31 Arthroscopic Fixation of Fractures Around the Knee

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31.1 Tibial Eminence Avulsion Fractures

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31.1.1 Epidemiology and Mechanism of Injury

Tibial eminence avulsion fractures occur most commonly in children and adolescents aged between 8 and 14 years (3/100,000 children [74]). Falls from a bike, motor vehicle accidents and sport activities (mostly soccer and skiing) are the most frequent causes in paediatric population; in these cases, a valgus-directed force associated with an external torsion when the knee is in hyperextension is the most frequently referred mechanism, which closely resembles the one for anterior cruciate ligament (ACL) tears. In adults, this lesion is rare and associated either with high-energy trauma, boot-induced injuries in skiers or forced internal rotation with flexed knee [10, 11, 17, 27, 35, 41, 48, 51, 60].

Tibial eminence avulsion fractures are often considered the paediatric equivalent to ruptures of the ACL. This happens because the epiphyseal ossification process reaches the tibial eminence only in late childhood or adolescence, leaving this area more vulnerable to tensile forces than the ACL itself [1, 5, 39, 61]. A greater ligamentous elasticity in children has also been advocated as possible aetiology for this fracture [55, 83].

Avulsion fractures may either involve the intercondylar depression where the ACL insertion lies only or, less frequently, the entire tibial spine with medial and lateral plateau [16].

31.1.1.1 Associated Lesions

Tibial eminence avulsion fractures are associated with a high incidence of bony contusions, typically on the lateral femoral condyle and the posterior tibia, especially in children [71]. Meniscal

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tear incidence ranges from less than 5 % to up to 40 % across different studies [30, 47, 50–52]. In older patients, tibial eminence fractures are often combined with lesions of the menisci, capsula or collateral ligaments [51, 65]. In addition to intra-articular pathology, tibial eminence fractures may be associated with tibial plateau fractures, specifically Schatzker type V and VI fractures [38, 66].

31.1.2 Diagnosis

31.1.2.1 History and Presentation

Presentation of acute and chronic avulsions may vary. In acute cases, pain, knee swelling and inability to bear weight are the most frequent complaints. Restricted range of motion may be present due to pain and swelling, loose bodies, impingement of the bone fragment or associated meniscal lesions. Patients affected by chronic tibial eminence avulsion fractures may complain about joint instability, recurrent effusion and restriction in passive and active knee extension [39, 46, 49, 73].

31.1.2.2 Clinical Examination

Reduced active and passive range of motion is often reported; swelling, guarding reactions or spasms may complicate clinical examination in acute lesions, making some tests for ligament stability impossible to perform. Depending on patient reaction and time to presentation, Lachman, anterior drawer and pivot shift tests may be slightly or clearly positive. Collateral ligament and posterior cruciate ligament stability should be tested; meniscal injuries may be suspected after a careful clinical examination. Assessment of neurological and vascular status completes the clinical examination [21, 30, 65, 73].

31.1.2.3 Imaging

A complete radiographic evaluation of the injured knee, including standard anteroposterior, lateral and oblique radiographic views, is usually diagnostic. Computed tomography (CT) surely helps to better define bony architecture and precisely identify the fracture anatomy (Fig. 31.1). Magnetic resonance imaging (MRI) offers a good visualisation of soft tissues: this permits to determine the substance quality of the ACL, assess other ligaments' integrity and identify possible meniscal or chondral injuries. Doppler ultrasonography, arteriography and subsequent vascular surgery consultation must be considered in the presence of diminished pulses, if dislocation is suspected or in cases of abnormal vascular examination [39, 46, 65, 73].

31.1.3 Classification

The system suggested by Meyers and McKeever in 1959 is still today the most commonly used (Fig. 31.2 and Table 31.1 [51]). Zaricznyj implemented this classification with a type IV for comminuted fractures [85].

Later, Zifo and Gaudernak proposed another scheme, which distinguished between isolated ACL avulsions and fractures including the intercondylar eminence [86].

31.1.4 Management

31.1.4.1 Principles

Anatomic reduction is the goal of tibial intercondylar eminence avulsion treatment. Isometry and tension are fundamental to restore ACL and knee kinematics and must be obtained with the surgical operation. A generally accepted rule is that over-reduction should be avoided to prevent excessive tightening of the ACL, resulting in limitation of knee motion [41]. However, some authors believe that permanent intersubstance stretching of the ACL occurs before the fracture and therefore recommend over-reduction; this is supported also by the evidence that long-term evaluation of well-reduced tibial eminence fractures reveals subtle increases in anteroposterior knee laxity but that slight laxity can be tolerated without limitations in daily life and sports [37, 64, 75, 81, 82].

31.1.4.2 Indications

Meyers type I fractures are treated conservatively; no consensus is obtained on the better

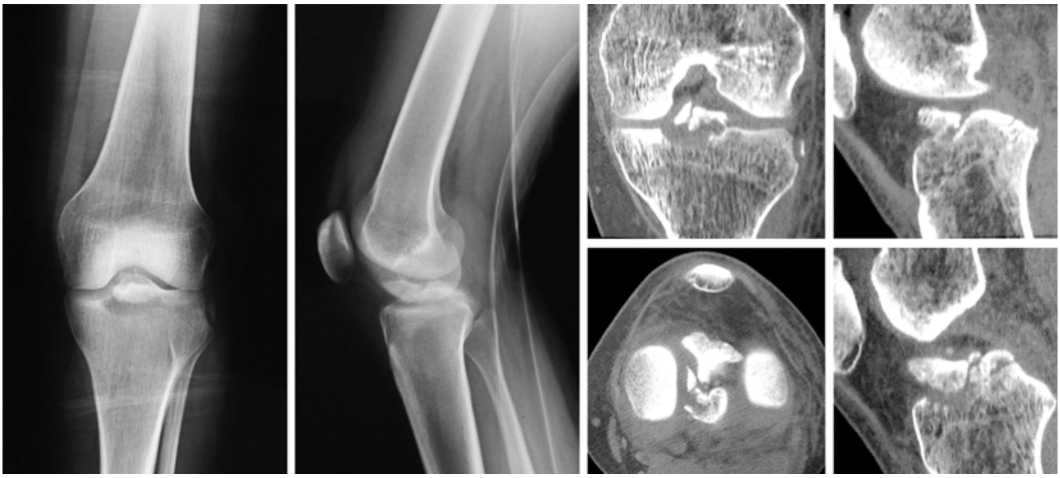

Fig. 31.1 Preoperative radiographs and CT scan in a Meyers and McKeever type III B fracture and Segond bony avulsion

