Outcomes and prognostic factors of surgical management of floating knee injuries

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Received 11 December 2018
Accepted 1 January 2019

The Egyptian Orthopaedic Journal 2018, 53:210–218

Background
Floating knee injuries are complex injuries that are generally caused by a high-energy trauma such as a motorcycle or a car accident. Local trauma to the musculoskeletal and the soft tissues is often extensive and life-threatening; associated injuries may also be present, producing a challenging problem to manage. In this study, the authors presented the outcome of these injuries after surgical management.

Patients and methods
In this prospective study, 32 patients with 34 floating knee injuries were managed over a 3-year period; both fractures of the floating knee injury were fixed surgically by different modalities. The associated injuries were managed appropriately. Fractures were classified according to Fraser classification, and the outcome was evaluated by the Karlstrom criteria.

Results
The main mode of injury was motorcycle accident (62.2%). Twenty-nine (90.3%) patients had associated visceral or skeletal injuries. The complications presented in 17 (50%) patients. According to the Karlstrom criteria, the end results were as follows: excellent – 15 (44%), good – seven (20.6%), acceptable – eight (23.6%), and poor – four (11.8%).

Conclusion
The optimal final outcome of floating knee injuries was achieved with appropriate management of the associated injuries, intramedullary nailing of both the fractures and early aggressive postoperative rehabilitation. The associated injuries and the type of fracture (open, intra-articular, comminution, knee ligament injuries) are the prognostic indicators in the floating knee.

Keywords:
Fraser classification, floating knee, Karlstrom criteria

Egypt Orthop J 53:210–218

1110-1148

Introduction

Floating knee is a flail knee joint resulting from fractures of the shafts or adjacent metaphyses of the femur and ipsilateral tibia. Floating knee injuries may include a combination of diaphyseal, metaphyseal, and intra-articular fractures [1]. Blake and McBryde initially described this injury, which is generally caused by a high-energy trauma such as a motorcycle or a car accident. Local trauma to the musculoskeletal and the soft tissues is often extensive, and life-threatening injuries to the head, chest, or abdomen may also be present [2].

Floating knee injuries seem to be increasing in frequency. A male preponderance is observed, particularly in young adults 20–30 years of age [3].

Floating knee injuries must be included in the assessment and treatment protocols for patients with polytrauma. An initial evaluation is of critical importance to determine the extent of a patient's injuries, including neurovascular assessment, to detect limb-threatening injury. The incidence of open fracture approaches 50–70% at one or both fracture sites [2,3]. Knee joint ligaments receive strong attention because a portion of the trauma energy is absorbed by the capsuloligamentous complex of the knee. Thus, early detection and thorough management are important for better outcome [4].

Orthopedic surgeons typically recommend various treatment regimens for floating knee injuries, especially early surgical stabilization of both femoral and tibial fractures, followed by aggressive rehabilitation to restore the function of the limb [5–7]. Regardless of the treatment method, some authors have reported that the complication rate and mortality remain high [8].

Table 1 Patients' characteristics and associated injuries

Cases	Age	Sex	Side	Mode of injury	Associated visceral injuries	Associated skeletal injuries
1	29	M	L	Motorcycle	Nil	Clavicle fracture
2	19	M	L	Motorcycle	Nil	–
3	35	M	R	Pedestrian	Intracranial hematoma	Humerus fracture
4	29	M	R	Motor vehicle	Nil	–
5	21	M	L	Motorcycle	Nil	–
6	43	M	L	Motor vehicle	Nil	Acetabulum fracture ACL injuries
7	28	M	L	Motorcycle	Partial sciatic nerve injuries	Ankle fracture
8	38	M	L	Motor vehicle	Hemothorax	Multiple ribs fracture
9	22	M	L	Motorcycle	Nil	Metacarpal fracture ACL injuries
10	39	F	R	Motorcycle	Nil	Contralateral femur fracture
11	19	M	L	Motor vehicle	Nil	Radius fracture
12	32	M	L	Motorcycle	Nil	Contralateral femur fracture
13	24	M	R	Motorcycle	Nil	Fractured ulna and radius
14	27	M	L	Motor vehicle	Cerebral contusion	Distal radius fracture
15	28	M	R	Motorcycle	Nil	Contralateral tibial fracture
16	42	M	R	Motorcycle	Nil	PCL injuries
17	45	M	L	Motor vehicle	Nil	Popliteal artery injury, forearm fracture
18	29	M	L	Motorcycle	Nil	Ankle fracture
19	34	M	L/R	Motorcycle	Retroperitoneal bleeding	Patellar fracture+ACL injury
20	26	M	L	Motor vehicle	Nil	Humerus fracture
21	31	M	L	Motorcycle	Degloved skin	–
22	37	M	L	Motorcycle	Nil	Pelvis fracture
23	28	M	L	Motorcycle	Nil	Patellar fracture+ACL injury
24	23	F	R	Motor vehicle	Nil	Other tibia fracture
25	19	M	L\R	Motorcycle	Nil	Fractured clavicle
26	25	M	R	Motor vehicle	Nil	ACL injury
27	36	M	R	Motorcycle	Fat embolism	Contralateral femur fracture
28	48	F	L	Motorcycle	Nil	Clavicle fracture
29	21	F	R	Motor vehicle	Hepatic tear	–
30	48	M	R	Motorcycle	Cerebral bleeding	–
31	19	M	L	Motorcycle	Splenic rupture	–
32	41	M	L	Pedestrian	Nil	Distal radius fracture

