Paediatric fractures around the knee

Paediatric fractures around the knee are relatively rare, accounting for 0.7% of all paediatric fractures (Rennie et al, 2007). Interestingly, their incidence seems to have increased over the last few decades, perhaps as a result of the increasing number of children participating in sports. Anatomical knowledge of the juvenile, immature skeleton and its growth characteristics will help to understand these fractures. As some paediatric knee fractures can cause growth arrest and knee instability, early diagnosis and optimal treatment is necessary in these young patients.

ABSTRACT

Paediatric fractures around the knee are not common but their incidence seems to be increasing as a result of the increasing number of children participating in sports. Given the characteristics of the growing skeleton, specific fractures only occur in children. Diagnosis is mainly based on history, clinical examination and plain radiographs. Advanced imaging may be required in special fracture types. Although many of these injuries can be managed non-operatively, early referral to a specialist team is necessary to avoid delays in surgical management and to reduce the risk of acute or late complications.

Anatomy of the paediatric knee

The immature skeleton of a child is different to the adult skeleton because of the presence of physes (growth plates) and apophyses (ligament and tendon attachment sites). These areas of growing cartilage in children are weaker than the ligaments or tendons that are attached to them. Hence, a sudden tensile force can result in a fracture of the physis rather than a soft tissue rupture (Zionts, 2003). At birth, the distal femoral physis is present and closes on average at the age of 14–18 years, depending on gender (Dimeglio, 2001). The proximal tibial physis appears during the first few months of life and the secondary ossification centre of the tibial tubercle appears around the age of 9 years in girls and 11 years in boys. After 2–3 years, this fuses with the proximal tibial epiphysis and this combined proximal epiphysis will close, on average, at the age of 13 years in girls and 17 years in boys (McKoy and Stanitski, 2003). Ossification of the patella does not begin until 3–5 years of age.

The anatomy of the ligaments is similar to that seen in adults. The anterior cruciate ligament originates on the anterior aspect of the tibial eminence and inserts into the medial aspect of the lateral femoral condyle. The origin of the posterior cruciate ligament is located on the posterior aspect of the tibial epiphysis and its insertion is on the lateral aspect of the medial femoral condyle. The medial and lateral collateral ligaments originate respectively on the medial and lateral aspect of the distal femoral epiphysis. The medial collateral ligaments inserts into the medial aspect of the proximal tibial epiphysis deep to the pes anserinus tendons. The lateral collateral ligament inserts into the proximal fibula.

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Clinical presentation and diagnosis

A fracture around the knee should be considered in every knee trauma, no matter what age or what trauma mechanism. A complete history and clinical examination are paramount for the correct diagnosis and a history of the exact trauma mechanism can help to understand the fracture pattern. Most fractures around the knee in children are caused by sports trauma, traffic accidents or high energy trauma (Beaty and Kumar, 1994). Most children will complain of knee pain and the inability to bear weight on the injured leg. Clinical examination should concentrate on inspection of the injured knee, palpation and assessment of range of movement followed by examination of joint laxity in different planes.

Knee fractures often reveal knee swelling or intra-articular effusion (haemarthrosis) and tenderness around the physis. As the ligaments are stronger than bone, an avulsion fracture can present as ligamentous laxity. Neurovascular examination of the knee is required in all trauma cases. The first radiological investigation of choice is a standard anteroposterior and lateral radiograph of the knee. This may confirm the fracture or show the haemarthrosis. In some cases a computed tomography or magnetic resonance imaging scan may be required to evaluate the bony congruence and the ligaments (Luhmann, 2003).

Physeal fractures around the femur and tibia

Physeal fractures or fractures of the growth plate were first classified by Salter and Harris (1963) and this classification system is still widely used (*Figure 1*). Mercer Rang (1969)

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Figure 1. Salter–Harris classification of physeal fractures. Type I fractures are transverse fractures through the physis. In these fracture types, radiographs can appear normal. Type II fractures, which are the most common type, are fractures through the physis and the metaphysis. The epiphysis is not involved. A type III fracture is a fracture through the physis and epiphysis, sparing the metaphysis. A type IV fracture is through physis, metaphysis and epiphysis. The least common fracture type, type V, is a compression fracture of the growth plate. Also in this type of fracture, radiographs can appear normal.