immobilisation technique and the correct knee extension to maintain. Some authors prefer to hold the knee in slight flexion, a condition in which ligament tension is minimal, to allow maintenance of reduction [5, 16, 47, 50, 51]. Some others prefer to hold the knee in full extension to avoid extension deficit [21]. Full weight bearing is allowed if tolerated; follow-up of the patient is required with radiographs every 2 weeks to monitor possible displacement.

Treatment for Meyers type II fractures is controversial; an attempt to close reduction with knee extension or hyperextension after aspiration of the haemarthrosis is generally performed, although the rationale has been criticised. Anteroposterior and lateral radiographs (and CT or MRI if the radiograph is difficult to interpret) are required to assess reduction. Reduction might not be obtained due to meniscal interposition or insufficient congruency between condyles and avulsed tibial eminence [30, 48]. Nowadays, if persistent displacement of the anterior aspect is present, the old indication of cast immobilisation has been in most cases substituted by arthroscopic revision and fixation [3, 17, 39, 50, 51, 73].

Close reduction of Meyers type III fractures may be unsuccessful due to displacement of the osseous fragment; several papers have reported worse results for type III fractures treated non-operatively [25, 37, 47, 57, 76, 79]; therefore, arthroscopic reduction and internal fixation (ARIF) has become the standard procedure for this type of fractures.

Open reduction and fixation of tibial eminence avulsion fractures is never recommended, unless other lesions requiring open surgery are present [11].

31.1.4.3 Timing

Acute definitive treatment for tibial eminence avulsion fractures showed an earlier return to full preinjury activity and is therefore recommended, in combination with modern surgical techniques and accelerated rehabilitation protocols which reduce significantly the incidence of arthrofibrosis [56, 62].

31.1.4.4 Procedures

Setting, Portals and Diagnostic

McLennan in the 1980s and Van Loon and Lubowitz in the 1990s were the first to introduce ARIF to treat tibial avulsion fractures [35, 41, 48]. Currently, ARIF is considered the gold standard in the treatment of tibial eminence avulsion fractures.

The patient is placed supine. General or epidural anaesthesia may be used. Examination under anaesthesia may be useful to confirm ligamentous injuries. A leg holder may be used and a tourniquet

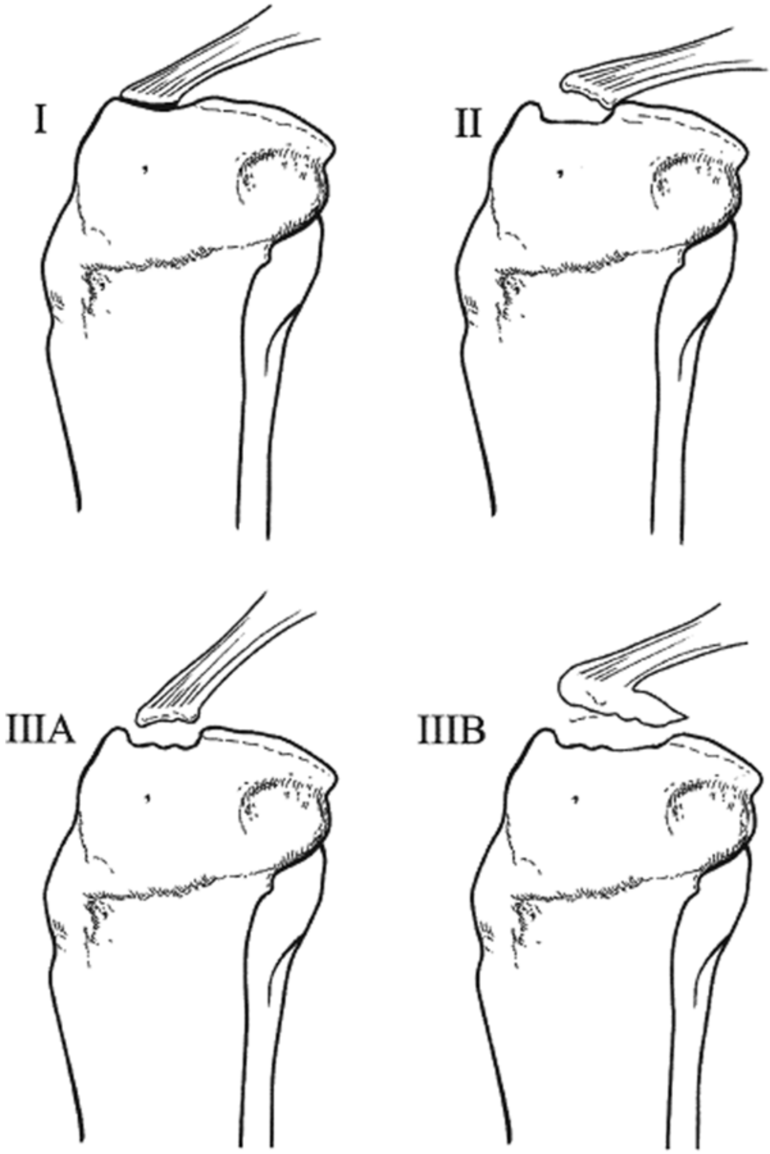

Fig. 31.2 The Meyers and McKeever classification of tibial eminence avulsion fractures (Reprinted from Lubowitz et al. [40], Copyright © 2005 Elsevier Inc, with permission from Elsevier). Type I: non-displaced or associated with minimal displacement of the anterior margin. Type II: superior displacement of the anterior aspect with an intact posterior hinge (bird's beak). Type IIIA: completely displaced, involves the ACL insertion only. Type IIIB: completely displaced, includes the entire intercondylar eminence

Table 31.1 Meyers and McKeever tibial eminence avulsion fractures classification

Type	Pattern
I	No or minimal displacement
II	Superior displacement of anterior aspect with intact posterior hinge
IIIA	Complete displacement only of ACL insertion
IIIB	Complete displacement of the entire inter condylar eminence
IV[a]	Comminuted fracture

[a]Type IV added by Zaricznyj [85]

may facilitate visualisation. Fluoroscopic imaging is not always required but may help confirm correct positioning of fixation devices.

