Patellar Fractures – a Review of Classification, Genesis and Evaluation of Treatment

Zlomeniny pately – přehled klasifikací, vývoj a hodnocení léčby

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SUMMARY

The patellar bone is involved in repetitive, load bearing motion sequences every day and functions as a vectorial force translator. A fracture rate of 1% of all skeletal fractures is reported and surgical treatment often required. Beside a direct trauma mechanism, indirect mechanism but as well as fatigue fractures after reconstructive knee surgery are published.

The fracture management is dependent on the soft tissue condition and a variety of surgical options are known. New generation of low profile plates show promising results but the conventional cerclage wiring technique with K-wires is widely preferred. Best functional results with sustainable stability are biomechanically seen after a combined fixation technique using anterior cerclage wiring with cannulated screw fixation. A definite algorithm of treatment of patellar bone fractures is yet not defined but a review of classification and surgical techniques should give assistance in decision making.

INTRODUCTION

The patellar bone is the largest sesamoid bone of the human body and functions as a hypomochlion for the extensor mechanism of the knee joint. The patella conducts the tensile forces of the extensor mechanism to the patella tendon and improves the efficiency of the complex by elevating the extensor mechanism away from the axis of rotation of the knee joint (22). Therefore the quadriceps muscle is reinforced by 30% due to the accelerated lever arm and serves as a pulley (28, 29). Remarkable for the patellar bone is its thickness of cartilage surface of 5–7 mm. The patellar bone is embedded into the quadriceps muscle with 50% insertion of its tendinous part to the proximal patella pole. Its superficial tendinous fibers extend distally into the patellar ligament and insert at the tibial tuberosity. Most important for the knee extensor mechanism is the provisional extra function of the medial and lateral retinacula, which are aponeurotic fibers of the quadriceps muscle and may allow an extension of the knee joint even if the quadriceps tendon is injured (16). Its blood supply is guaranteed by the inferior and superior, medial and lateral geniculate artery, branches of the popliteal artery. As the patellar bone is responsible for the strong extensor mechanism of the knee joint its reconstruction and restoration is favourable.

ETIOLOGY

Patellar fractures are rare and account for approximately 1% of all osseous fractures (10). Peak age of affected patients is between 20–50 years of age (5, 27, 46) but in cases of periprosthetic fractures the patella is second most commonly injured after the femur and has a reported incidence of 0.05% – 21% in resurfaced patellae (8, 66).

Mechanism of injury is a direct fall or blow ('dashboard injury') on to the patellar bone. An indirect fracture mechanism is an unexpected, sudden flexion or tear through concentric muscle contraction of the quadriceps. This indirect mechanism may lead to an avulsion fracture, equivalent to patella tendon ruptures with less soft tissue damage (50).

Only rarely reported are patellar bone fractures after reconstruction of the anterior cruciate ligament (ACL) using a bone-tendon-bone (patella tendon) graft (14, 57, 58). Incidence of this weak fracture is reported to be 2% due to a surgical, technical mistake, although fatigue fractures during late follow up after ACL reconstruction, following a low velocity mechanism of injury, are published (60).

With the upcoming trend of refixation of the medial patellofemoral ligament (MPFL) in patellofemoral disorders, fatigue patella fractures after replacement of the MPFL are reported. For these rare cases no incidence is yet defined as well as the exact mechanism (36). An attenuation of the bony structure and consecutively extensor mechanism is suggestable.

EXAMINATION AND EVALUATION

Definite clinical fracture signs are osseous crepitation, a palpable distance between the fractured bony parts and in open fractures an open praepatellar bursa (59). Indirect fracture signs are a local haematoma, haemarthros, bruises and contusion marks. Straight leg raise may be impossible, or in undisplaced or incomplete fractures painful and forcefully reduced due to an intact function of the retinacula, iliotibial band and adductor muscle function (33). The inability to actively extend and lift the leg is relatively indicative of an incompetent extensor mechanism. More than 35% of all patella fractures are non-displaced and the extensor mechanism remains intact (2, 10, 41).