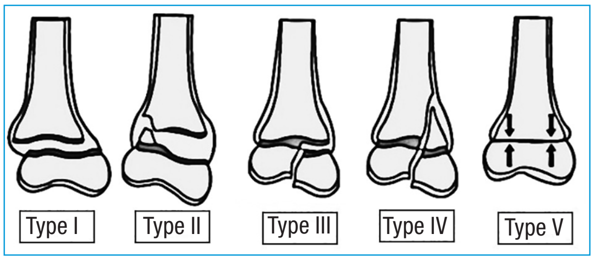
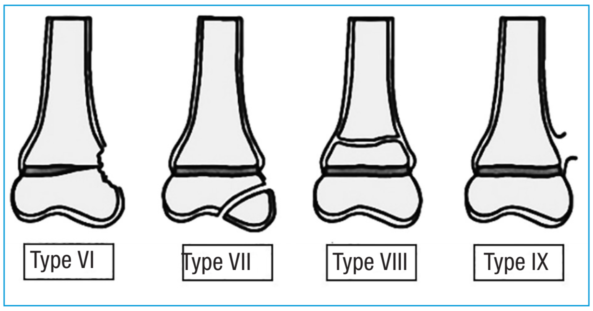


Figure 2. Ogden–Rang classification of physeal fractures.



added a type VI fracture to the classification system, and 13 years later, Ogden (1982) added types VII, VIII and IX (*Figure 2*). A type VI injury is a rare injury to the peripheral region of the physis (a portion of the physis shears off). Peripheral osseous bridge formation in these fracture injuries can lead to localized epiphysiodesis and can cause an angular deformity. A type VII injury is an isolated injury of the epiphyseal plate. An example of this fracture type is osteochondritis dissecans, as discussed later. Type VIII injury is an isolated injury to the metaphysis which can damage the vascular blood supply. This can cause impairment of endochondral ossification. A type IX injury is an injury to the periosteum at the level of the diaphysis, with potential implications for intramembranous bone growth.

Fractures of the distal femoral physis (*Figure 3*) are rare and mostly found in adolescents (Arkader et al, 2007). These fractures are often the result of a direct trauma with some degree of rotation or angulation. Patients present with tenderness and swelling of the distal thigh and knee joint and the inability to weight-bear (Riccio et al, 2013). In displaced injuries, clinical deformity may be evident and crepitus or motion of the fragments can be felt. Standard anteroposterior and lateral radiograph may confirm the fracture, but in some cases, stress radiographs are necessary to accurately diagnose the fracture. A computed tomography or magnetic resonance imaging scan can help to identify fracture lines and to evaluate intra-articular extension.

Figure 3. Anteroposterior radiograph and lateral three-dimensional computed tomography scan showing a Salter–Harris type II fracture (arrow) of the distal femoral physis.

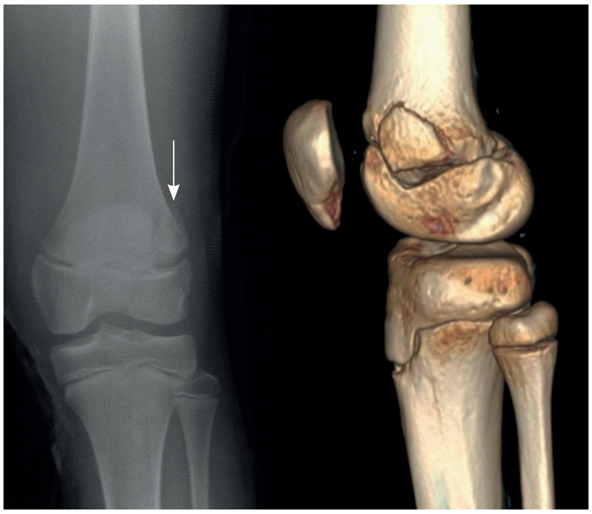
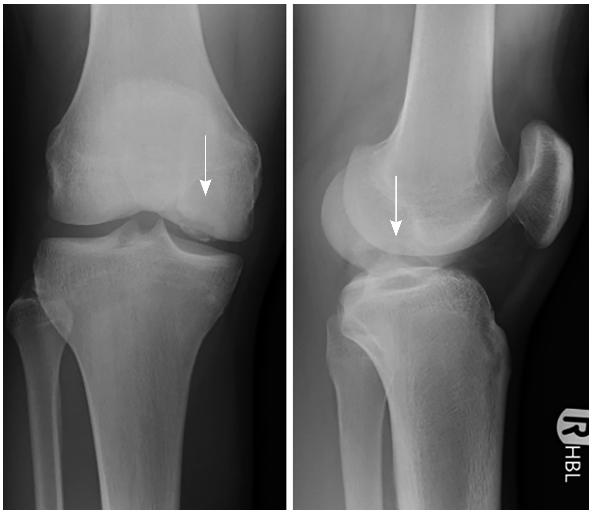