ACL, anterior cruciate ligament; F, female; L, left, M, male; PCL, posterior cruciate ligament; R, right.

The aim of this prospective study was to assess the outcome of surgical treatments for floating knee injuries and to determine prognostic factors and complications of these injuries.

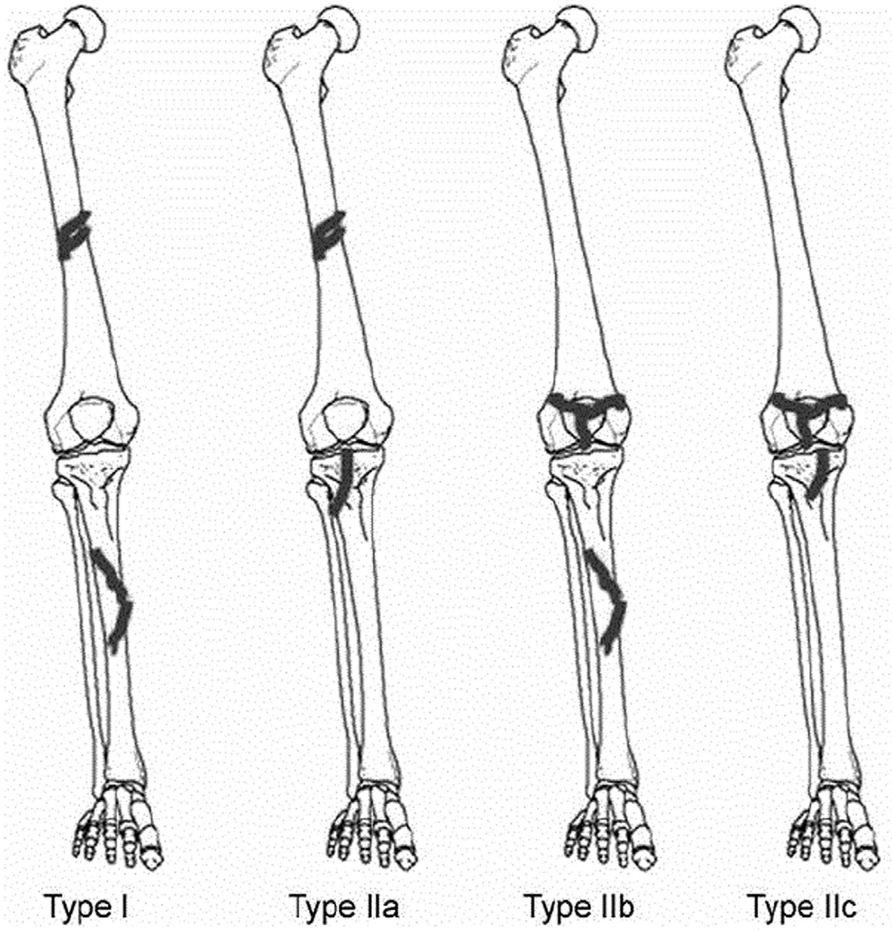
Patients and methods

This prospective study was conducted at Mansoura Emergency Hospital. All floating knee injuries presented in the period between January 2011 and December 2013 and managed surgically were included. In this study, floating knee injuries were managed conservatively, and children were excluded. Preoperative Informed consents were given by all patients. The ethical clearance certificate was accepted by the ethical committee at Mansoura University.