Standard anterolateral and anteromedial portals are used. An accessory central transpatellar portal may facilitate reduction and fixation [39]; other additional portals for instrumentation may be established if necessary. Irrigation and debridement are performed first, to evacuate blood clots and loose bodies. Diagnostic arthroscopy is performed to document the pattern of the fracture and identify possible associated meniscal, ligamentous and chondral injuries. Capsular or meniscal lesions may be treated before or after fracture fixation, depending on specific situation and surgeon's preference [39, 73].

Reduction Techniques

The anterior horn of the medial or lateral meniscus or the intermeniscal ligament a frequently trapped within the fracture site. A probe or a meniscal hook may be used to retract it and free the fracture site; a temporary meniscal suture loop may also be used to facilitate retraction. The intermeniscal ligament can be resected if mobilisation is not possible. Once the fracture site has been debrided, a ligamentoplasty aiming guide or a probe is used to attempt fracture reduction. Depending on the chosen fixation technique, the surgeon may directly proceed with definitive fixation or may obtain a temporary fixation with a Kirschner wire or a Steinmann pin [15, 22, 30, 42, 60, 62, 72, 79, 82].

Fixation Techniques

Screw Fixation

Anterograde or retrograde screw fixation techniques have been described. The screw must not be larger than one third of the fragment diameter, to prevent comminution [6]. A single 3.5 or 4.0 mm anterograde transepiphyseal screw (with or without washer) has been indicated as sufficient to hold the fragment in anatomic position [6, 22, 41, 53, 68]. The screw may be inserted from a superior anteromedial or a transpatellar portal, with the knee in 100–120° flexion. If cannulated screws are used, the wire or pin used for temporary fixation may also serve as a guide (Fig. 31.3) [41, 68].

Physeal-sparing fixation can be achieved with a more horizontal positioning of the screw; in this case, fluoroscopy is fundamental to prevent transepiphyseal fixation. Fixation with two screws has also been proposed as physeal-sparing technique [2, 29].

Before closure, full range of motion must be checked to avoid impingement. Screw removal is not compulsory but recommended, between 8 and 12 weeks postoperatively (Fig. 31.4) [68].

Suture Pull-Out Fixation

Suture pull-out technique can be used when the fracture is small or comminuted. some cases of growth defects have been observed when this technique is used with still opened growth plates; transphyseal tunnel placement may in these cases be considered as an alternative to transepiphyseal tunnels [32, 39, 58, 67].

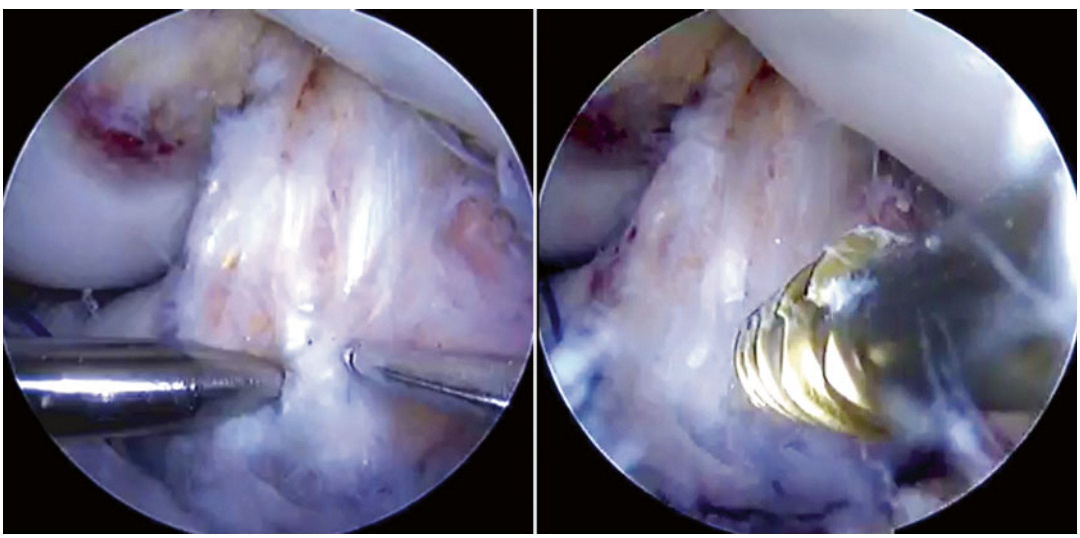

Fig. 31.3 Reduction and fixation with a cannulated screw. The Segond bony avulsion has been treated conservatively

Fig. 31.4 Radiographic results of screw fixation: immediately after screw positioning and 8 weeks after surgery, when full ROM and weight bearing has been reached

One or more high-resistance sutures are passed through the ACL fibres or the fracture fragment with the help of a curved suture lasso, a hook or a bended cannula, percutaneously or through an accessory portal. From a short longitudinal incision centred over the tibial tubercle, two 2.4 mm tibial bone tunnels are then drilled from the anterior aspect of the tibia, 1–2 cm apart from each other; a ligamentoplasty guide aids in obtaining the correct exit points, at the medial and the lateral edges of the fracture bed in its midcoronal plane. A suture retriever or a wire loop is passed through each tunnel to pull down the ends of the reduction sutures. These are finally tied together or tied to a screw, checking for appropriate reduction, with the knee flexed at approximately 30° [2, 7, 20, 23, 39, 45, 46].

