9 years) for the girls and 14 years (range, 12.2–15 years) for the boys. These fractures involved the lateral condyle in nine cases and the patella in five cases. The injury mechanism was secondary to demonstrated patellar dislocation (n = 9) or a direct impact (n = 4). In nine cases out of 14, a leisure sports accident was the cause. The injury was treated a mean 5.2 days (range, 0–20 days) after the accident. All of the detached fragments were repositioned surgically with screw fixation (n = 5), resorbable pins (n = 5), or pull-out suture (n = 4). Biological glue was added for six patients. Patellar stabilization was associated during the same procedure in two cases.

Results: No postoperative complications were observed. The results at the mean follow-up of 30 months (range, 15–89 months) showed no revision for failure, with all of the fractures demonstrating union at the final examination. The mean IKDC 2000 subjective score was 88 ± 6 (range, 79–98) out of 100 points. The subjective satisfaction level was very satisfied in two cases and satisfied in the 12 others. The final IKDC score was A for eight patients, B for five patients, and C for one patient. Three patients underwent secondary patellar stabilization surgery.

KEYWORDS
Knee; Osteochondral fracture; Children; Adolescent; Treatment outcome; Prognosis
Conclusion: Better knowledge of this fracture and attentive reading of the radiographic images of a knee with hemarthrosis should result in more frequent diagnosis of this condition and adapted treatment. Unexplained hemarthrosis in a context of trochlear dysplasia should be considered to be associated with an OCF until proof of the contrary. A fragment released in a weightbearing zone should ideally be repositioned within 10 days but remains possible at 2 months. It regularly provides bone union and good results in children.

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Introduction

Whereas osteochondritis is the leading cause of cartilage loss of the knee’s medial condyle in children, osteochondral fractures (OCFs) preferentially involve the lateral condyle (as well as the femoropatellar compartment) [1, 2]. The rare cases of osteochondritis of the lateral condyle should suggest a search for malformative discoid meniscus [3]. At an SFA symposium titled “Cartilage losses of the knee”, [4], we studied osteochondral fractures of the knee in children. This fracture, frequently neglected in its initial phase, has motivated a multicenter study.

The literature reports a few isolated cases, emphasizing the diagnostic problems [4—7] of the possible fixation techniques [8—11], but very few series provide information on the prognosis of these lesions [2—12].

Certain experimental studies have demonstrated that these lesions are very distinct, depending on whether or not they occurred in skeletally immature animals [13, 14]. The aim of the present study was to analyze healing after repositioning and fixation of an osteochondral fracture in children.

We hypothesize that the excellent healing ability of these lesions in children should encourage repositioning and fixation of the osteochondral fragment.

Material and methods

This was a retrospective multicenter study. A survey had been sent to members of the French Pediatric Orthopaedic Society (Société française en orthopédie pédiatrique [Sofop]) via e-mail to inventory the medical files of cartilage loss on knee with open physi. Seven pediatric centers responded and contributed material to the studies with a total of 51 medical files (Toulouse, Tours, Nice, Strasbourg, Anger, Gap, and Lyon). After having ruled out cases of osteochondritis, only osteochondral fractures (OCFs) were retained.

The patient inclusion criteria were the following: (a) knee with open physi at time of accident; (b) surgical repositioning of the avulsion fragment; (c) 2 years minimum follow-up at revision; and (d) no previous knee surgery. Epiphysal ligament avulsion fractures were excluded from this study.

Between 2000 and 2009, 14 patients (seven females, seven males) and 14 knees (eight left, six right) were included in the study. The mean age at the time of the accident was 12.9 years (range, 11.2—14.9 years) for the girls and 14 years (range, 12.2—15 years) for the boys. The patients’ mean weight was 47 kg (range, 36—63 kg), their mean height was 152 cm (range, 140—181 cm), and the mean BMI was 20.29 (range, 18.3—24).

These OCFs involved the lateral condyle in nine cases and the patella in five cases.

The injury mechanism was secondary to objective dislocation of the patella in nine patients (five of whom had already presented at least one episode of patellar dislocation) and was related to direct impact resulting from falling from a height in four patients. Nine out of 14 patients had experienced a sports accident, for the most part leisure sports. The energy at the time of injury was qualified as low (n = 8), very low (n = 3), high (n = 1), and was not determined in two cases. None of the patients presented associated peripheral laxity or central pivot involvement.