Among the 39 adult patients having floating knee injuries that were managed surgically in the study period, four patients died due to causes related to associated injuries, and three patients were lost to follow-up and were excluded from the study, and only 32 patients with 34 floating knee injuries were included in this study. There were 28 (87.5%) men and four women (Table 1). Initial management involved resuscitation and hemodynamic stabilization of the patient, splinting of the affected limb followed by a thorough secondary survey to identify other injuries. Radiographs of the chest, pelvis, cervical spine, affected lower limb including all its joints and other suspected bony injuries were obtained. Open fractures were classified according to Gustilo and Anderson's [9] classification. Initial wound wash, tetanus immunization, and intravenous antibiotic were initiated for open fractures. Floating knees were classified according to the classification system of Fraser *et al.* [10] (Fig. 1).

Computed tomographic scan of the brain was performed for all patients with decreased conscious levels and those with history of head trauma. If an intracranial hematoma or bleeding was diagnosed,

Figure 1



Classification system of Fraser *et al.* [10]. Type I: fractures are extra-articular. Type II: fractures are classified according to the knee injury. Type IIA: a tibial plateau fracture and an ipsilateral femoral shaft fracture. Type IIB: an intra-articular distal femoral fracture and a tibial shaft fracture. Type IIC: ipsilateral intra-articular fractures of the tibial plateau and the distal femur.

these patients were referred to the neurosurgery unit for further management. Surgical stabilization of the fractures was delayed until the head injury was treated. Chest drains were inserted in patients with hemothorax or pneumothorax. Patients were observed closely for fear of fat embolism (tachypnoea, confusion, tachycardia). If fat embolism was diagnosed, patients were managed in the surgical intensive care. Detection of abdominal injuries was by clinical assessment and ultrasonography. If there was a suspicion of intra-abdominal injury, an urgent abdominal computed tomographic scan was performed. If significant abdominal injuries were detected, these took priority over surgical stabilization of the fractures.

When patients were not hemodynamically stable or unfit for surgery, or there were extensive local soft tissue injuries (including open injury grades IIIB and IIIC), the fractures were initially stabilized by either a Thomas splint or bridging external fixator waiting for optimization of the general patient's and local soft tissue conditions. Permanent surgical management of both fractures was carried out once patients were hemodynamically stable and fit to undergo surgery with good local conditions (Table 2).

The femoral fractures were fixed prior to the tibial fractures. Intramedullary nailing of both fractures was the preferred method. Tibial nails were inserted antegrade, while femur nail were inserted retrograde through the same 4 cm medial parapatellar incision. Associated injuries that needed surgery were treated under the same anesthesia. Knee ligament injuries were diagnosed by clinical assessment by the surgeon after surgical stabilization of the fractures. If a knee ligament injury was detected, a ligament repair done on the same operation.

Thromboprophylaxis was initiated in all patients after the admission and extended to the postoperative period. Patients' rehabilitation was initiated on the basis of hip and ankle active-assisted mobilization, as soon as possible after surgery, while the patients were seated

Table 2 Types of injuries and fracture stabilization

Cases	Fraser type	Gustilo and Anderson type		Stabilization of fracture		Time interval between initial and permanent ttt (days)
		Femur	Tibia	Initial femur/tibia	Permanent femur/tibia	
1	1	–	–	Traction	Nail/nail	0
2	2A	–	2	BEF	Nail/plate	12
3	1	–	–	BEF	Nail/plate	16
4	2B	1	–	BEF	Plate/CEF	21
5	1	–	–	Traction	Nail/nail	0
6	2C	–	3A	BEF	Plate/plate	21
7	1	–	3A	Traction	Nail/nail	15
8	2B	2	3A	BEF	Plate/nail	20
9	2C	–	–	BEF	Plate/plate	18
10	1	3A	–	BEF	Nail/nail	0
11	1	–	–	Traction	Nail/nail	2
12	2C	–	3A	BEF	Plate/plate	22
13	2B	2	–	BEF	Plate/nail	12
14	1	–	–	Traction	Nail/nail	12
15	1	–	–	Traction	Nail/nail	8
16	2B	–	2A	BEF	Plate/nail	0
17	1	–	3C	BEF	Nail/nail	21
18	2A	–	–	Traction	Nail/plate	7
19	1/2A	–/2	3A/–	BEF	Nail/nail/Nail/plate	30
20	2C	–	–	BEF	Plate/plate	4
21	1	–	3B	Traction	Nail/nail	3
22	2A	2	–	BEF	Nail/plate	21
23	1	–	–	Traction	Nail/nail	0
24	2A	–	3A	BEF	Nail/plate	14
25	2A/1	–/–	–/3A	BEF	Nail/plate/nail/nail	8
26	2C	–	–	BEF	Plate/plate	14
27	1	2	3A	External fixator for tibia	Nail/CEF	21
28	1	1	–	Traction	Nail/nail	0
29	2B	–		BEF	Plate/nail	21
30	1	2	–	BEF	Nail/nail	20
31	2B	–	3B	Traction	Plate/nail	7
32	1	–	3A	BEF	Nail/nail	0