After clinical examination, including palpation, documentation of the muscular force, evaluation of the active and passive ROM, plain X-rays in minimum two planes (ap and lateral, eventually sunrise view (45 degrees flexed knee)) are essential and will give further information about the injury. Moreover transverse fracture lines can be missed if a lateral view is not performed. In uncertain cases plain radiographs of the contralateral side should be performed to exclude bipartite patellae. In case of a high velocity trauma mechanism an additional radiographic examination of the ipsilateral hip joint is mandatory to exclude further injuries. Ultrasound evaluation is sufficient in children or pregnant patients. In very displaced and/or comminuted fractures further investigation by CT scan is helpful for surgical planning (6). MRI scan is indicated to exclude osteochondral or singular chondral fractures as well as exclusion of additional soft tissue injuries (e.g. ligamental ruptures, meniscal tears).

Table 1. A proposed algorithm of patella fracture management. The soft-tissue condition has to be respected individually

Fracture type	Management
A1	nonoperative
A2	(percutaneous) screw fixation
A3	(percutaneous) screw fixation
B1	Mc Laughlin Cerclage +/- screw fixation of the distal pole
B2	screw fixation
B3	screw fixation +/- cerclage wiring / low-profile plate
C1	screw fixation +/- cerclage wiring / low-profile plate
C2	screw fixation +/- cerclage wiring / low-profile plate
C3	cerclage wiring / low-profile plate

CLASSIFICATION

The majority of classification systems use descriptive terms of the fracture pattern or location. In general patella fractures can be divided into stable, non-displaced and unstable, displaced ones (56). Depending on the displacement surgical treatment is indicated. A displaced fracture is generally defined by fracture fragment separation of more than 3 mm or an articular incongruency of 2 mm or more (22). Numerous classification systems are known, a very accurate one has been presented by Hohl and Larson (23) which differentiates between nondisplaced, transverse (viewable on lateral X-ray views), longitudinal or vertical (seen on sunrise X-ray views), lower or upper pole and comminuted (stellate) fracture types.

Further classifications for patella fractures have been introduced by Rogge, Oestern and Gosse in 1985, and Speck and Regazzoni in 1994 (48, 55) (Fig. 1b), which simplify the patella fractures in type A longitudinal, B transverse and C comminuted fractures.

The AO classification (see Fig. 1a), which is based on the classification of Speck and Regazzoni, respects its alphanumeric coding system and classifies patella fractures as

– Extraarticular: 34-A1 (avulsion), 34-A2 (isolated body)

