Review

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# Current trends in the treatment of knee fractures in children and adolescents

*Tendencias actuales en el tratamiento de las fracturas de rodilla en niños y adolescentes*

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**ABSTRACT.** Fractures about the knee are common in children and adolescents. Characteristics of the growing skeleton make children susceptible to specific fractures that do not occur in adults. Understanding the relevant anatomy, pathophysiology, diagnosis, and treatment options are important to decrease the risk of complications. The aim of this article is to discuss the current trends in diagnosis and treatment of tibial eminence, tibial tuberosity sleeve, and osteochondral fractures in children and adolescents.

**Keywords:** knee, fractures, children, adolescent, treatment.

**RESUMEN.** Las fracturas en el área de la rodilla son frecuentes en los niños y adolescentes. Las características del esqueleto en crecimiento hacen que los niños sean susceptibles de sufrir fracturas específicas que no se producen en los adultos. La comprensión de la anatomía, la fisiopatología, el diagnóstico y las opciones de tratamiento pertinentes son importantes para disminuir el riesgo de complicaciones. El objetivo de este artículo es discutir las tendencias actuales en el diagnóstico y el tratamiento de las fracturas de eminencia tibial, manguito de tuberosidad tibial y osteocondrales en niños y adolescentes.

**Palabras clave:** rodilla, fracturas, niños, adolescentes, tratamiento.

## Introduction

Fractures about the knee are common in children and adolescents. Characteristics of the growing skeleton make children susceptible to specific fractures that do not occur in adults. The distal femoral and proximal tibial physis account for 70% of the lower limb growth and fractures near this area may affect bone growth, causing limb length discrepancies and angular deviations.[1] Due to the physiological characteristics of the immature skeleton, fractures are more common than ligamentous injuries in children and adolescents.[2] Furthermore, despite being rare, fractures involving the extensor mechanism of the knee, such as tibial tubercle avulsion fractures and sleeve fractures may cause function impairment and extensor lag which need to be treated with attention. Intra-articular injuries including tibial eminence fractures and osteochondral fractures may cause future limitations such as osteoarthritis and chronic knee pain. Traumatic forces applied to the immature knee result in different injuries than those seen in adults. As cartilage is abundant in children and adolescents, plain radiographs may not accurately diagnose these lesions. CT scans and/or MRI are often necessary for better study and treatment planning.[3,4] Careful evaluation of plain radiographs should include not only the bone but also periarticular soft tissues and joint effusion.[5] Some fractures, such as hyperextension

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lesions at the distal femoral or proximal tibial epiphysis, or displaced tibial tubercle avulsion fractures, may present neurovascular involvement.[4] Understanding the relevant anatomy, pathophysiology, diagnosis, and treatment options are important to decrease the risk of complications.[3] The aim of this article is to discuss the current trends in diagnosis and treatment of knee fractures in children and adolescents.

## Tibial eminence fractures (TEF)

Tibial eminence fractures are epiphyseal avulsion injuries, that typically occur in children from 8 to 14 years of age, and account for 5% of the traumatic effusions around the pediatric knee.[6,7] The most common mechanism of injury is a non-contact sports trauma, or falls from bicycle,[8] competitive sports, and traffic accidents.[9,10] In children, ossification of the proximal tibial leaves the tibial eminence at risk of avulsion as it is cartilaginous. When excessive stress is applied to the ACL the incomplete ossified tibial spine presents less resistance than does the ligament, resulting in a fracture through cancellous bone beneath the tibial spine.[4] Patients with TEF may present with knee pain, joint effusion, inability to bear weight and reduced knee range of motion.[11] Although most patients can be diagnosed with plain knee radiographs, a high percentage may have associated injuries.[12] MRI is valuable to identify associated meniscal tears, collateral ligament, and chondral injuries which can be present in up to 40% of the cases.[12,13,14,15,16,17] The Meyers & McKeever classification divides TEF into three types according to the degree of displacement. Further modifications have been described to include comminution and articular involvement *(Figure 1)*.[18,19,20]