BEF, bridging external fixator; CEF, circular external fixator.

in a wheelchair, maintaining the limb in full extension. Knee range of motion (ROM) increased progressively according to pain tolerability of patients and degree of stability of fracture-implant construct. Strengthening of quadriceps and hamstrings muscle started early together with lumbopelvic and ankle muscles. The program extended until the patient returned to normal daily activity.

Patients were followed-up monthly until bony union (clinical and radiological) and then every 3 months until last follow-up. Final outcome was measured at last follow-up using the Karlstrom's criteria [11] (Table 3).

Statistical analyses

Data were analyzed using statistical package for the social sciences, version 15 (SPSS Inc., Chicago, USA). Qualitative data were presented as number and percent. Comparison between groups was carried out by χ^2 test, wherein P value less than or equal to 0.05 is significant. Quantitative data were tested for normality by the Kolmogorov–Smirnov test.

Results

The mean age of the patients was 30.8 years (range, 19–48 years); 20 (62.5%) patients were involved in motorcycle accidents, whereas 10 (31.25%) patients were involved in motor vehicle accidents, and two patients were pedestrians. The right side was involved in 13 and left side in 21 knees. There were 17 (50%) patients with Frazer type 1, six with type 2A, six with type 2B, and five with type 2C floating knee injuries (Fraser's classification) (Fig. 1). There were nine open fractures of the femur and 14 open fractures of the tibia. Sixty-eight percent of patients in this study had open fracture in the femur or tibia or both. Twenty-five (90.6%) patients had associated visceral or skeletal injuries or both. The average time interval between initial and permanent treatment was 12.2 days

Table 3 Complications and final outcomes

Cases	Follow-up (months)	Complications	Final outcome (Karlstrom criteria)	Delay in rehabilitation
1	12	None	Excellent	0
2	14	None	Excellent	0
3	12	None	Excellent	6 weeks
4	16	Delayed union	Accepted	0
5	14	None	Excellent	0
6	12	Knee stiffness	Accepted	4 weeks
7	12	Foot drop, fixed equinus	Accepted	8weeks
8	15	None	Excellent	3 weeks
9	15	DVT, knee stiffness	Accepted	4 weeks
10	13	None	Excellent	0
11	30	None	Excellent	0
12	20	Stiff knee	Poor	0
13	15	None	Excellent	0
14	12	Delayed union	Good	4 weeks
15	12	None	Excellent	0
16	18	Knee stiffness	Accepted	4
17	24	Superficial infection	Excellent	4 weeks
18	26	None	Excellent	3 weeks
19	26	None	Good, excellent	4 weeks
20	32	Knee stiffness	Good	4 weeks
21	19	Secondary soft tissue defect	Good	6 weeks
22	28	Knee stiffness	Accepted	6 weeks
23	20	Nonunion	Accepted	4 weeks
24	19	Deep infection	Poor	12 weeks
25	20	None	Good, excellent	1 week
26	19	Delayed union, knee stiffness	Accepted	10 weeks
27	40	Delayed union+fat embolism	Excellent	3 weeks
28	22	None	Excellent	0
29	12	None	Good	3 weeks
30	42	None	Good	0
31	14	Deep infection and nonunion	Poor	12
32	23	Nonunion	Good	4 weeks

DVT, deep venous thrombosis.

(range, 0–30). Permanent surgery was delayed due to head injury (three patients), fat embolism (one patient), hemothorax (one patient), abdominal injuries (three patients), and extensive local soft tissue injuries (12 patients). Intramedullary nailing for both fractures was performed in 15 knees. Other modalities of surgical fixation are shown in Tables 2, 4 and Figs 2, 3.