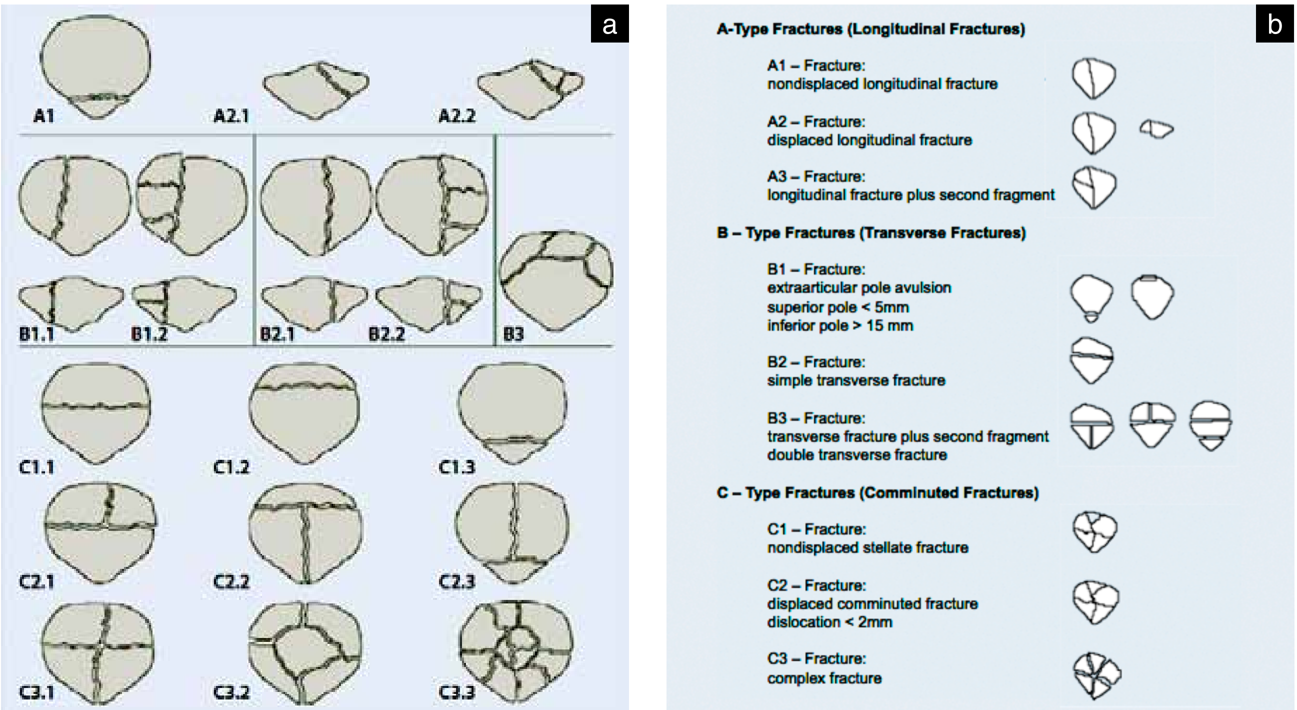

Fig. 1. The AO – Classification (a) is based on the classification system of Speck and Regazzoni (b) (56).

Fig. 2. A 25-year-old sports student sustained a direct trauma to his right knee. The patella fracture AO type C2 was treated in a classic cerclage wiring technique.