Treatment was provided within a mean 5.2 days (range, 0—20 days) of the accident; five patients were managed in an emergency setting within 24 hours. Arthroscopy surgery was performed in 12 cases and arthroscopy in two cases. After repositioning, the fragments were set with screw fixation (n = 5), resorbable pins (n = 5), or pull-out suture (n = 4). Six patients also received biological glue. In only two cases out of 14 was a patellar Goldthwait stabilization procedure associated with the OCF treatment.

In the recovery period, 10 patients were immobilized. For the condylar lesions, the time to loading with partial weightbearing was 5 weeks (range, 0—6 weeks) and the time to total weightbearing was 8 weeks (range, 6—12 weeks). No postoperative complications were observed.

Assessment method

The revision exam included a subjective patient satisfaction evaluation as well as an objective clinical examination using the IKDC 2000 system. An AP x-ray of the knee was taken and an MRI for five patients.

No statistical analysis was possible given the small sample studied.

Results

The patients were evaluated at a mean follow-up of 30 months (range, 15—89 months). There was no revision for osteochondral fragment repositioning failure. All the fractures seemed to have achieved union at the final examination, but this was documented with MRI for only five patients. For three knees, secondary patellar stabilization...
surgery was performed at a later date because of discomfort related to new episodes of instability.

The mean subjective IKDC 2000 score at the last follow-up was $88 \pm 6$ (range, 79–98) out of 100 points. The subjective satisfaction score was ‘‘very satisfied’’ in two cases and ‘‘satisfied’’ in 12. The clinical examination at revision showed a dry knee in 13 cases out of 14 and the presence of joint effusion in one case. The mean range of motion in flexion was $140^\circ$ (range, 130–145$^\circ$), for a mean 5$^\circ$ range of motion deficit (range, 0–14$^\circ$) compared to the flexion in the normal contralateral knee. Amyotrophy of the thigh was found in four cases out of 13. The final IKDC score was A for eight patients, B for five patients, and C for one patient.

Discussion

The hypothesis postulated, in this study, seems to be verified: repositioning OCF of the knee with open physis consistently provides good short-term clinical results, encouraging a decisively surgical approach.

The prevalence of osteochondral fractures is unknown. These fractures seem to be very rare judging from the few short retrospective series that report only the results of surgical repositioning (Walsh et al., 13 cases; Toupin and Lechevallier, 19 cases) [2,12]. These fractures may be much more frequent in prospective studies on acute patellar dislocation because they are involved in 30 and 50% of dislocations [15,16]. However, a large number of these lesions do not warrant repositioning. The urge of competitive sports in younger patients and the better diagnosis with modern imaging techniques could explain the increase in these cases.

MRI studies have shown that these are frequently incidental lesions due to tangential injury to the joint surfaces at the time of dislocation or more frequently at time of reduction of the patellar dislocation. Kissing bone bruises are found on the medial side of the patella and the lateral trochlear condyle [17]. Intra-articular patellar fractures, when present, have an inferomedial location. Femoral involvement may vary depending on the position of the knee when the dislocation is reduced: in the lateral trochlear area when the knee is close to extension [18] and in the non weightbearing or weightbearing anterior lateral condylar area depending on whether or not flexion surpasses 90$^\circ$ flexion [19] (Fig. 1).

This hypothesis is reinforced by the presence of trochlear dysplasia, which is very often associated in OCF series [12]. Acute traumatic patellar dislocations resulting from direct injury can occur without trochlear dysplasia and are associated with a higher rate of OCF than dislocation in case of trochlear dysplasia in which the risk of impact with the joint surfaces is lower.

OCF occur preferentially in adolescents and young adults. In Toupin and Lechevallier’s series, the patients were older than 16 years [12]. The present series studied patients with open physis at the time of their accident.

On a bovine model, Broom et al. demonstrated that the osteochondral junction of a mature subject was 1.5 times more resistant to shear deformation than its immature counterpart [13]. They observed that tissue delaminates within a well-defined region, whereas in immature tissue the lesion occurs more deeply through the subchondral bone into which fingers of articular cartilage penetrate. This difference explains the better prognosis of these lesions in children compared to adults. The existence of articular hyperlaxity in the young could suggest that the joint surfaces are more susceptible to shearing stresses during the torsion mechanism. However, this laxity is potentially associated with patellar dislocation. Later, the same team demonstrated that the adolescent is more susceptible than immature or mature bovine tissue to this type of injury [14]; cartilage rupture submitted to pure shear stress occurs at 3.8 MPa in immature, 2 MPa in adolescents, and 2.6 MPa in the mature bovine tissue. The energy required for fracture was 3.6 kJ/m, 2.3 kJ/m, and 10.2 kJ/m for immature, adolescent, and mature bovine tissues, respectively.