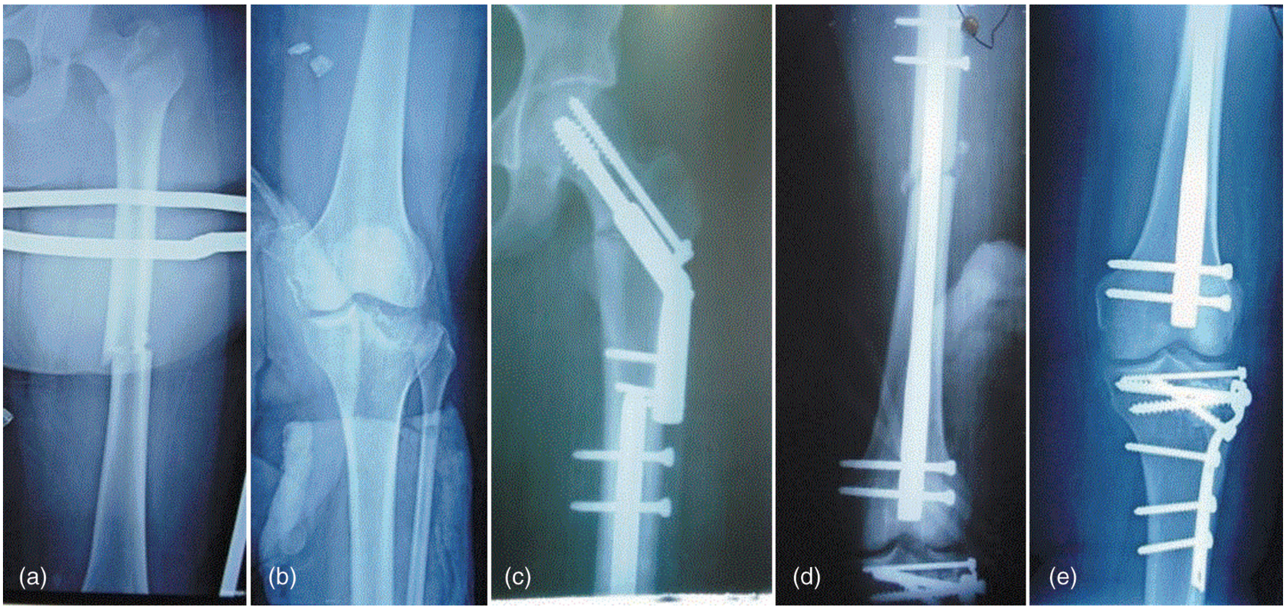
Table 4 Fixation methods and bony union times for the femoral and tibial fractures

Type of fixation	Patient's number	Union time
Intramedullary nailing – diaphyseal femur	21	17.3 weeks
Intramedullary nailing – diaphyseal tibia	20	18.7 weeks
Dynamic hip screw – proximal femur	2	14 weeks
Dynamic condylar screw – distal femur	8	22.6 weeks
Locked plate – distal femur	3	23 weeks
Buttress plating – tibial plateau	7	16.4 weeks
Locked plate – proximal tibia	5	17 weeks
Circular external fixation	2	26.5 weeks

One patient developed fat embolism and needed ventilatory support with monitoring in the ICU. The delay in surgery in that patient was 21 days. One patient had a popliteal artery injury, which was suspected clinically and evaluated by a femoral angiogram. This revealed an intimal injury of the artery that needed a femoropopliteal bypass graft, which was performed by the vascular surgeons, after surgical stabilization of the fractures. Surgical stabilization of the fractures was carried out initially to avoid placing stress on the vascular bypass graft during reduction of the fractures. In these patients, there was a delay in rehabilitation of 4 weeks. One patient had partial sciatic nerve injury affecting the anterior tibial portion with foot drop. This lesion was treated conservatively with ankle brace, but the patient developed fixed equinus deformity due to negligence that needed posterior ankle release and tendoachilles lengthening, and, by 1.2 years, good functional nerve and muscle recovery occurred. Six patients had ipsilateral knee injuries (two patellar fractures, three anterior cruciate ligament tears, and one posterior cruciate ligament tear). When a knee ligament injury was diagnosed by examination after fracture stabilization, primary ligament repair was carried out under the same anesthesia. The patellar fracture surgical stabilization was also carried out under the same anesthesia. The mean delay in rehabilitation was 4 weeks in patients with ipsilateral knee injuries, as these patients were placed in a brace postoperatively.