Figure 4. Anteroposterior and lateral radiograph showing osteochondritis dissecans (arrows) in the medial femoral condyle.



Non-displaced fractures can be treated conservatively in a long plaster cast or brace. Operative treatment is indicated for displaced, open or intra-articular fractures or fractures through the physis (type IV). Note that these type of fractures can result in growth arrest in 30–50% of cases (Basener et al, 2009). These patients can develop limb-length discrepancies and angular deformities, depending on the amount of arrested physis and the age of the patient. Patients and family should be counselled about this at the time of diagnosis.

Osteochondritis dissecans

A special type of femoral physeal fracture is osteochondritis dissecans. This is a osteocartilaginous injury to the epiphysis of the femur with progressive loosening of the fragment.

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Figure 5. Magnetic resonance imaging scan showing osteochondritis dissecans (arrow) in the medial femoral condyle.

While a variety of aetiologies have been proposed, most authors support the theory of repetitive microtrauma leading to subchondral bone contusion, devascularization and necrosis (Heyworth and Kocher, 2015). The most common location for osteochondritis dissecans in the knee is the lateral aspect of the medial femoral condyle. The clinical presentation is quite variable. Stable lesions can be asymptomatic, whereas unstable lesions can cause mechanical symptoms, such as locking and clicking and recurrent effusions. Plain radiograph can show the lesion (*Figure 4*), but skeletal scintigraphy or magnetic resonance imaging is required in most cases (*Figure 5*). Treatment is conservative for stable lesions and consists of protected weight-bearing with crutches and bracing. Unstable lesions require surgical fixation (Jones and Williams, 2016).

Fractures of the proximal tibial physis are infrequent, but these fractures are often unstable. The mechanism of injury, clinical presentation, diagnosis and classification are similar to those of distal femoral physeal fractures. Because of its close proximity to the proximal tibial epiphysis, the popliteal artery is at risk in these injuries and arterial injury must be considered in all cases, especially with posterior displacement of fracture fragments. Careful neurovascular examination is mandatory, feeling the pulses of the dorsalis pedis and tibialis posterior artery and evaluating the function of posterior tibial and peroneal nerves. Treatment of proximal tibial physeal fractures consists of immobilization for stable, non-displaced fractures and surgical intervention for displaced, unstable and intra-articular fractures. Acute complications in these fractures include vascular injury to the popliteal artery (Zionts, 2002). Late complications are similar to those of distal femoral physeal fractures and include angular deformities and limb-length discrepancies. Just as for physeal femoral fractures, close follow up of these fractures is mandatory.

Figure 6. Anteroposterior and lateral radiograph showing a tibial eminentia fracture (arrows).

Tibia eminence fractures

Tibia eminence fractures are associated with sport injuries, particularly snowboarding, skiing and cycling, and are considered the child equivalent of an adult anterior cruciate ligament rupture (Lafrance et al, 2010). The mechanism of injury is similar to anterior cruciate ligament ruptures: landing with a rotational component, combined with hyperextension or a valgus force. Feucht et al (2017) reported concomitant meniscal injury in 37% of patients with a tibial eminence fracture.

