MINI-SYMPOSIUM: MANAGEMENT OF FRACTURES AROUND THE KNEE JOINT

(ii) The “floating knee” in adults and children

Byron Chalidis, Saurabh S. Metha, Eleftherios Tsiridis, Peter V. Giannoudis*

The Academic Unit of Orthopaedic Surgery, A Floor, Clarendon Wing, Leeds General Infirmary, Great George Street, Leeds LS1 3EX, UK

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Summary
The treatment of simultaneous ipsilateral femoral and tibial fractures is a therapeutic challenge, often complicated by concomitant multisystem injury. This combination necessitates vigilance in identifying and promptly treating associated neurovascular compromise. In the context of multiple trauma, a spanning external fixator could be considered to allow restoration of haemodynamic stability and to minimise the immunoinflammatory response to injury. Definitive reconstruction can be performed at later stage. Intramedullary nailing appears to be the most common method of stabilisation.

Introduction
“Floating knee” is the term applied to a flail knee joint segment resulting from fractures of the shaft or adjacent metaphysis of the ipsilateral femur and tibia.1 The injury, which was initially described by Blake and McBryde,1 is generally caused by high-energy trauma. Local trauma to the soft tissues is often extensive and life-threatening injuries to the head, chest or abdomen may co-exist.2,3 The initial evaluation of the extent of injuries is of critical importance and should be followed by an appropriate sequence of emergency diagnosis and therapeutic measures according to the ATLS guidelines.

These injuries have received a lot of attention during the last few decades. The rates of infection, non-union, malunion and stiffness of the knee are relatively high, leading to functional impairment and frequently unsatisfactory results.4 In the paediatric population this fracture combination is less common than adults but epiphyseal injury can adversely affect the open growth plates, predisposing to limb length discrepancy and angular deformities.5

The aim of this review is to address the current management options for ipsilateral femoral and tibial fractures, including a consideration of the prognostic factors that may be correlated with the final outcome.

Mechanisms of injury—associated injuries

A traffic accident is the most common mechanism of trauma, reported in up to 97% of cases, followed by gunshot wounds and a fall from a height.4,6 There is a male preponderance, particularly in young adults and especially in the age range of 20–30 years.7

“Floating knee injuries” are often combined with extensive multisystem injuries and they are accompanied by significant morbidity.1,2,5 Ostrum8 reported that the average Injury Severity Score9 was higher in patients with
ipsilateral femoral and tibial fractures than in cases of isolated femoral shaft fractures (19 and 16.6, respectively). Furthermore, Rios et al.11 found 42% of patients to have a head injury, 28% chest injuries and 16% abdominal trauma. The above figures indicate that these combined fractures are more severe than simply the sum of the skeletal injuries and must be included in a polytrauma-based assessment and treatment protocol.

Vascular damage and nerve lesions are also quite common. Adamson et al.10 and Paul et al.11 reported arterial lacerations in 30%, mainly in the popliteal and posterior tibial arteries. The majority of vascular injuries were associated with limb ischaemia necessitating vascular reconstruction. The incidence of nerve dysfunction was approximately 10% and the most commonly affected nerve was the peroneal nerve, as a result of traction injury. Traction usually causes neurapraxia, and resolution of nerve palsies is anticipated in the majority of cases.10,11

The incidence of open fractures is very high, approaching 50–70% at one or both fracture sites.2,4,7,10,12 The most common combination is a closed femoral fracture with an open tibial fracture. In the 89 floating knee injuries described by Hee et al.,12 there were 55 open fractures, 32 open tibial fractures, 3 open femoral and 20 both femoral and tibial open fractures. Out of 55 open fractures, 29 were Grade III and 3 of them required knee amputation.

Knee ligament injury occurring in association with ipsilateral femoral and tibial fractures is well documented, occurring in roughly ⅓ of patients.13,14 Anterolateral rotatory instability seems to be the most common instability pattern. Knee ligament injury is not always suspected and joint swelling due to haemarthrosis may be mistaken for a “sympathetic effusion”. It seems apparent that the ipsilateral femoral and tibial shaft fracture and knee ligament injury is part of a continuum of combined injuries resulting from complex high-energy forces. There is no clear correlation between the side or type of the fracture and which of the ligaments are involved. On the basis of the experience of many authors, a high index of suspicion for knee ligament damage is advisable.13,14

In skeletally immature patients the injury is uncommon; few existing studies report on floating knee in children.5,15–17 Data from the studies that are available show that the results are comparable with adults in terms of the mechanism of fracture, the incidence of associated major injuries and the complexity of treatment.