The complications encountered in this study included knee stiffness in six patients, foot drop and fixed equinus in one patient, delayed union of tibia in four

Figure 2



(a, b) A preoperative radiography of a 36-year-old male patient with type II Fraser floating knee showing involvement of the tibial plateau and double fracture of femur. (c–e) Postoperative radiographs after fixation by buttress plate with bone substitute for tibia and by retrograde nail and dynamic hip screw for femur.

patients, nonunion in three patients, secondary soft tissue defect in one patient, infection in three patients, and deep venous thrombosis (DVT) in one patient. Nerve conduction study was carried out in the patient with foot drop, which revealed an axonotmesis of the common peroneal nerve and good function recovery achieved after 1.2 years. The additional procedures were manipulation under anesthesia for knee stiffness, dynamization in delayed union, and bone grafting in nonunion and delayed union. Bone transport with Ilizarov fixation was used for treatment of deep infection and nonunion with bone defect. All fractures achieved solid bony union at the last follow-up.

In this study, the final outcome was excellent and good in 15 (88.2%) knees of 17 (knees with extra-articular fracture; Fraser type I) and in eight (47%) knees of 17 knees with intra-articular fracture (type II), respectively; this was statistically significant (P=0.041). Twenty-two (78.6%) knees of 28 knees without associated knee injuries had excellent final outcomes and good final outcome in only one (16.7%) knee of six knees with associated knee injuries; this was statistically significant (P=0.008).

The average follow-up was for 19.6 months (range, 12–42 months). In the assessment of end results at last follow-up according to the Karlstrom criteria, the following results were obtained: excellent – 15 (44%), good – 7 (20.6%), acceptable – 8 (23.6%), and poor – 4 (11.8%).