Clinical examination will show acute knee pain and a haemarthrosis. In most cases, patients will not be able to weight bear. Ligamentous laxity can be found, comparable with an anterior cruciate ligament rupture. Standard anteroposterior and lateral radiographs confirm the diagnosis (*Figure 6*). A computed tomography scan can help to evaluate subtle fractures and there should be a low threshold to request a magnetic resonance imaging scan to look for concomitant ligament or meniscal injuries. Classification is according to the displacement of the avulsed fragment on lateral radiograph. Meyers and McKeever (1959) originally classified three fracture types. In 1977, Zaricznyj added a fourth fracture type (*Figure 7*). Types I and II can be treated conservatively in an above-knee cast in slight flexion for 5–6 weeks. This will allow the fragment to reduce to its anatomical position and to heal. Meniscal entrapment under a displaced tibial eminence fragment may prevent reduction (Kocher et al, 2003). If closed reduction is not successful, open reduction and fixation is required. Type III and IV fractures require open reduction and internal fixation with wires or a screw (*Figure 8*). Early complications of these fractures are loss of extension and knee stiffness. Willis et al (1993) reported anterior knee instability in 64% of cases at long-term follow up.

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Figure 7. Classification of tibial eminentia fractures. Type I is an undisplaced or minimally displaced fracture. Type II is an avulsion fracture with anterior angulation and displacement hinging on the posterior cortex. Type III is a complete fracture. Type IV is a complete displaced fracture.

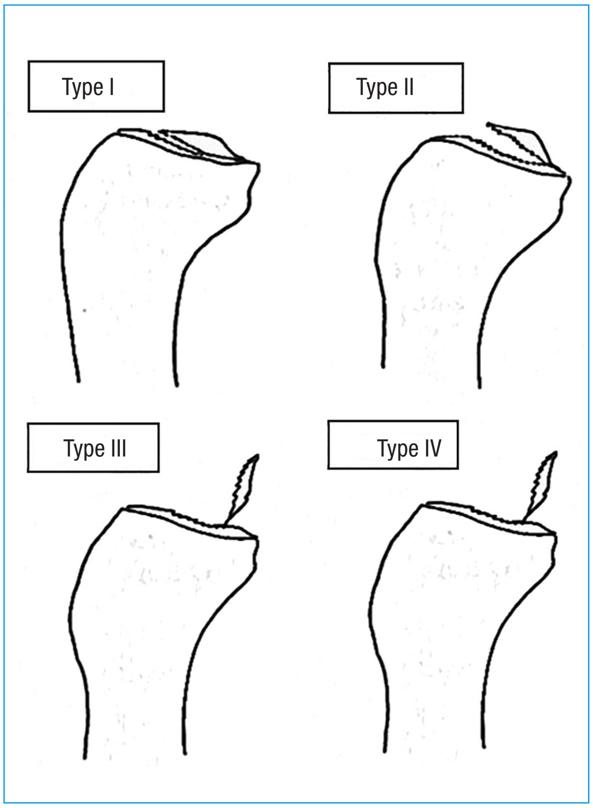
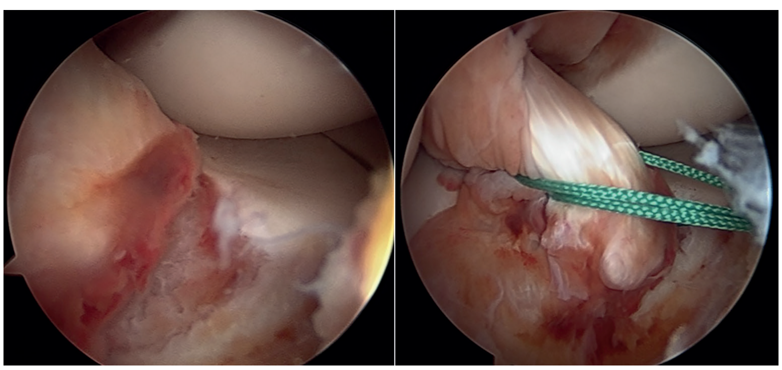


Figure 9. Patella sleeve fracture: a sleeve of non-ossified cartilage is avulsed from the distal pole of the patella.