Suture Anchor Fixation

Suture anchor fixation has been first advocated as a physeal-sparing technique. Titanium or biocomposite screws loaded with two or three high-resistance sutures are introduced through the anteromedial portal and placed either 2–3 mm anterior to the fracture site, with 45° inclination to the frontal plane to avoid physis penetration and ensure minimal pull-out risk. Placement in the posterior aspect of the fracture or all around the fracture site has also been described. The sutures are then passed through the ACL fibres and tied, with the knee flexed between 20 and 45°, with a simple arthroscopic sliding knot or different arthroscopic suture patterns, such as a mattress suture [24, 44, 80].

Other Fixation Techniques

Fixation with one or two Kirschner wires has also been described; hardware removal is recommended after 6 months [4, 9, 81].

Staple fixation has been proposed, with the advantage of not requiring tibial incision [28, 77].

Short bioabsorbable nails [34], meniscus arrows [84] and suture-button systems [14] have also been described for treatment of tibial eminence avulsion fractures.

A variation of the suture pull-out technique with metal wires instead of high-resistance sutures has been described [59].

31.1.4.5 Postoperative Care

Drainage is usually unnecessary. Surgery may be on outpatient basis or be followed by a short hospital stay. Crutches are optional and recommended at first, and patients are then permitted to bear full weight, unless additional procedures as meniscal repair or microfractures have been performed. An accelerated rehabilitation to reduce stiffness should be weighed against the possibility of displacement an malunion [19]. Some authors still recommend cast immobilisation for 3–6 weeks [22, 26, 63, 69, 72], while others suggest early range of motion exercise in a hinged brace, with the knee first locked in a brace in full extension and gradual unlocking to full range of motion by 6 weeks [19, 27, 39, 42, 62, 64, 68, 79]. Rehabilitation techniques are heterogeneous and not well described in the literature. Time to return to sport also varied from 4 weeks to 5 months [11]. Cycling can be permitted as soon as the range of motion is sufficient, followed by light jogging. Pivot-twist manoeuvres should be avoided until 12 weeks after surgery. After 6 weeks, the brace is discontinued, resisted flexion is permitted through a full range of motion, and resisted extension is permitted through a range of 30–90°. Terminal resisted extension should not be performed until 3 months, when quadriceps usually reach the preoperative strength [39, 46, 73].

31.1.5 Complications

Residual laxity may be found after arthroscopic reduction and fixation of tibial eminence avulsion fractures; nevertheless, the majority of patients have functional stability and are not adversely affected. Revision surgery with ACL reconstruction should be considered if persistent complaints of instability are reported, which can be caused by displacement, malunion, non-union or ACL substance injury [6, 22, 29, 42, 46, 48, 52, 53, 73, 81].

Pain or discomfort due to metal hardware is common with the use of cannulated screws; implant malpositioning may lead to loss of full knee extension or secondary osteoarthritis. Limited range of motion can also result as a consequence of abundant scar tissue formation in the intercondylar notch [46].

Arthrofibrosis is rare if the patient undergoes early ARIF and early active range of motion rehabilitation [19, 62].

Growth disturbances are rare but worrying complications in paediatric tibial eminence avulsion fracture fixation. The most severe cases with coronal and sagittal plane deformities have been reported following transepiphyseal screw fixation; screw removal is fundamental and may be followed by hemiepiphysiodesis or corrective osteotomy [2, 13, 31, 54].

Residual quadriceps weakness and persistent retropatellar pain may be observed. Meniscal entrapment can be a cause of residual pain, requiring revision surgery [10].

31.1.6 Literature Results

No systematic reviews or meta-analyses have been produced regarding tibial eminence avulsion fracture treatment in adults. Coyle et al. and Leeberg et al. published two systematic reviews on tibial eminence fractures in paediatric population, in which better long-term results are reported with arthroscopic surgery, compared to open surgery; no indication on the best type of fixation was specified [11, 33]. Papers describing outcomes of tibial eminence fractures at more than 5 years follow-up show an improvement in results with the transition from open to arthroscopic approach [11, 36, 63, 72].

Comparisons between screw and suture fixation showed ambiguous results. Sharma et al. found slightly superior clinical results for absorbable sutures in comparison to non-absorbable materials; a statistically significant difference was found for adults but not for children in knee laxity after a mean of 44 months follow-up [70]. Seon et al. found no significant differences between screw and suture fixation in terms of average Lysholm knee scores and stability at a minimum of 2 years follow-up [69]. Biomechanical studies showed controversial results, sometimes favouring metal implants or sutures, sometimes showing no significant differences between them [8, 12, 18, 43, 78].

31.2 Tibial Plateau Fractures

Pietro Randelli, Davide Cucchi, Filippo Randelli, Chiara Fossati, Paolo Cabitza

31.2.1 Mechanism of Injury and Epidemiology

Fractures of the tibial plateau represent approximately 1–2 % of all fractures; the vast majority of them are related to traffic injuries, falls from height, sports or trauma of other kind. Sport-related injuries, most of which affect skiers, account for 5–10 % of all cases [88, 109, 113, 115, 136].

Tibial plateau fractures may occur as a result of an axial compressive force, a valgus force or a varus force; combinations of these forces are also possible and may produce more complex fractures. The direction, magnitude and location of the force, as well as the position of the knee at impact, determine the fracture pattern, location and degree of displacement. In most cases, the medial or lateral femoral condyle act as an anvil imparting a combination of both shearing and compressive forces to the underlying tibial plateau [104, 134, 152]. Either one or both compartments of the tibial plateau may be involved; due to the anatomic axis at the knee joint and the predominance of injuries caused by a lateral-to-medial-directed force, when a single compartment is involved, it is usually the lateral plateau [131, 147].