Classification—evaluation

A. Adults

Blake and Mcbryde1 used the terms “true” or type I injury and “variant” or type II injury to classify the “floating knee” fracture pattern. In type I injury there is a pure diaphyseal fracture of the femur and tibia, whilst in variant type II injury the fracture extends into the knee, hip or ankle joint. Fraser et al.18 classified the injury in a similar way, according to knee involvement. Their type I is the same as Blake’s and McBryde’s “true” injury, with extra-articular fractures of both bones. Type II is subdivided into three groups: Ila, with femoral shaft and tibial plateau fractures, Ilb with fractures of distal femur and shaft of the tibia and Ilc with distal femur and tibial plateau fractures (Fig. 1). In both classifications, type II fractures with intraarticular involvement have been linked with higher complication rates and poorer functional results than type I injuries.10

There is wide acceptance of the evaluation of functional outcome according to criteria established by Karlstrom and Olerud.19 Subjective symptoms from thigh or leg, subjective symptoms from knee or ankle joint, walking ability, participation in work and sports, angulation and/or rotational deformity, shortening and restricted joint mobility (hip, knee, or ankle) are recorded and the result is characterised as excellent, good, acceptable or poor (Table 1).

B. Children

In children “floating knee” injuries are classified according to the Bohn–Durbin5 and the Letts et al.17 classification systems. The Bohn–Durbin5 classification describes the double-shaft pattern of fracture as Type I, the juxtaarticular pattern as Type II and the epiphyseal type as Type III. However, it does not take into consideration open fractures and cannot be used to predict complications and prognosis. The authors determined that femoral union in a position of greater than 30° anterior angulation, 15° valgus angulation, 5° posterior or varus angulation, or more than 2 cm of shortening, should not be accepted. Tibial malunion was defined as greater than 5° angulation in any plane or greater than 1 cm of shortening, whereas rotational malunion was defined as any internal rotation deformity exceeding that of the unaffected side or greater than 20° external rotation of the extremity as detected during gait or stance.5

Letts and Vincent17 designed a new classification system, recognising not only diaphyseal, metaphyseal or epiphyseal knee fractures (types A, B, C) but also open fractures (types D and E), (Fig. 2). The drawback of their classification system is that they do not indicate how to classify patients.
with epiphyseal separation in the distal femur and tibia, or how to describe the location of any open fracture in the epiphysis, metaphysis or diaphysis.

The subjective outcome of floating knee injuries can be evaluated using Yue et al.\textsuperscript{15} criteria as follows:

(a) Excellent, no complaints or limitations secondary to the extremity injury.
(b) Good, occasionally minor extremity pain or decreased ability in athletic competition.
(c) Fair, intermittent moderate extremity pain but able to perform all activities of daily living and most recreational activities.
(d) Poor, constant extremity pain and inability to perform activities of daily living secondary to their extremity injury.

**Treatment**

**Adults**

Several approaches have been reported in the literature concerning the treatment of ipsilateral femoral and tibial fractures.\textsuperscript{1,2,3,4,11,19} Early reports favoured a non-operative approach to one or both fractures because of the unpredictable methods of internal fixation that were available, high infection rates and lack of knowledge of posttraumatic critical care.\textsuperscript{4} However, conservative methods entailed considerable risks of fracture shortening and angulation in combination with a delay in fracture union and time to return to normal activities.\textsuperscript{19} As a result, non-operative methods became unfavourable and gradually replaced by internal fixation techniques.\textsuperscript{4} Lately, advances in internal fixation methods have led orthopaedic surgeons to recommend more aggressive

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**Table 1** Karlstrom’s criteria for assessment of functional outcome.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Excellent</th>
<th>Good</th>
<th>Acceptable</th>
<th>Poor</th>
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<tbody>
<tr>
<td>Subjective complaints from thigh or leg</td>
<td>0</td>
<td>Intermittent slight symptoms</td>
<td>More severe symptoms impairing function</td>
<td>Considerable functional impairment; pain at rest</td>
</tr>
<tr>
<td>Subjective symptoms from knee or ankle joint</td>
<td>0</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Same as above</td>
</tr>
<tr>
<td>Walking ability</td>
<td>Unimpaired</td>
<td>Unimpaired</td>
<td>Walking distance restricted</td>
<td>Use cane, crutch, or other support</td>
</tr>
<tr>
<td>Work and sports</td>
<td>Same as before accident</td>
<td>Given up sport; work same as before accident</td>
<td>Change to less strenuous work</td>
<td>Permanent disability</td>
</tr>
<tr>
<td>Angulation, rotational deformity, or both</td>
<td>0</td>
<td>$&lt;10^\circ$</td>
<td>10–20$^\circ$</td>
<td>$&gt;20^\circ$</td>
</tr>
<tr>
<td>Shortening</td>
<td>$&lt;1$ cm</td>
<td>1–3 cm</td>
<td>$&gt;3$ cm</td>
<td></td>
</tr>
<tr>
<td>Restricted joint mobility (hip, knee or ankle)</td>
<td>0</td>
<td>$&lt;10^\circ$ at ankle; $&lt;20^\circ$ at hip, knee or both</td>
<td>$20–40^\circ$ at hip, knee or both</td>
<td>$&gt;40^\circ$ at hip, knee or both</td>
</tr>
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**Figure 2** Letts et al.’s classification of floating knee injuries in children.
treatment, with early stabilisation of both fractures, integrated with a multisystem approach that emphasises early mobilisation of the patient to facilitate better care and quicker respiratory recovery.\(^4,8,12,20\)