a|b
c|d
e|f|g

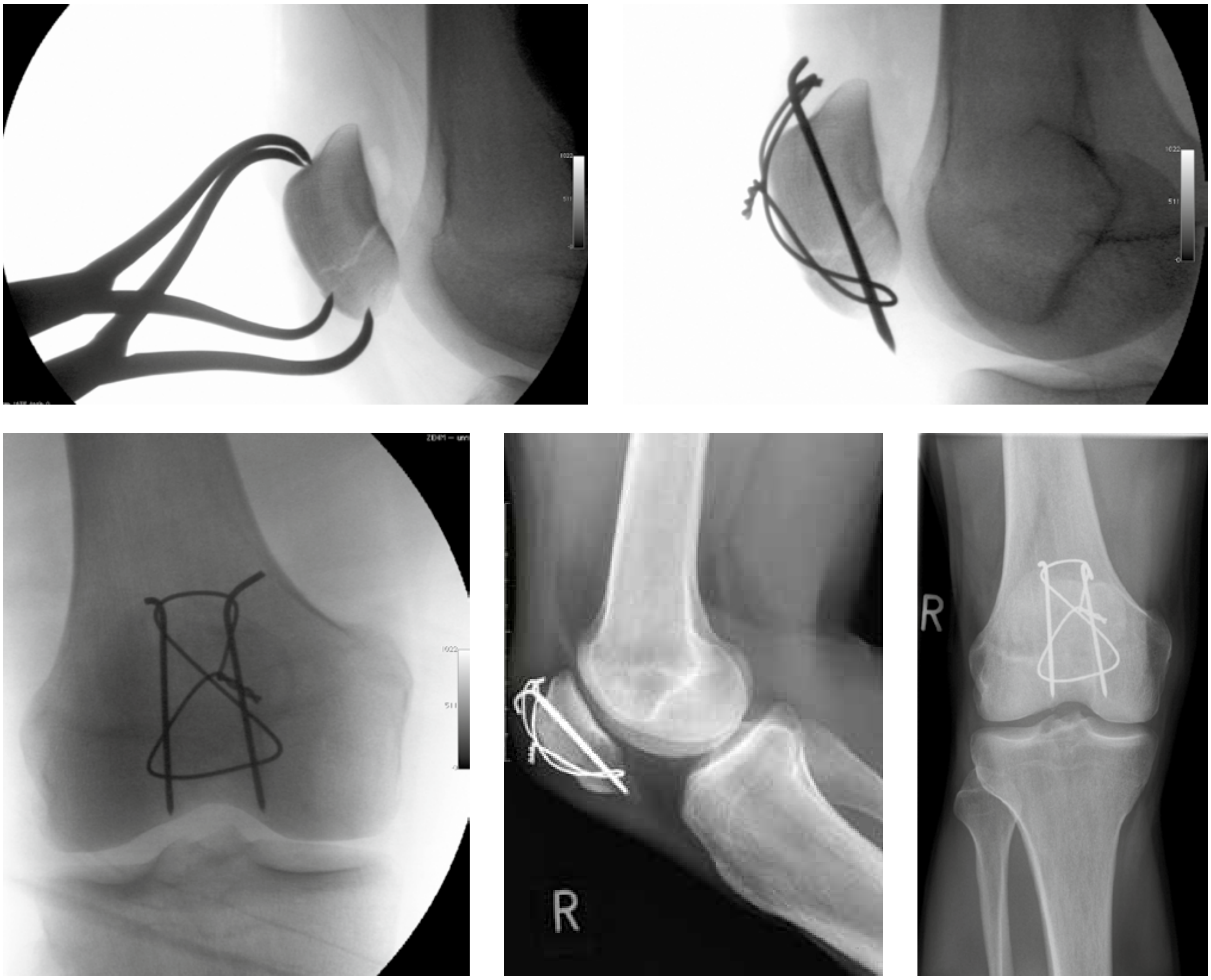

Fig. 3. The patella fracture AO type C2.3 in a 22-year-old woman after a bicycle injury. Percutaneous screw fixation was used for fracture management. One screw broke due to strong torque forces while implant removal.

a|b|c g
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– Partial articular: 34-B1 (vertical, lateral / B1.1 noncomminuted / B1.2 comminuted), 34-B2 (vertical, medial / B2.1 noncomminuted / B2.2 comminuted)
– Complete articular: 34-C1 transverse (C1.1 middle / C1.2 proximal / C1.3 distal), 34-C2 transverse plus second fragment, 34-C3 complex fracture.

A special fracture type of the patella bone is described as a ‘sleeve fracture’ as the mechanism of injury leads to an enucleation of the osseous part of the patella from the periost. In plain X-rays the mal-impression of a tendinous injury might be misleading as the patella flips either cranially or caudally but the periost remains attached to the patella ligament or quadriceps tendon. This fracture type is mainly seen in children and often reported to be a juvenile fracture type (51). An MRI scan is mandatory to detect these cases as they are often missed.

Periprosthetic knee joint fractures have an incidence of 0.3–2.5% (8, 30) with periprosthetic patella fractures as the second most common location after periprosthetic femur fractures with a prevalence of <1% (47).

Classification systems for periprosthetic patellar fractures respect the stability of the implant, knee function and quality of the surrounding bone stock. Goldberg et al. presented in 1988 three main characters for periprosthetic patella fractures (19). Type I with an intact extensor mechanism and a stable implant, Type II complete disruption of the extensor mechanism +/- stable implant, Type III is divided into a) intact extensor mechanism, loose patellar component, b) intact extensor mechanism, loose patellar component and poor bone stock.

TREATMENT

To restore the strong extensor mechanism of the knee joint reconstruction of patellar fractures should be achieved. Aim of every surgical intervention is to allow a high stability for early active range-of-motion exercises. Open fractures should be treated within 6–8 hours post injury (59). Superficial skin lacerations or bruises are regarded as open fractures as the patellar bone is located superficial.