Older patients with reduced bone mineral density are prone to sustain depression-type fractures because their subchondral bone is less resistant to axially directed loads. In contrast, younger patients with denser bone sustain more likely split-type fractures and have associated ligamentous disruption [92, 125, 128, 129, 152].

31.2.1.1 Associated Lesions

Fractures of the tibial plateau compromise the blood supply from the intramedullary arterial network but usually leave the periosteal network intact [119]. The popliteal vessels and nerves may be also damaged, especially in the event of a high-energy trauma [147].

These fractures are frequently associated with other bony or soft tissue lesions. The tibial intercondylar eminence is often avulsed in association with fractures of the tibial plateau [138]. Fractures of the femoral, tibial or peroneal shafts or epiphyses of the patella or other bones of upper or lower limbs have been reported, especially after high-energy trauma [88].

The frequency of meniscal lesions varies widely across studies (2–47 %). Vangsness et al. reported the highest rate of associated meniscal lesions, with almost half of the knees with closed tibial plateau fractures requiring surgical meniscal repair [121, 155].

Up to one third of knees with tibial plateau fractures may have complete or partial tears of the anterior cruciate ligament [115]. Lesions of the collateral ligaments and of the posterior cruciate ligament may be present and should be sought routinely. Ligamentous injury occur more frequently in case of split-type fractures of the lateral plateau, in which energy is transmitted from the rigid cancellous fragment to the ligaments without dissipation [147].

31.2.2 Diagnosis

31.2.2.1 History and Presentation

Frequent presentation signs and symptoms are pain, knee swelling and inability to bear weight on the affected leg. Trauma history and mechanism of injury may be precisely described by the patient or may not be reported or available. It is always important to confirm the level of energy involved in the injury; associated injuries are most often present after high-energy trauma [113, 134, 147].

31.2.2.2 Clinical Examination

Clinical examination may be complicated by swelling, apprehension or spasms; reduced active and passive range of motion is usually reported, and haemarthrosis is generally present. If possible, tests for ligament stability or meniscal integrity should be performed. Any open wounds must be evaluated; injection of at least 50 ml sterile saline solution in the knee may help to ascertain if the wound communicates with the joint space [131]. Popliteal, dorsalis pedis and posterior tibial pulses must be palpated; if absent and in any case of suspected knee dislocation or blood vessel injury, Doppler ultrasonography, angiography and vascular surgery consultation must be considered. Disproportionate pain, pain arising with passive toe movement or a swollen leg in an unconscious patient may suggest an impending compartment syndrome and require compartment pressure monitoring. Evaluation of the peroneal and tibial nerve function completes the clinical examination [113, 134, 147].

31.2.2.3 Imaging

Radiographic evaluation of the injured knee is mandatory (Fig. 31.5); complete radiographic evaluation includes standard anteroposterior, lateral, two oblique projections and a 10–15° caudally tilted tibial plateau view [104, 134, 147].

Computed tomography (CT) provides a very detailed visualisation of the fracture pattern, permitting to identify the extent of the articular involvement and the presence of intra-articular fragments. CT must be routinely performed in these fractures. Magnetic resonance imaging (MRI) offers a better visualisation of soft tissues; this permits to identify ligamentous, meniscal or chondral injuries and to plan the surgical intervention accordingly. CT and MRI scans have been demonstrated to provide a far more superior accuracy than plain radiography; in fact, they have partially substituted plain radiography and are considered the gold standard for bony and soft tissue injuries [100, 135, 157].

31.2.2.4 Arthroscopic Evaluation

Diagnostic arthroscopy is considered a valid tool to allow direct visualisation of the articular surface. Soft tissue injuries are commonly associated with tibial plateau fractures and can be diagnosed by arthroscopic evaluation [87, 99, 134, 141].

31.2.3 Classification

Different classification systems are available for tibial plateau fractures. The majority of these systems recognise split/wedge, compression and bicondylar types.

Gerard-Marchant and Duparc described the first classification systems for proximal tibial fractures, which established the basis for current classifications [112, 114]. Hohl proposed the first widely accepted classification of tibial plateau fractures, later expanded by Moore [120, 140]. In 1992, Schatzker described the currently most frequently used classification for tibial plateau fractures (Fig. 31.6 and Table 31.2) [94, 134, 152].

Fig. 31.5 Preoperative radiographs and CT scan in a Schatzker type III fracture

In the AO/ASIF classification, proximal tibia is denoted as segment 43, and its fractures are divided into three main categories [150].

31.2.4 Management

31.2.4.1 Principles

The ultimate goals of tibial plateau fracture treatment are to restore a painless knee function and prevent post-traumatic arthritis; this can be obtained by re-establishing joint stability, alignment and joint surface congruity while preserving full range of motion. Different types of conservative or surgical therapy are available, depending on articular damage, depression or comminution of the fracture and soft tissue conditions [94, 104, 122, 137].

31.2.4.2 Indications

Although the indications for nonoperative versus operative treatment of tibial plateau fractures