The use of intramedullary nails either side of the knee joint is presently the best treatment modality for fracture management.\(^4,7,8\) An antegrade technique is usually used when nailing fractures. The procedure is performed after adequate resuscitation and physiological stabilisation of the injured patient. This is especially important in cases with a high Injury Severity Score due to associated injuries. If immediate intramedullary nailing is not possible then a spanning external fixator can be applied to stabilise the entire limb. This can be replaced by internal fixation when the patient’s general condition is stable and/or neurovascular lesions and soft tissue coverage have been managed.\(^7\)

However, the technique of antegrade nailing has the drawbacks due to difficulties in patient positioning, two incisions, prolonged anaesthetic and surgical time and the inability to perform other surgical procedures at the same time.\(^8\) In order to overcome the above concerns, retrograde intramedullary nailing of the femur with antegrade nailing of the tibia through the same incision has been proposed as an alternative\(^4,8\) (Fig. 3). Ostrum\(^8\) using the above technique through a 4 cm medial parapatellar tendon incision, reported 88% good or excellent results with a full range of knee motion in 19 out of 20 patients.

The femoral shaft fracture is always addressed first. The reasons for this are twofold. First, stabilisation of the femur allows mobilisation of the patient without traction, should the patient suffer decompensation during the operation necessitating abandonment of the second procedure. The extremity with the tibial fracture can be placed in a splint, cast, or an external fixator can be applied quickly. Second, stabilisation of the femoral shaft fracture allows the surgeon to flex the knee sufficiently to obtain access to the proximal tibial starting point and gives a stable proximal limb for support.\(^8\)

In cases where the fracture pattern involves the metaphyseal region of the tibia and/or femur, with or without intraarticular extension, stabilisation can be achieved using locking plates.\(^21\) In 21 cases with “floating knee injury”, Hung et al.\(^20\) treated 16 femoral fractures and 15 tibial fractures with plates and screws. All the patients had a type II or “variant” injury. The authors concluded that in cases with knee involvement intramedullary nails are not recommended. Plate fixation can offer anatomic reduction of the articular surface allowing rigorous mobilisation and maximising the functional outcome.

Early diagnosis of ligament injuries is essential to facilitate an appropriate rehabilitation programme. In cases of isolated injury to medial collateral ligament, conservative treatment is preferred. It is suggested that anterior or posterior cruciate ligament reconstruction is delayed if it is necessary until after union of the fractures. Posterolateral corner injuries and avulsion fractures of cruciate ligaments either from femur or tibia should be repaired at the time of the initial procedure or in the early postoperative period.\(^13,14\)

**Children**

The treatment of ipsilateral femoral and tibial fractures in children is controversial, especially in patients under 10 years of age.\(^5,15-17\) Non-operative treatment consists of skeletal traction for the femoral fracture with closed reduction and casting or splinting of the tibial fracture. A hip spica cast is applied when sufficient femoral healing has occurred. Operative treatment options include flexible nails, plates or external fixators for diaphysis fractures and crossed K-wires in epiphyseal or metaphyseal fractures.\(^15\)

A disappointingly high incidence of complications of fracture healing occurs in older children treated with conservative methods.\(^5,17\) Malunion, non-union, refracture and limb-length discrepancy are documented in 40–50% of closed treatment cases. Bone et al.\(^5\) highlighted a difference between the results in patients who were treated by closed methods and those who had operative stabilisation of

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**Figure 3** (a) AP radiograph illustrating a mid shaft femoral and tibial fracture. (b) AP and lateral radiographs showing stabilisation of the floating knee injury pattern with retrograde femoral and antegrade tibial intramedullary nailing via a single incision.
the femoral fracture. Most authors suggest operative treatment of at least the femoral fracture in patients older than 10 years of age.\cite{5,15,16}

Letts et al.\cite{17} recommend that even in younger patients (less than 9 years old) at least one fracture must be rigidly fixed, and it is usually most appropriate for this to be the tibia, despite the fact that none of their patients were treated with operative fixation. Moreover, juxtaarticular fractures are difficult to stabilise with closed methods and assessment of knee instability cannot be evaluated without fixation of one or both of the fractures.