Type I fractures are nondisplaced and can almost universally be treated with a non-weight bearing long leg cast for 3 to 4 weeks. Type II fractures, which are hinged posteriorly with superior displacement of the anterior segment, were also historically treated nonoperatively. However, if the eminence is not appropriately reduced with closed treatment, outcomes may be complicated from lack of extension due to impingement or increased laxity from failure to restore the ACL insertion. Because of these complications, surgical management is typically recommended for type II fractures unless anatomic reduction can be achieved with knee extension and immobilization. Type III and IV fractures are entirely displaced and require surgical treatment.[21,22]

Surgical treatments range from open surgery to arthroscopy.[23] Arthroscopic-assisted fracture reduction and internal fixation has become increasingly popular for the management of articular fractures of the knee, as it has

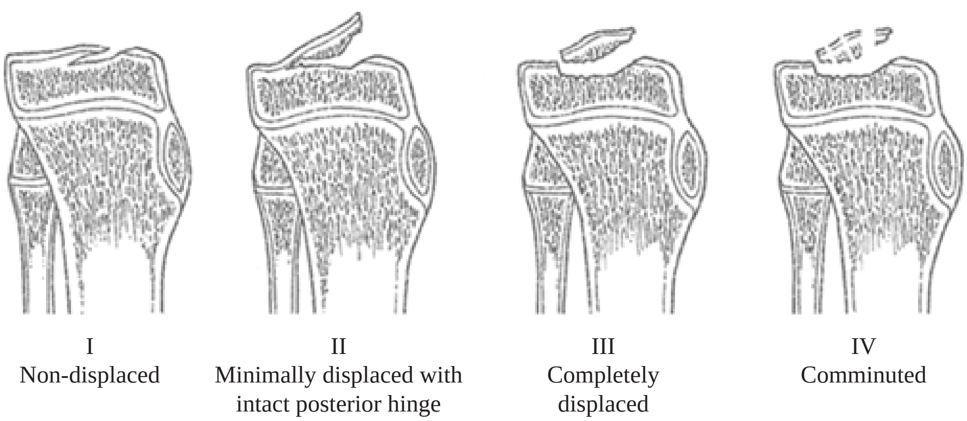


**Figure 1:**

Type I: non-displaced, TYPE II: partially displaced with intact posterior hinge, type III: completely displaced, type IV: comminuted fracture.
Modified Meyers & McKeever's classification.

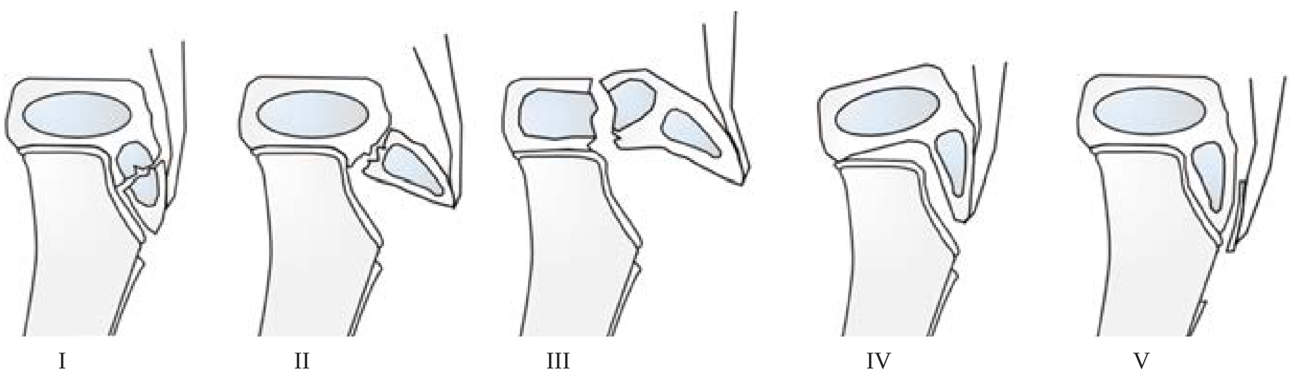


**Figure 2:** Type I is a fracture of the secondary ossification center near the insertion of the patellar tendon. Type II the fracture propagates proximally between primary and secondary ossification centers. Type III is a fracture that traverses the primary and secondary ossification centers. Type IV is a fracture through the entire physis. Type V is an avulsion of the periosteal sleeve.
Modified Ogden classification.