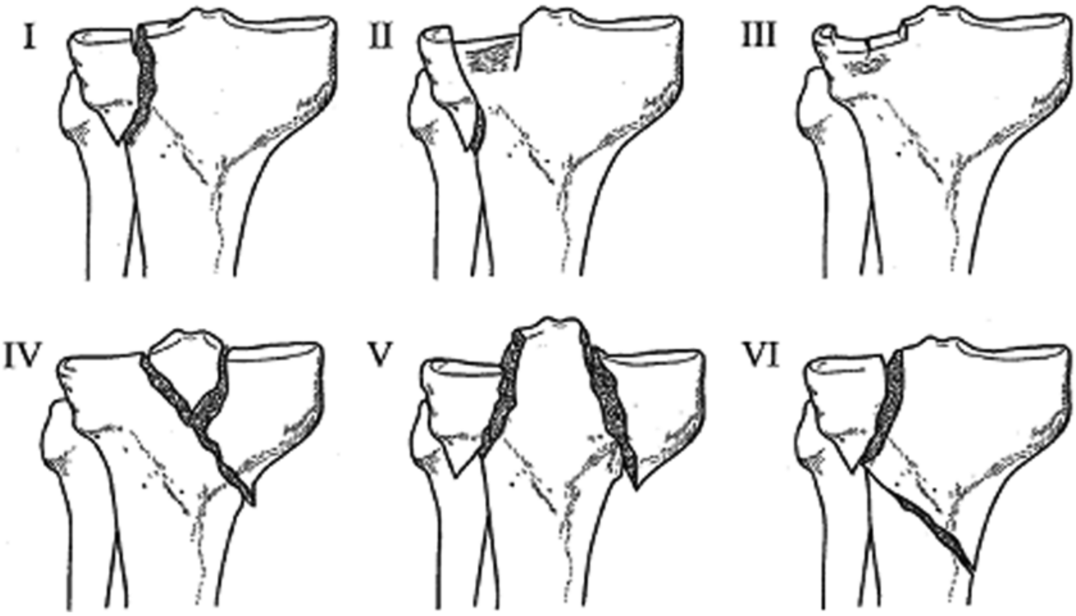

Fig. 31.6 The Schatzker classification of tibial plateau fractures (Reprinted from: Lubowitz et al. [134], Copyright © 2004 Elsevier Inc, with permission from Elsevier). Type I: wedge or split fracture of the lateral aspect of the plateau. Type II: lateral wedge or split fracture associated with compression. Type III: pure compression fracture of the lateral plateau. Type IV: fracture of the medial plateau, either split or split and compression. Type V: fracture of the medial and lateral aspects of the plateau, either split or split and compression. Type VI: fracture of the medial and lateral aspects of the plateau, complex

Table 31.2 Schatzker tibial plateau fractures classification

Type	Plateau involved	Pattern	Force direction
I	Lateral	Wedge/split	Valgus and axial
II	Lateral	Wedge/split + compression	Valgus and axial
III	Lateral	Pure compression	Axial
IV	Medial	Split ± compression	Varus or axial
V	Lateral + medial	Split ± compression	Axial (high energy)
VI	Lateral + medial	Complex fracture	Combinations of forces (high energy)

vary widely in the literature, there is consensus on nonoperative treatment for non-displaced or minimally displaced and stable fractures with no absolute indications for surgery (as neurovascular injury or compartment syndrome). Advantages of nonsurgical treatment include a short hospitalisation and no risk of infection; disadvantages are possible displacement and joint stiffness after prolonged immobilisation. If nonoperative management is pursued, it is recommended to use a hinged brace and start early active range of motion as soon as possible; close follow-up of the patient with radiographs every 2 weeks for the first 6 weeks is required to monitor depression, displacement and axis deviation [136, 141, 147, 150].

If displacement or articular compression are present, surgery is required to restore limb alignment, articular congruity and knee stability.

Arthroscopic treatment of tibial plateau fractures is generally accepted for Schatzker types I, II, III and IV fractures. Authors favouring arthroscopically assisted procedures claim numerous advantages when comparing them to open reduction and internal fixation (ORIF): arthroscopic treatment is less invasive, and a better visualisation of the entire articular surface is achieved. Moreover, it allows accurate fracture reduction; it is easy to evacuate blood clots or debris and to treat meniscal or ligamentous injuries. Finally, hospitalisation and rehabilitation are faster and with less pain [95, 115, 136].

More complex fracture patterns (Schatzker types V or VI) may not be suitable for arthroscopic treatment. In these cases, ORIF is preferred; the use of arthroscopy in complex proximal tibial fractures has also been suggested, to improve the quality of the reduction [95, 101, 102, 139].

31.2.4.3 Timing

No published studies have produced evidence-based recommendations on surgical timing for arthroscopic treatment of tibial plateau fractures. Studies on open treatment suggest lower wound complication rate if surgery is performed within 4 h after trauma or after 5 days [156]. In type V and VI fractures, the degree of soft tissue swelling dictates the timing of definitive surgery and the need for provisional stabilisation with an external fixator [135].

31.2.4.4 Procedures

Setting, Portals and Diagnostic

Arthroscopically assisted reduction and internal fixation in the treatment of tibial plateau fractures was first introduced by Caspari and Jennings in the 1980s [98, 126]. Currently, arthroscopically assisted approaches are being widely used in the treatment of tibial plateau fractures [89, 97, 102, 103, 107, 110, 111, 115, 116, 123, 124, 127, 130, 133, 142, 146, 148, 149, 151, 153].

The patient is placed supine. General or epidural anaesthesia may be used. If autologous iliac bone graft or concomitant ligament reconstruction procedures are planned, draping must consider the donor sites as well. Examination under anaesthesia may be useful to confirm ligamentous injuries. Gentleness is crucial, to avoid increasing the displacement of the bone fragments. A leg holder may be used and a tourniquet may facilitate visualisation.

Standard anterolateral and anteromedial portals are used. An accessory lateral portal, lateral to the standard anterolateral one and at the level of the joint line, may be useful to retract the meniscus with a loop or with a hook and improve anterior plateau view [145]. Irrigation and debridement are performed as a first step, to evacuate blood clots and loose bodies. Diagnostic arthroscopy is performed, the articular pattern of the fracture and the amount of depression are identified, and meniscal, ligamentous and chondral injuries are documented.

Reduction Techniques

Schatzker type I fractures (fractures characterised by pure cleavage) may be reduced via external traction or with a reduction forceps. Temporary fixation is achieved using one or two Kirschner wires, which should be placed approximately 1 cm under the joint surface. These wires may also be used as a joystick to elevate the fragment and to correct rotational displacement. If the apex of the split is displaced, a small incision can be made to allow anatomic reduction of the distal fracture spike. If traction is insufficient to achieve reduction, a palpation hook can be used to disimpact the bone fragments. Arthroscopy is used to verify reduction and fluoroscopy to confirm the adequate placement of wires. Two percutaneous cannulated screws with washers are placed for definitive fixation. In case of comminution or instability, a buttress plate, with or without additional compression screws, is required and can be placed percutaneously or with a standard extra-articular incision [96, 134].