Patella sleeve fractures

Fractures of the patella are uncommon in children, representing 1% of all patella fractures (Duri et al, 2002). A special type of fracture, which only occurs in children, is the patella sleeve fracture. This is a fracture in which a sleeve of non-ossified cartilage is avulsed from the distal pole of the patella (*Figure 9*). The mechanism of injury is typically a forceful eccentric quadriceps contraction, often during landing. Clinical symptoms are tenderness and swelling of the distal pole of the patella. In worse cases a large haemarthrosis, a patella alta (a high-riding patella), and a palpable defect in the patellar tendon can be found (Strahan, 2008). Active straight leg raise test can be compromised in these patients. A plain radiograph will confirm the diagnosis and often the non-ossified cartilage avulsion and patella alta are visible on the lateral radiograph. However, the avulsed fragment is not always clearly visible and the diagnosis of this injury can be missed. An additional magnetic resonance imaging scan may be useful to make the diagnosis. Non-displaced fractures with intact extensor mechanism can be treated conservatively in an extension cast or brace. Displaced patellar sleeve fractures require surgery. Open reduction and internal fixation, followed by cast immobilization, is the treatment of choice. Range of motion and muscle strengthening exercises can be started as soon as the fracture is healed. Growth disturbance is uncommon in patella sleeve fractures, but loss of range of motion is reported.

Figure 8. Intraoperative image showing fixation of a displaced tibial eminence fracture.



Tibial tubercle fractures

Watson-Jones (1955) first classified these fractures into three types, according to the degree of involvement of the tibial epiphysis. Later, Ogden et al (1980) added a subclassification A and B, according to the displacement and comminution of the fragment (*Figure 10*).

Tibial tubercle fractures are rare in children and are mostly seen in athletic boys between 14 and 16 years of

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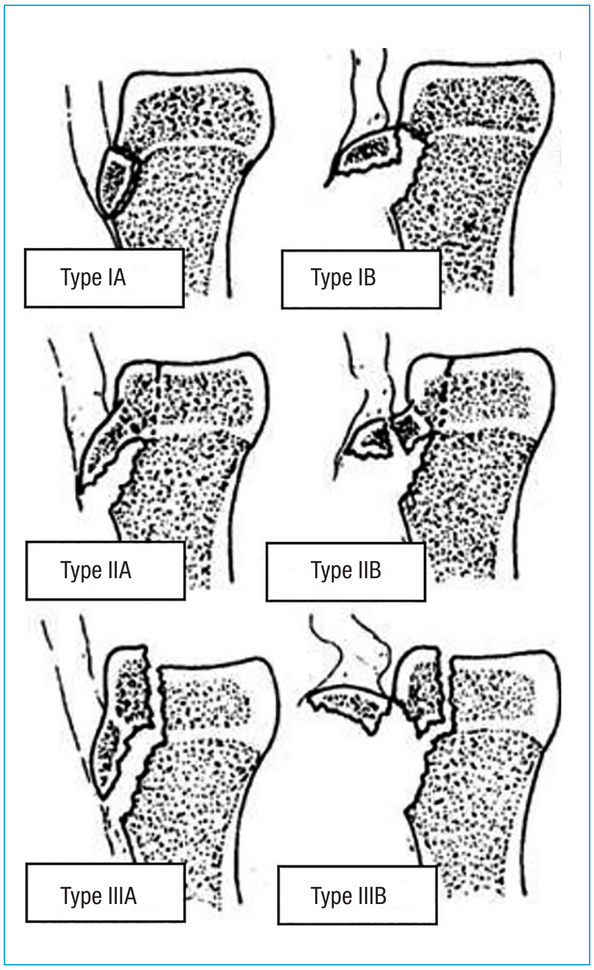
Figure 10. Classification of tibia tubercle fractures. Type I fractures involve an avulsion of a small fragment of the tubercle. Type II fractures extend to the junction between the tibial tubercle and the proximal tibial epiphysis. Type III fractures extend through the proximal tibial epiphysis and into the joint.



age (Ogden et al, 1980). These type of fractures occur as a result of a forceful quadriceps contraction in an extended knee (McKoy and Stanitski, 2003). In adults this mechanism will result in a quadriceps or patellar tendon rupture, but because of the strong ligaments and weak physis in children, the patellar tendon avulses the tibia tubercle apophysis. Clinical examination will show bruising and tenderness around the tibia tubercle, and painful or impossible straight leg raise, depending on the severity of the fracture.

A lateral radiograph is best to visualize the fracture (*Figure 11*). Non-displaced type I and type II fractures can be treated conservatively in an extension cast or brace. Displaced or comminuted type I and II fractures, and all type III fractures require open reduction and fixation of the avulsed fragment with screws. Complications of tibial tubercle fractures are uncommon, but if growth arrest occurs, patients can develop a recurvatum deformity through anterior tibial growth arrest (knee bending backwards) (Pandya et al, 2012).