lower morbidity, earlier mobilization and shorter length of hospital stay than those treated with open surgery.[24,25] It also allows for simultaneous treatment of associated soft tissue injuries, such as meniscal tears, meniscal and intermeniscal ligament entrapment, intrasubstance anterior cruciate ligament (ACL) tears, and removal of loose fragments. There are several fixation methods available: cortical screws, headless screws, absorbable or nonabsorbable suture, suture anchors, or Kirschner wires. Clinical and radiographic results do not differ in relation to the chosen method of fixation.[24] Screws and suture fixation are the most commonly used techniques and they produce reliably satisfactory results. Cannulated screws are associated with anterior impingement, leading to a higher rate of implant removal. One of the advantages of the suture technique is the possibility to treat fractures with different patterns including small or comminuted fragments. Also, sutures can provide a stable fixation with no need for further intervention to remove the implant. Beyond the chosen technique, the ultimate goal must be to obtain the most stable fixation and not cause impingement to allow an early range of motion to prevent arthrofibrosis (most common complication). Risk factors for postoperative stiffness include malunion, prominent hardware, complete fracture displacement, revision, and length of postoperative immobilization.[26] Other reported complications include instability,[15] non-union, malunion,[22] growth arrest, and pain. Complication rate increases with progression of the Meyers and McKeever classification. Anterior cruciate ligament laxity and/or an extensor lag have been documented after anatomical reduction and consolidation.[27,28,29] Despite the laxity, few patients complain of pain or instability.[4] Overall prognosis is good with a high rate of successful healing, complete restoration of knee stability and returning to prior level of sport.[30]

## Tibial tuberosity avulsion fractures (TTAF)

Tibial tubercle avulsion fractures are rare, accounting for less than 1% of all physeal injuries and 3% of all proximal tibial fractures.[31,32] The proximal tibia begins to ossify from posterior-medially to anterior-laterally, and then from proximal to distal. It has two centers of ossification, the primary physis parallel to the knee joint and a secondary physis at the tibial tubercle. As ossification develops in a different pattern throughout the proximal tibia, the secondary center is the last part to fuse, placing the tibial tubercle at risk mainly in adolescents nearing skeletal maturity.[33,34]

Tibial tubercle fractures are produced by a concentric contraction of the quadriceps during jumping or an eccentric contraction of the quadriceps during forced knee flexion.[35] TTAF are more common in male adolescents involved in jumping activities.[36,37,38] Girls are affected in only about 3% of all avulsion fractures of the tubercle.[39] Males are more at risk than females presumably because of greater quadriceps strength, higher sports engagement, and later closure of the tibial tubercle in boys.[40,41]

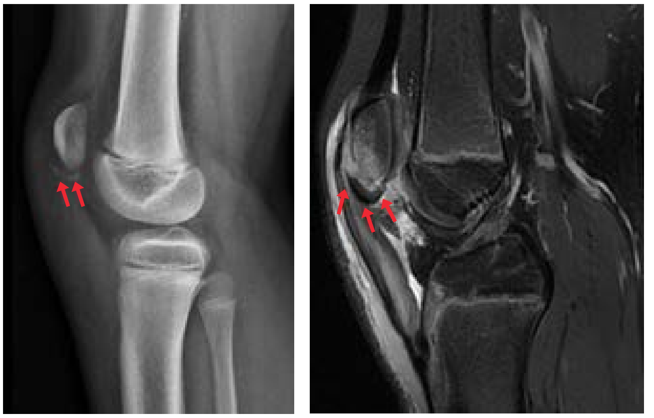

**Figure 3:** Sleeve fracture. Image demonstrates lateral radiograph and MRI of the knee with displacement of the distal pole of the patella (red arrows).