Schatzker type III fractures (characterised by isolated depression) and fractures in which depression is combined with cleavage (type II and IV) require reduction of all depressed elements first. To elevate the subchondral bone and the joint surface, a tool is inserted through the metaphysis, under fluoroscopic and arthroscopic control.

The elevating force must be applied from the centre of the depressed area; this may be performed directly, by means of an osteotome introduced through an anterolateral cortical window or through the fracture site or with the help of a ligamentoplasty aiming system, which can be used to place a drill-guide pin in the centre of the depressed fragment (Fig. 31.7). A 9 or 10 mm drill is then used to penetrate the cortex, either anterolateral or anteromedially, manually or using a power tool. Careful manoeuvres under arthroscopic and fluoroscopic control must avoid

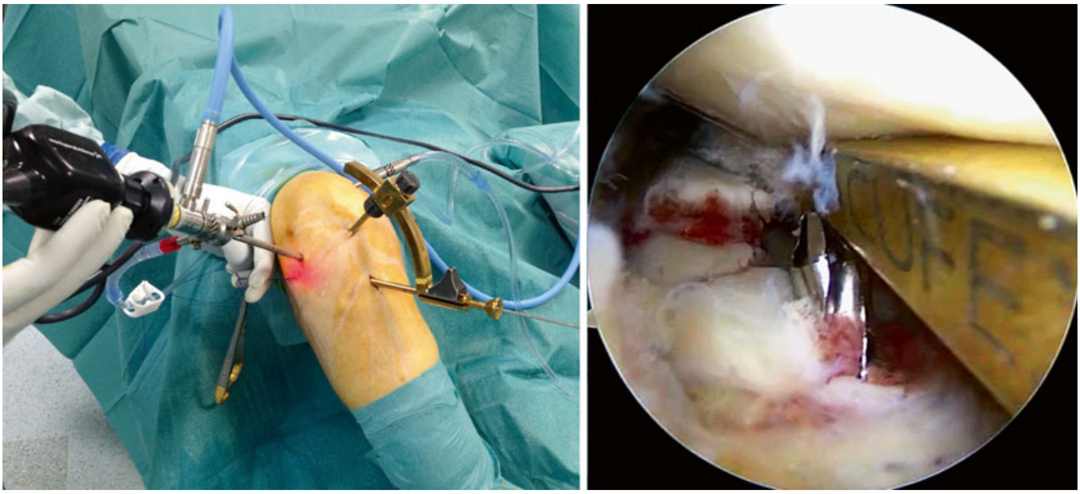

Fig. 31.7 Ligamentoplasty guide to place the drill-guide pin in the centre of the depressed fragment; external and arthroscopic view

Fig. 31.8 An impactor is used to elevate the fracture site, under arthroscopic control

worsening the displacement or violating the joint surface [98, 126, 145].

A cannulated tamp or impactor is used to elevate the fracture site (Fig. 31.8). A spatula may be useful to correct the reduction from the articular side. Slight overcorrection of the joint surface depression followed by flexion of the knee is desirable to allow the femoral condyle to shape the joint surface.

Temporary stabilisation is achieved using one or two pins introduced 1 cm below the joint surface, either under fluoroscopic guidance or with automatic pinning systems (Fig. 31.9) [154].

The bone defect created in the metaphysis may then be grafted. Fixation occurs under arthroscopic and fluoroscopic control and associated lesions are treated [96, 134].

Fixation Techniques

Lateral tibial plateau fractures should be stabilised using two or three large-diameter (6.5 mm) cannulated titanium screws with washers, inserted percutaneously (Fig. 31.9). Screw length and position must be checked fluoroscopically.

Since the first cannulated screw acts also to close the fracture widening, it might result too long and medially prominent. If this happens, to avoid postoperative pain, this screw should be replaced with a shorter one, once stable fixation is obtained with the second screw. Fractures of the medial compartment are exposed to a higher load than those of the lateral; biomechanical studies have suggested that better stability may be achieved by plate-screw fixation rather than by screw fixation [108], but at present no studies compared the clinical outcomes of these different techniques. Extensive and invasive fixation can be used in comminuted fractures and in patients with reduced bone mineral density. A buttress screw at the inferior apex of the fracture or a buttress plate may be needed for additional stability in Schatzker types I, II and IV frac-