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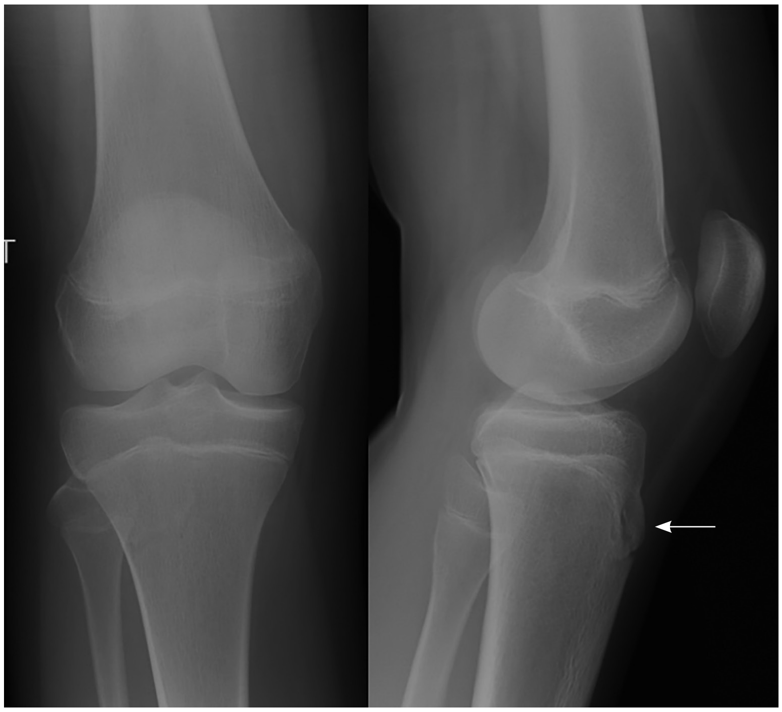
KEY POINTS

- In children, a fracture of the physis or apophysis will occur rather than a ligamentous rupture.
- There should be a high index of suspicion in young children with knee pain and swelling around the knee.
- Plain anteroposterior and lateral radiographs are the investigation of choice. Computed tomography scan or magnetic resonance imaging scans are occasionally indicated.
- Management of paediatric knee fractures depends on the fracture pattern.
- If unrecognized or treated inappropriately, acute or late complications can occur.

Figure 11. Anteroposterior and lateral radiograph showing a type IA tibial tubercle fracture (arrow).



Conclusions

Fractures around the knee are infrequent in children and adolescents, but may have serious consequences. Prompt assessment allows early and accurate diagnosis from which appropriate management is possible. A knowledge of the relevant anatomy and possible complications of each injury type will facilitate communication with the patient and the family. Although many injuries can be managed non-operatively, early referral to a specialist team is necessary to avoid delays in surgical management if this is required. **BJHM**

Conflict of interest: none.

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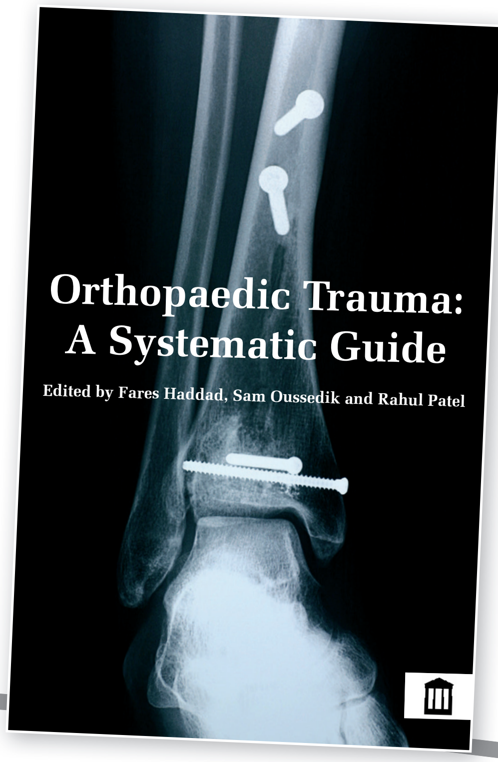

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