Patients with tibial tubercle avulsion fractures often present with anterior knee pain, effusion, and hemarthrosis. Type I injuries can be mild and mistaken for Osgood Schlatter disease. Patients with a small tibial tubercle avulsion fracture may still have an intact extensor mechanism due to intact retinacular structures. These patients may extend the knee against gravity but not against resistance. Patients with more extensive tibial tubercle avulsion fractures usually present with impaired extensor function. TTAF may present with extensive soft tissue damage, including anterior periosteum stripping and medial/lateral retinaculum tears.[42,43,44] A detailed neurovascular exam is very important as there is a risk of developing compartment syndrome. Evaluation of tibial tubercle avulsion fractures includes anteroposterior and lateral radiographs of the knee. Plain radiographs may underestimate injury severity. MRI or CT scan should be used to rule out intra-articular involvement.

The Ogden classification, a modification of the original Watson-Jones classification, is commonly used to describe these fractures. It was originally described with 3 types and 2 subgroups (A: non-displaced fractures, and B: displaced fractures), and later added types IV and V *(Figure 2)*.[45,46,47,48] Goals for treatment include restoration of articular surface and function of the extensor mechanism. Type I and non-displaced fractures can be treated with a long leg cast for 4-6 weeks.[37] Surgical treatment is indicated in fractures with more than 2 mm of displacement or articular joint incongruity. Open reduction and screw fixation (ORIF) is the treatment of choice for displaced or intra-articular tibial tubercle avulsion fractures.[32,41] A longitudinal incision centered over the fracture site or a medial parapatellar incision may be used for better assessment to the articular surface. After withdrawal of any interposition tissue fixation is achieved with 4.5 mm cannulated screws with washers, from anterior to posterior, parallel to the articular surface avoiding the physis.[49,50] In particular cases a soft tissue repair, and evaluation of the articular surface through an arthrotomy or arthroscopy may be needed. Prophylactic fasciotomy at the time of internal fixation is preferred by the authors of this paper. After surgery, the patient is immobilized with an extension brace or cylinder cast in extension with non-weight bearing for 4 to 6 weeks. Return to sport may vary from 2-3 months with Ogden type I and II injuries to 4-6 months with types III, IV and V.[33] Prognosis after a TTAF is excellent, regardless of fracture type, with fast recovery, restoration of function and satisfactory outcomes.[32,41,51]

Complications after tibial tubercle avulsion fractures are relatively uncommon. Compartment syndrome is a potentially severe complication due to disruption of the anterior tibial recurrent artery which can result in bleeding into the anterior compartment of the leg.[34] Regional anesthesia should be avoided during surgery to facilitate postoperative evaluation. Other complications include physeal arrest, decreased range of motion, quadriceps contracture, and painful implants (most common).[33,49] Obesity may increase the risk of complication.[37]

## Sleeve fractures

Sleeve fractures are rare injuries seen almost exclusively in skeletally immature patients characterized by separation of a «sleeve» of cartilage or periosteum with or without an osseous fragment. Patients with sleeve fractures present with a hemarthrosis, the inability to extend the knee, and either *patella alta* (inferior sleeve) or patella baja (superior sleeve). The diagnosis of these injuries could be challenging. Large osseous fragments are obvious on plain radiographs, but in some cases, they are easily missed, because only a minimal portion of bone is avulsed, and the fragment is largely composed of un-ossified peripheral cartilage. MRI can confirm the injury pattern and can be helpful to evaluate the size of the sleeve. Failure to diagnose these injuries can result in patellar instability, extensor lag, and anterior knee pain.[52]

Sleeve fractures can be classified by the location of the avulsion into proximal patellar pole, distal patellar pole (most common), and tibial metaphysis.[53] Most fractures are displaced and require treatment with open reduction and internal fixation. Non-operative management can be considered in non-displaced fractures (2 mm or less), if active knee extension is intact. Sousa et al.[54] evaluated five patients with distal pole sleeve fracture treated nonoperatively. Final radiographic evaluation revealed fracture healing and all five patients had full terminal knee extension and symmetric range of motion. Mean IKDC score was 96.4 (range: 82-100) mean Tegner's activity score was 60 (range: 5-8), and mean Kujala's score was 89.7 (range: 63-100) at final follow-up.