Nonoperative treatment could be discussed in nondisplaced or minimally displaced fractures with an intact extensor mechanism. But as a patella fracture is not an isolated bony injury, but a chondral injury as well, an anatomic reduction is mandatory. Studies have shown an early onset of osteoarthrosis after incomplete reduction of patella fractures (47, 53, 54). Even a blunt trauma mechanism may lead to a contusion of the articular cartilage surface with consecutive chondral biomechanical and structural defects (15, 42).

Longitudinal fractures and extraarticular proximal pole fractures may classify for a conservative treatment scheme (10, 11, 16). Nondisplaced transverse fractures can be treated in a cylinder cast with strict radiographic follow up. Secondary fracture dislocation is caused by muscular tension and once fracture dislocation is detected conservative treatment has to convert into a surgical one. Undisplaced stellate fractures with an articular displacement of < 2 mm can be treated in a Range-of-Motion brace with partial weight bearing and full weight bearing in an extension brace. The degree of active range of flexion is dependent on the comminution of the fracture type. Relative contraindications for both conservative managements are loss of reduction and or disruption of the extensor mechanism. In nondisplaced vertical patella fractures the extensor mechanism usually remains intact, therefore an exorthosis is not indicated.

An operative approach is necessary in displaced fractures or with an incomplete extensor mechanism. Previous clinical studies demonstrate that approximately 30% of patella fractures require surgery and that 20% involve severe comminution (37). Surgical options are ranging from tension band wiring (23, 43–45, 63) (see Fig. 2) to Kirschner wires or cannulated or interfragmentary screw fixation (11–13) (see Fig. 3), combined techniques and recently introduced new generation of low profile plates (see Figs 4 and 5). The overall patella length is crucial for the restoration of the lever arm, hence partial or complete patellectomy are rarely indicated and should be considered carefully.

The surgical approach is preferable a lateral knee approach to protect the medial ligamentous structures to restore the strong medial tensile strength to maintain the patellafemoral congruency (18). Through an additive small lateral arthrotomy a palpable inspection of the retropatellar surface to control reduction results is possible. Minimal invasive approaches with percutaneous screw fixation and arthroscopic inspection of the retropatellar surface are feasible in closed, noncomminuted transverse or vertical fracture types (21).