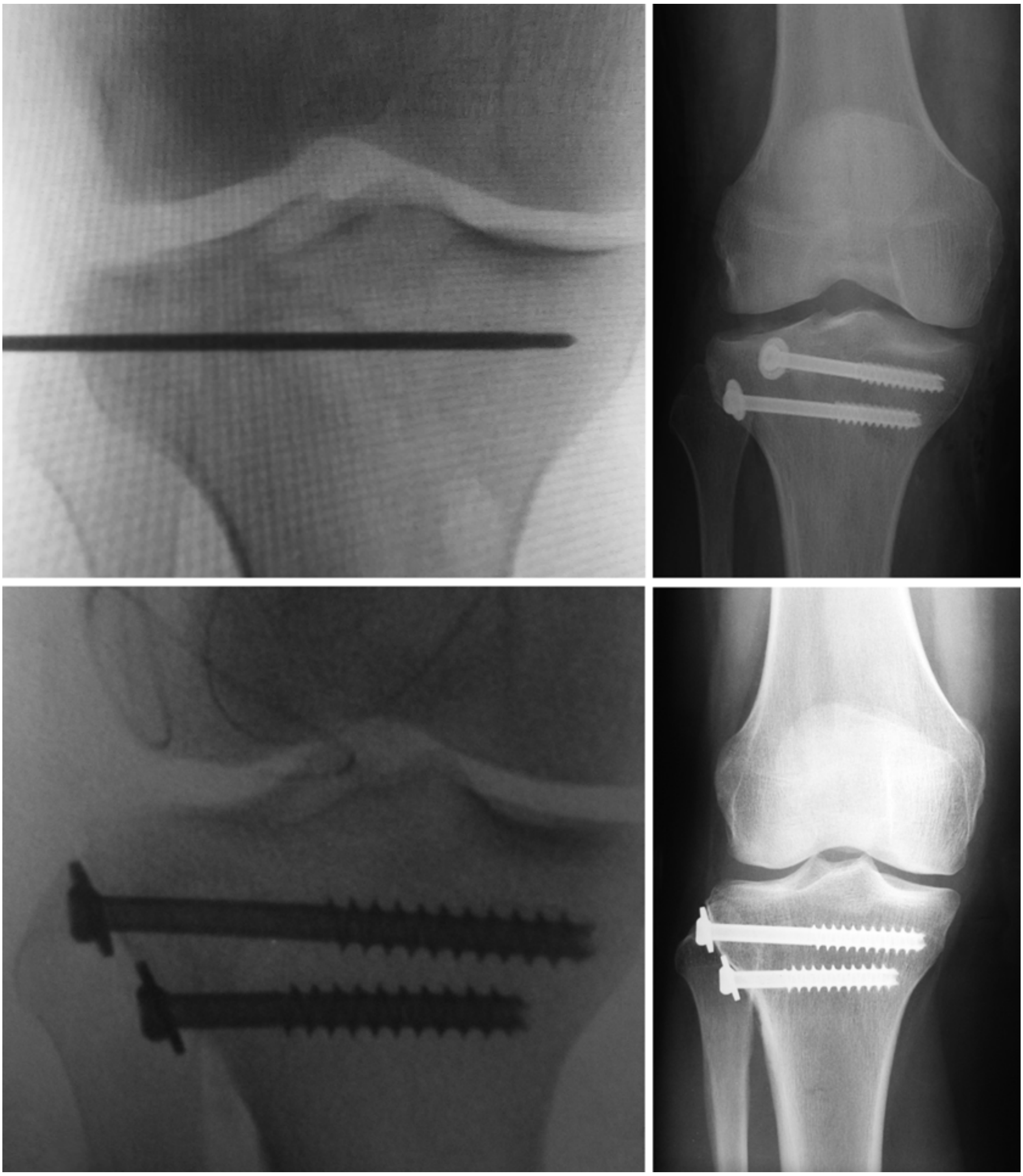

Fig. 31.9 Temporary fixation of a Schatzker III fracture with a Kirschner wire and definitive fixation with two cannulated screws with washer

tures. In Schatzker type III fractures, cannulated screws with washers placed directly under the subchondral plate are usually enough to maintain elevated the depressed fragments. Although clinical studies support the use of screws to stabilise tibial plateau fractures, biomechanical studies present controversial results [93, 108, 132, 144].

Bone Graft Sources

Bone grafts are divided into biological and synthetic materials. Despite a lack of good quality randomised control trials, there is sufficient evidence supporting the use of bone graft substitutes in depressed plateau fractures [117]. The most frequently used grafts include autograft from the comminuted metaphysis or the iliac crest, allograft freeze-dried croutons, demineralised bone matrix and tricalcium phosphate. Poly-methyl methacrylate is also used to fill bone defects; it provides immediate mechanical strength but may cause problems in the event of infection or revision surgery. Hydroxyapatite combines the immediate mechanical strength of cement and the osteoinductive properties of biological grafts [118, 143].

31.2.4.5 Postoperative Care

Drainage is usually unnecessary. Hospitalisation is 3–7 days long. The patient is kept in a hinged brace, and mobilisation is started immediately on the day after surgery. Early passive and active range of motion should be encouraged with a goal of 0–90° to be achieved by the first week. Full range of motion should be obtained by the sixth postoperative week. Weight bearing is restricted for 6–12 weeks, with this range depending on the fracture pattern and the patient's bone quality and needs. Radiographic follow-up is recommended and should guide the progression from non-weight bearing to partial and full weight bearing. Thromboembolism prophylaxis is given until the resumption of weight bearing [92, 96, 137].

31.2.5 Complications

Compartment syndrome, due to fluid extravasation, is a worrying but rare early complication after tibial plateau arthroscopicaly assisted reduction and internal fixation. We suggest to avoid any excessive increase in the pump pressure during the procedure. Deep venous thrombosis and pulmonary embolism may complicate every fracture of the lower limb treated with a surgical procedure followed by non-weight bearing or immobilisation. Misalignment, infection, malunion, non-union and stiffness may complicate the procedure at long-term follow-up [90, 91, 94, 96, 130].

31.2.6 Literature Results

The most recent available high evidence literature reports on arthroscopicaly assisted reduction and internal fixation for tibial plateau fractures are two systematic reviews by H. Chen et al. [105] and X. Chen et al. [106]. The first review analysed 12 studies, five prospective and seven retrospective, involving 353 patients, most of which are affected by Schatzker type I–III fractures. At least 80 % of patients had excellent or good clinical results measured with the Rasmussen scores, and more than 63 % of patients had excellent or good radiological outcomes. Postoperative osteoarthritis complicated a variable number of procedures, ranging from 0 to 47.6 % across the studies considered. The authors indicate ARIF as an effective procedure.

X. Chen et al. included in their review two retrospective comparative studies, 16 case series studies and one clinical series based on a technical note, involving 609 patients, most of which are affected by Schatzker type II–III fractures. Incidence of associated lesions was 42.2 % for meniscal injuries and 21.3 % for anterior cruciate ligament injuries. 90.5 % of patients had excellent or good clinical results, and 90.9 % of the patients were satisfied. Secondary osteoarthritis at a mean follow-up of 52.5 months ranged between 3.2 and 63.0 % across the studies. There were six cases of severe complications: one case of compartment syndrome, three cases of deep infection and two cases of deep venous thrombosis [89, 110, 130]. The authors concluded that ARIF is a reliable, effective and safe method for the treatment of tibial plateau fractures, especially when presented with concomitant injuries.

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