Non-displaced inferior pole fractures can be easily confused with Sinding-Larsen-Johansson syndrome (SLJS) *(Figure 3)*.[55] Displaced fractures can be stabilized using transosseous sutures, suture anchors, small screws with suture supplementation, or tension band wiring.[15] Torn medial/lateral retinaculum and/or quadriceps/patellar tendon are commonly associated findings and should be repaired if present. Immobilization in a brace for three to four weeks is required post operatively. Data regarding clinical outcomes after surgical treatment of sleeve fractures is limited, and mostly limited to case reports and very small case series. Perkins et al,[56] in the largest case series in the literature, evaluated 20 patients (17 males, mean age of 11.7 years), treated with transosseous repair. All patients had a healed patellar sleeve fracture and intact extensor function at final follow-up. Final mean knee ROM among

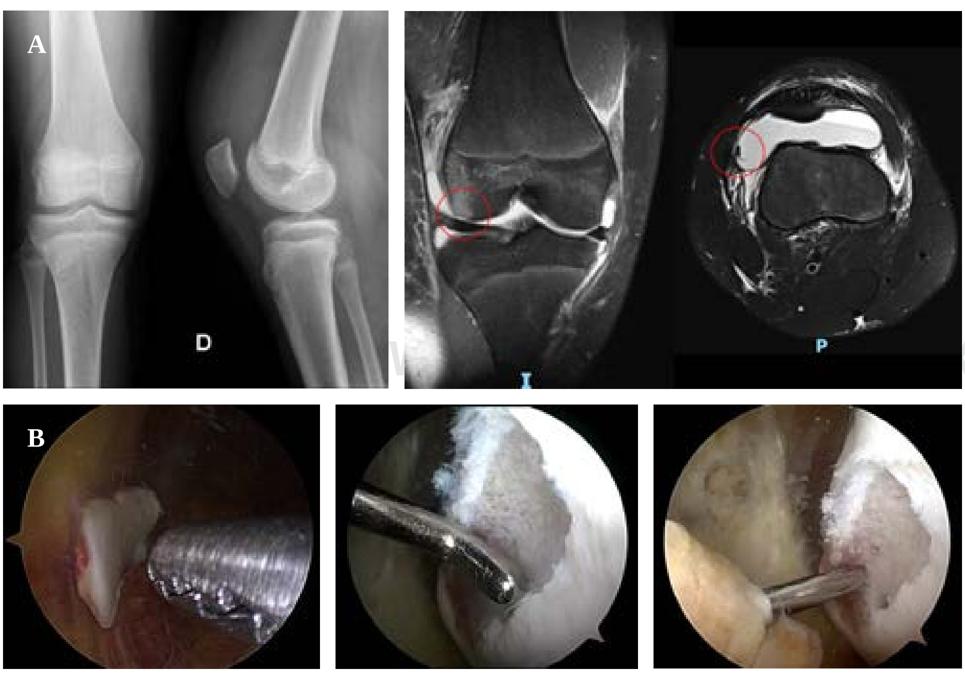


**Figure 4:**

**A)** Anteroposterior and lateral radiograph, and MRI showing a displaced small osteochondral fragment from the lateral condyle. **B)** Arthroscopic image of a 10 × 5 mm osteochondral fragment in the non-weight bearing area of the lateral condyle. The patient underwent fragment excision, bone marrow stimulation and patellar stabilization.