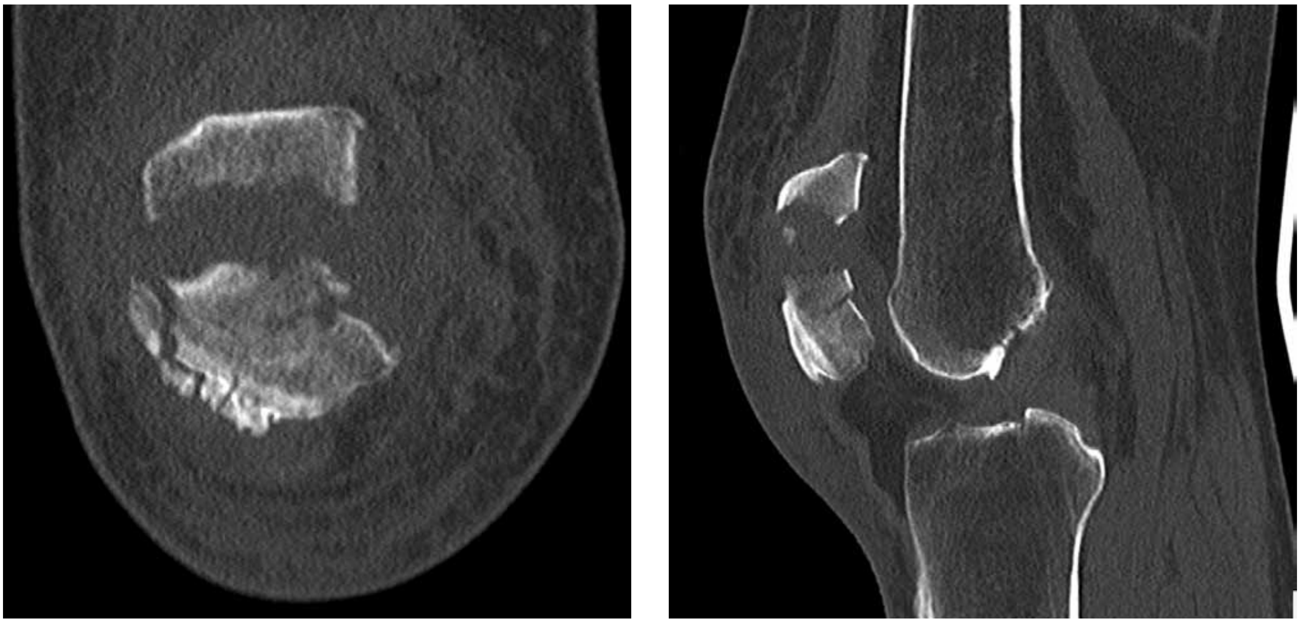

Fig. 4. After initial fracture management of a Speck and Regazzoni type B3 patella fracture in a 76-year-old female patient with screw fixation, secondary fracture dislocation occurred after 6 weeks. Re-osteosynthesis was performed using cerclage wiring, a low profile plate (Star – plate, ArthrexÒ) and a McLaughlin Cerclage for additional stability.

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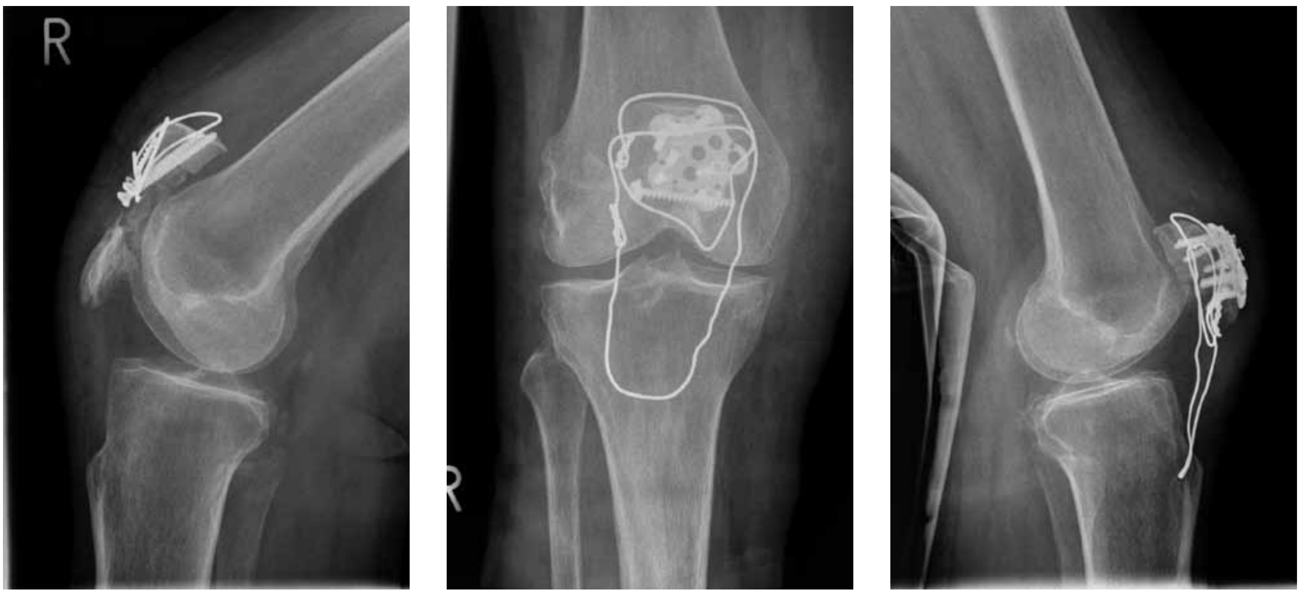