Actually, the major issue in OCF is diagnostic because these fractures frequently go unrecognized. The severity of the injury could be underestimated on the x-ray when a very fine bone chip is detached (Fig. 2), whereas the chondral section is more voluminous. MRI allows better detection of this type of lesion, although this diagnosis must be anticipated [7].

Nonetheless, hematrhrosis in a context of trochlear dysplasia and all the cases of more objective dislocation of the patella should be considered to be associated with an OCF until proof of the contrary (Fig. 3). Using specific cartilage sequences, MRI is the key exam for establishing the diagnosis [7].

The surgeon’s options are limited in cases of OCF. Ablation of the fragment leads at best to formation of a fibrocartilage in the defect [20] and very probably to early evolving degeneration of the external compartment of the knee if the fragment is voluminous [21]. This option should, therefore, be reserved for small fractures in the non weightbearing area [22].

Apart from these cases, repositioning the avulsion fragment is recommended. In this study, a variety of fixation
methods were used given that the study was conducted in several centers. The main advantage of resorbable implant fixation is the absence of a second intervention to remove the material. Walsh et al. reported good results with polyglycolic acid pins [2]. The same was reported by Matsusue et al., Braune et al., and Lüthje and Nurmi-Lüthje in a total of five adolescents [8,9,11]. Fuchs et al. successfully used polylactide acid pins, screws, and nails [23]. Jehan et al. [10] argue in favor of using resorbable screws to add a compressive effect, but the screw head should be perfectly flush with the bone. Occasionally, autologous bone grafting can be useful to stimulate bone union and reconstruct the contour of the subchondral bone [24]. Although the wisdom of repositioning a purely chondral fragment is debatable in adults [25], it should be attempted in children given their potential for healing. Whichever technique is used, the fixation must be stable and stabilization should never be simple casting (Fig. 4).

For Stefancin and Parker, onset of an OCF during the first episode of patellar dislocation, is an indication for stabilizing patellar surgery [26]. The question of whether or not to associate, simultaneously, OCF repositioning and patellar stabilization in a single surgery remains highly controversial. None of the studies published to date have provided sufficient evidence in either direction. We believe that it is preferable to dissociate the procedures to allow for complete assessment (including long after the accident) of the risk factors of dislocation that could decide in favor of "à la carte" surgery [27], rather than operating on an injured knee in an acute situation with the risk of potential stiffness and more complex postoperative recovery.

The frequent delay in diagnosis naturally leads to discussing the time from injury to repositioning these lesions. It seems that successful repositioning remains possible beyond 2 months after the accident [11,28] and not 10–15 days, as has been reported [12,29,30]. In the present series, one

**Figure 2** Rupture of the subchondral line (arrow) on the donor site; the essentially chondral fragment is only visible on MRI.

**Figure 3** Any case of a knee associating hemarthrosis and trochlear dysplasia calls for an attentive search for osteochondral fracture (arrow on fragment in supratrochlear area).

**Figure 4** Large multiple-fragment defect on the medial aspect of the patella successfully repositioned and fixed using resorbable pins.
patient underwent successful repositioning on D20 after the injury.

The limitations of this study involve the retrospective nature of the series, the short follow-up time, and the absence of objective MRI assessment for all patients at revision [31]. This study nevertheless has the value of attracting clinicians’ attention to this solution and perhaps increasing their diagnostic insight, in particular with cases of posttraumatic hemarthrosis in adolescent. A prospective study with long-term evaluation would be necessary to define the best management strategies.

Conclusion

Better knowledge of this fracture and attentive reading of the radiographic images of a knee with hemarthrosis should lead more frequently to this diagnosis and to proposing better-adapted treatment. Unexplained hemarthrosis in a context of troclear dysplasia should be considered to be associated with an OCF until proof of the contrary. A fragment released in the weightbearing part of the knee should ideally be repositioned within 10 days but remains possible at 2 months; it consistently provides bone union and good short-term results in children.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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