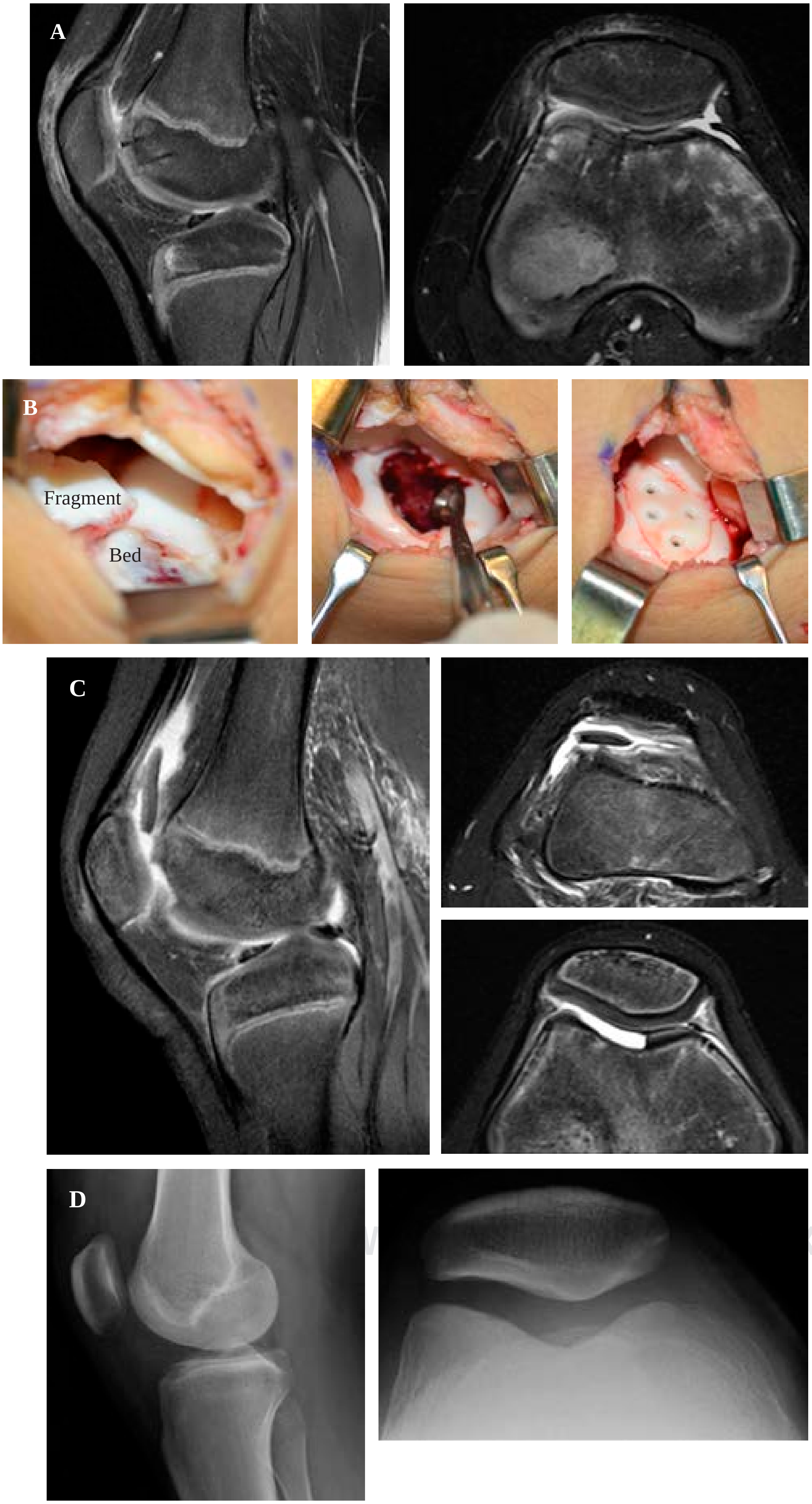


**Figure 5:**

**A)** Preoperative MRI demonstrates a large displaced osteochondral fragment from the femoral trochlea. **B)** Intraoperative picture of the displaced osteochondral fracture before and after fixation with bioabsorbable SmartNail. **C)** 4-month postoperative MRI reveals OC fracture healing. **D)** AP and axial radiograph at 9-year follow-up.

the 18 patients with minimum 3-month follow-up was 132 degrees. Thirteen patients (72%) achieved full ROM (≥ 130 degrees) and five patients (28%) achieved less than 130 degrees knee flexion. No patients experienced construct failure or extensor lag.

Sleeve fractures can lead to complications if not treated appropriately and in a timely fashion. Complications of missed or untreated patellar sleeve fractures include malunion, *patella alta*, anterior knee pain, and quadriceps atrophy. These can all result in severe limitations in daily activity.[57]

## Osteochondral fractures (OCF)

Osteochondral injuries in pediatric patients occur more often as a result of a direct blow on a flexed knee or shearing forces associated with an acute dislocation of the patella. The incidence of osteochondral fracture after patella dislocation was reported to be up to 39%.[58] The patient with an OCF presents with a painful, swollen knee joint, reluctant to bear weight, and any attempt to flex or extend the knee if resisted. Tenderness over the injured portion of the articular surface may be found.