Current treatment options are based on the type of fracture and clinical presentation found on physical examination. Berger first described in 1892 cerclage wiring of patella fractures (3) and in the 1950's Pauwel reported on the treatment of patella fractures using an anterior tension band wiring. This technique has been modified by the AO group and is advocated as a dynamic and functional form of patella fixation (43–45). The principle of the anterior tension band wiring is to convert the tensile forces acting on the anterior surface from the quadriceps mechanism to compression forces at the articular surface. Many surgeons have modified this technique and have incorporated screw fixation when indicated (3, 35, 39, 45). Biomechanical studies showed that tension band wiring with screw fixation have a significant better outcome (12, 13, 24). For severely comminuted fractures indirect reduction methods may be useful. A cerclage wire technique for initial reduction of the fracture may be used in multifragmentary fractures. In distal pole fractures a McLaughlin cerclage, placed through the centre of the patella bone and distal fixation through the tibial tuberosity is recommended. During cerclage placement the patella height should be carefully controlled, as the creation of a patella baja is well described (1).

The modern design and new generation of several angle plates, spider or basket plates, allow a less invasive surgical option and elegant reduction in comminuted fracture types or distal pole fractures (40). Newly designed plates with fixed-angles are comfortable and elegant in use, and showed good to excellent results in biomechanical tests (64). Their design allow for a fixed screw placement and are helpful in comminuted patellar fractures to restore the reductive result and in osteoporotic bone. A recent comparison to lag screw fixation with anterior tension wiring showed a preserved reduction and sustainable fixation in cyclic loading tests (61).

Partial patellectomy or resection of the distal or proximal pole may be indicated in small fracture fragments or non-unions, and is reserved for injuries that involve severe comminution of one patella pole which are not amenable for internal fixation (3, 4, 25, 26). All attempts should be made to retain all fragments and the articular surface when possible, as even a remaining part of the patella bone is helpful in restoration of the extensor mechanism of the knee joint and lever arm function of the musculotendinous parts. An osteosynthetic pole refixation is proven to achieve better outcome results compared to pole resection (28, 62). In situation of a severely comminuted distal pole fracture resection with patella tendon reattachment can be performed (4). Complications post partial patellectomy may be tilting of the patella and increased contact forces on the femoral condyles (4). For this reason correct patellofemoral alignement is mandatory.

Total patellectomy should be considered very carefully and still remains a salvage procedure for highly displaced and severely comminuted fractures, which are not primarily reduceable or all other surgical approaches failed, non-unions, chronic infections or type IIIB periprosthetic fractures (20, 25, 31, 34, 44). Advantages of total patellectomy are shorter immobilization and less complicated surgical technique (31, 34, 65). Although studies were presented showing good to excellent outcome post total patellectomy (49) other studies demonstrate the importance of retaining even one fragment of the patella to maintain the lever arm of the extensor mechanism (49, 62). Augmentation of the extensor mechanism are described in multiple ways, e.g. intraoperative, primary repair of excess tendon (65) or the turndown procedure in the absence of prepatellar tissue with a tendon weave technique. The most common turndown procedure is the V-plasty by Shorbe and Dobson (52) when a full-thickness V-shaped flap of the quadriceps tendon is turned down and sutured into the proximal portion of the patella tendon. For large defects a free fascial or tendinous strip weaved into the quadriceps tendon is described by Gallie and Lemesurier (17).

Treatment of periprosthetic patellar fractures can be guided by three main criteria: integrity of the extensor mechanism, stability of the patellar implant and quality of the remaining bone stock (47). Surgical approach is depending on the fracture classification and varies between open reduction and internal fixation, partial or complete patellectomy, revision of the patellar component or resection of the patellar component and patelloplasty.