Recently, Yue et al.\cite{15} in a comparative study on closed and operative methods, reported that operative treatment reduced complications, length of hospital stay and time to unsupported walking. Therefore, the above authors concluded that both femoral and tibial fractures should be treated operatively in all age groups. Similar results were recorded by Arslan et al.\cite{16} who stated that previous recommendations of closed treatment for children younger than 9 years old with a floating knee injury should be shifted to rigid stabilisation of both fractures.

**Results and complications**

**Healing time**

Healing of femoral and tibial fractures occurs in approximately 15–20 weeks after injury and can be increased to 40 weeks in type II fractures.\cite{10,20} As union time may be prolonged with external fixation or casting, rigid internal fixation appears to be the best method of treatment.\cite{11,20}

**Non-union–malunion**

Delayed union, non-union, malunion and stiffness of the knee are more prevalent in patients with this combination of fractures than in patients with an isolated femoral or tibial fractures.\cite{2} Adamson et al.\cite{10} reported a 12% incidence of limb shortening (range 2–7 cm), 9% of malrotation and 12% of angulation > 10°. Similarly, Hee et al. described 67% delayed union, 31% non-union, 2% incidence of malrotation > 10° and 6% of shortening of up to 2 cm. In the same study factors such as older age, increased number of pack years smoked at the time of injury, high injury severity score, open and comminuted fractures adversely affected the bony union time and reoperation rate.

In the paediatric population, open growth plates presented an additional dynamic factor associated with complications that are unique to children (overgrowth of bone after fracture or premature closure of the ipsilateral physis, genu valgum and physeal arrest). The mean overgrowth of femur and tibia is 1.4 and 1.1 cm, respectively.\cite{15,16} Patients younger than 9 years of age and those who were treated non-operatively were observed to have an increased incidence of leg length discrepancy. However, a subjective limp and lower extremity length discrepancy can occur regardless of the fracture type, extent of soft tissue injury, or treatment method. Patients and parents must be counselled and informed of these possible outcomes. Patients should be followed up until skeletal maturity to monitor for signs of these complications.\cite{15}

**Infection**

The incidence of infection and osteomyelitis is relatively high in ‘floating knee’ injuries, especially in open and type II fracture patterns. Rios et al.\cite{4} and Veith et al.\cite{2} in their series reported a 16% incidence of wound infection and 4.4% of osteomyelitis. In addition, Yokoyama et al.\cite{6} found that deep infection developed in 13.8% of patients and meticulous debridement, continuous suction/irrigation drainage, polymethylmethacrylate beads or sticks impregnated with antibiotics led to eradication of infection in the majority of cases.

**Functional outcome**

By using the criteria of Karlstrom and Olerud, most published series describe excellent to good results in up to 65% of operatively treated cases,\cite{2,8,10} while after conservative methods the success rates drop to only 29% of patients.\cite{18} In children, good to excellent results have been reported either with conservative or operative methods.\cite{5,15–17} Fixation of one or two fractures in children up to 9 years of age offers superior results, minimising the incidence of long-term dysfunction of the extremity.\cite{15,17}

Considering the intraarticular injuries (type II), good or excellent results are reported in only 24% of patients.\cite{10} The difficulty in obtaining satisfactory function in type II injuries may result from the possibility of morbidity by severe soft-tissue injuries or knee joint damage and the complexities of achieving sound reconstruction.\cite{6}

Delayed rehabilitation and associated injuries around the knee result in limitation of knee movement.\cite{20} In two studies with intraarticular extension of the fracture into the knee joint, average knee flexion of 79° and 96° was reported.\cite{10,20}

Half of the patients in the study of Fraser et al.\cite{18} considered that their activity, in relation to work or sports, was still moderately or markedly reduced as a result of their injuries; this was regardless of the treatment group to which they belonged (closed or operative).

Using multivariate analysis Yokoyama et al.\cite{22} found that apart from knee involvement and open Grade III femoral fractures, significant contributory factors affecting the functional outcome of floating knee injuries are:

1. involvement of knee joint,
2. severity of soft tissue injury in the tibia,
3. fixation time after injury in the tibia,
4. AO fracture grade in femur and tibia, and
5. fixation time after injury in the femur and severity of open femoral fractures.

**Conclusions**

Ipsilateral femoral and tibial fractures present following high energy trauma and they are accompanied by an increased risk of morbidity and mortality. Isolated fractures in stable patients could be treated acutely while in unstable or “in extremis” patients temporary fracture stabilisation with external fixation is indicated according to the concepts of Damage Control Orthopaedics (Table 2). When the patient’s physiological state has been stabilized conversion to internal fixation is desirable. Involvement of knee joint,
severe soft tissue trauma, fracture comminution and open fractures are associated with higher complication rates resulting in poorer functional outcome. In children, when the physis is involved the possibility of leg length discrepancy must be always taken into consideration.

References