Plain radiographs with AP, lateral, merchant view, and 45$^o$ flexed tunnel view should be obtained. Traumatic osteochondral fractures are represented by a disruption of the subchondral line compromising the lateral femoral condyle, medial facet of the patella or both. The ability to visualize the fracture fragment on radiographs is dependent on the amount of subchondral bone the piece contains. Those with very small bone components are often difficult to detect. MRI is the gold standard study to determine the presence of an articular cartilage injury, although it can often underestimate the size of the cartilage lesion or osteochondral defect.[59]

Surgical treatment is preferred and depends on the size and location of the osteochondral injury. Arthroscopic removal of the fragment is indicated if the fragment is < 1 cm in diameter and is in a non-weight bearing articular surface *(Figure 4)*. Reduction and fixation is the treatment of choice for larger osteochondral fragments where the cartilage is in good condition. Depending on the location of the lesion, this may be done either by open arthrotomy (usually for patellar lesions) or via arthroscopy. There are multiple fixation methods including metallic screws, bioabsorbable screws, bioabsorbable pins, autologous bone pegs, suture bridge, and fibrin glue (Hedgehog technique).[60,61,62,63,64] Fixation of traumatic OCF may result in successful healing in adolescent patients regardless of the characteristics of the fragment (osteochondral versus chondral-only) and time elapsed since the injury *(Figure 5)*. Fabricant et al.[64] in a multicenter study evaluated 15 patients with a median age at surgery of 12.7 years. The injured sites were the patella (n = 6), trochlea (n = 5), and lateral femoral condyle (n = 4). The median fragment surface area was 492 mm$^2$. Fixation with bioabsorbable implants was performed in all patients at a median of 1.6 weeks after the injury. One patient (7%) sustained a fall eight weeks postoperatively, requiring secondary surgery for excision of a dislodged fragment, and 1 patient (7%) underwent unrelated patellar stabilization surgery 3.4 years postoperatively, at which time the fragment was found to be stable. All 15 patients returned to sports and activities at a median time of around 6 months, with a median follow-up of 12 months. More recently, Kjennvold et al[65] evaluated 10 patients (median age of 15 years) with a pure chondral fracture of the knee treated with internal fixation. The lesions were located on the patella (n = 7), the trochlea (n = 2), and the lateral femoral condyle (n = 1). Median lesion size was 250 mm$^2$ (1.9-6.0 cm$^2$). All patients were treated within two months of injury (4-58 days). All patients returned to preinjury level of sports and MRI showed retained fragments that integrated well with surrounding cartilage at follow-up. Mean Lysholm score at mean 5 years follow-up was 90 (73-100). Therefore, preservation of native articular surface cartilage should be considered the first line of treatment as long as the fragment does not have excessive fragmentation.

Osteochondral autograft transplantation surgery may be useful in the instance of an osteochondral injury that is not amenable to repair.[60] Patellar stabilization is recommended if the osteochondral fracture is associated to an episode of patellar dislocation.[66] Medial patellofemoral ligament (MPFL) reconstruction has shown better outcomes than repairing techniques.[67] Complications after surgical treatment may include fixation failure, stiffness, quadriceps muscle atrophy, and post-traumatic arthritis. Patients with acute patellar dislocation can also experience recurrent subluxation or dislocation.

## Conclusion

Pediatric knee fractures are common lesions, most frequently seen in sports practice and motor-vehicle accidents. Appropriate diagnosis and evaluation are important to provide the best care for patients. The treatment of pediatric knee fractures is evolving, and evidence-based knowledge is helpful in providing optimal care. When managed appropriately, most pediatric knee injuries have an excellent prognosis. Patients and families should be educated on the complications of treatment, including possible secondary surgery for hardware irritation, growth disturbances, arthrofibrosis or infection.



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