COMPLICATIONS

Beside general peri- and postoperative complications for invasive surgical treatment like wound infection, bleeding and haemorrhage, specific complications are known. A fracture re-dislocation is found in 12.6% (Figs 4 and 5), infection rate is 2.3% and irritation of the soft tissue is found in 10.3% due to a study from Smith et al (53). In up to 20% of the cases a loss of reduction and or fixation after surgical treatment is described (24). Loosening of K-wires and tension band wires are mainly seen and repeat ORIF should be the treatment of choice. Biomechanical studies and clinical reviews reported a combination of screw fixation with anterior band wiring have significant higher failure loads ($p<0.05$) and are superior in the treatment of patellar fractures (7, 9, 12, 13). A singular Kirschner-wire-based tension band risks to fail in 22% (53).

The majority of the patients is disturbed by the prominent hard metal and claims for an early removal of the hard metal as the patellar bone is prominent and the hard metal can interfere with the extensor mechanism of the knee joint. It is the most commonly reported complication following fixation of a patellar fracture, and rates for implant removal range from 0–50% (38, 41). Nonunion of the refixed patellar bone is rarely reported but occurs in up to 12.5% of the cases (32) and should be treated with re-fixation +/- interposition of cancellous bone. Prolonged postoperative immobilization can lead to joint stiffness and loss of knee motion (53). In this situation a mobilization under anaesthesia should be

Fig. 5. Secondary fracture dislocation after 3 weeks of a Speck and Regazzoni type B2 patella fracture in a 61-year-old male patient with known cryptogenic epilepsy initially stabilized with 2 lag screws. A low profile plate (variable fixed angle patella plate, KönigseeÒ) was used for re-fixation.

a|b|c h
d|e|f i
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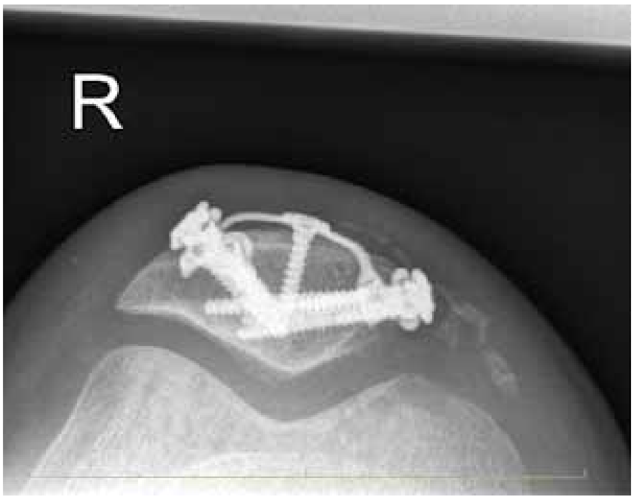
considered. Overall inadequate fixation with early displacement is reported in 10%–20% after surgical treatment (53).

CONCLUSIONS

A strict treatment algorithm with respect to known classification systems is indefinite as the surgical approach and management usually follows the preference of the surgeon. As a thumb role general indications for fracture treatment step in, but comorbidities and soft tissue management should be carefully considered. The surgical approach should be a lateral knee approach to restore the medial ligamentous structures.



A proposed algorithm of patella fracture management is based on the modified Speck and Regazzoni AO classification system and should assist in decision making of surgical treatment (see Table 1). Basically every patella fracture type can be fixed with a simple K-wire technique as no evidence of patella fracture management is reported. Furthermore individual fracture management is directed by personal experience and local institutional material availabilities, as especially modern devices like low profile plates are expensive.

Our experience showed good to excellent clinical and radiographic results using individual screw fixation technique. In highly comminuted fractures, distal pole fractures and osteoporotic bone structure the use of recently introduced low profile plates is recommended. A complete anatomical reduction is mandatory to prevent early onset of osteoarthrosis. Equally essential is the preservation of the overall patella length to restore the extensor mechanism of the knee joint.

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