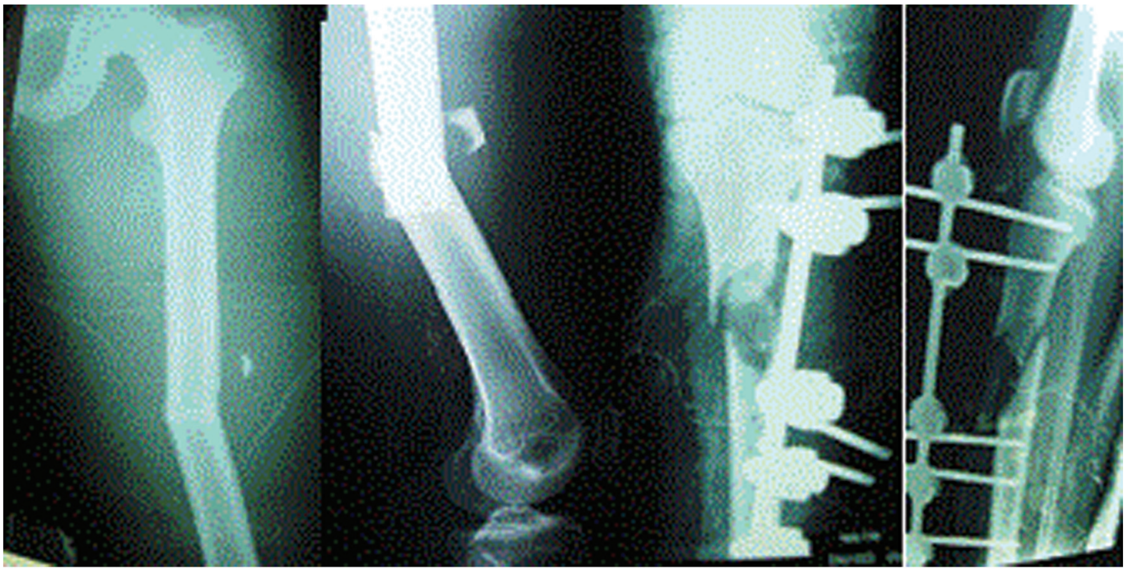
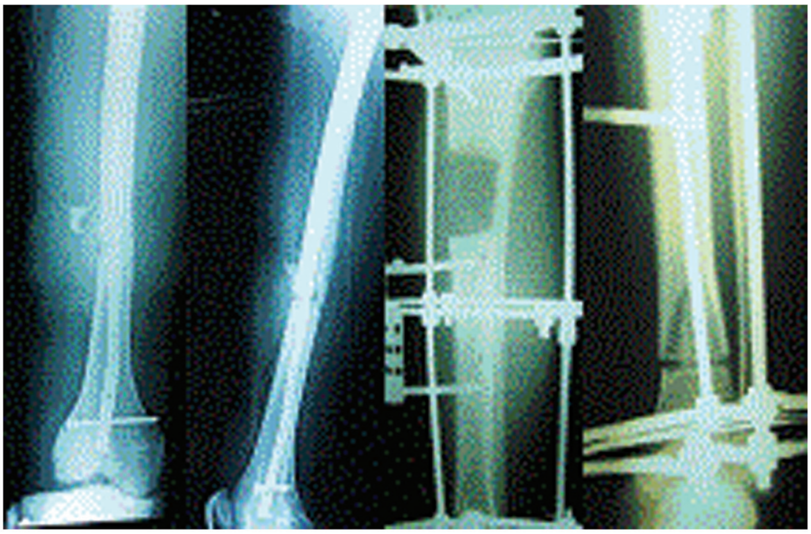
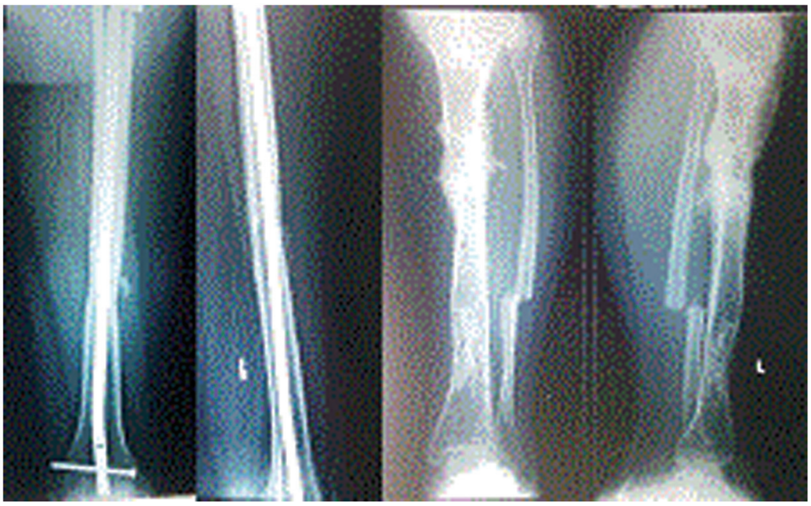
Discussion

Floating knee is defined as the isolation of the knee joint resulting from fractures of the shafts or adjacent metaphyses of the femur and ipsilateral tibia [2]. Survivors of high-energy traffic accidents often have injuries to several of the parenchymal organs as well as multiple fractures. Careful evaluation of these injuries and resuscitation of the patient must precede the definitive management of specific fractures.

Injuries that were associated with floating knee were head injuries, chest injuries, abdominal injuries, and injuries to other extremities. Most of the injuries to the head, chest, and abdomen were life threatening. Adamson *et al.* [12] in their study encountered 71% major associated injuries; of them, 21% were vascular injuries. The reported mortality rate ranged from 5 to 15%, reflecting the seriousness of the associated injuries [10]. Systemic and careful examination of the patient must be carried out in order to determine whether any major intracranial, abdominal, or thoracic injury is presented [5,13].

The mechanism of floating knee injuries of automobile passengers was that their feet were braced firmly against the sloping floor of the front seat, just before the collision, which resulted in their legs getting crumpled under the massive decelerating forces produced by the impact. Pedestrians were frequently thrown some distance

Figure 3

(a)

(b)

(c)


(a) Preoperative radiograph of floating knee (Fraser type I) with open tibial fracture provisionally fixed by monoplanar external fixator and showing bone loss. (b) Retrograde nailing of femur and bone transport by circular external fixator for the tibia. (c) Two years later, sound bony union of both femur and tibia with the fixator removed.

from the point of impact and were further injured by striking the pavement [14]. In a study of 222 cases of floating knee by Fraser *et al*. [10], all cases were involved in road traffic accidents. In our study, the road traffic accidents were the only mode of injury, especially motorcycle crash in 20 (62.5%) patients, due to the increased incidence of using motorcycles as a means of transport in Egypt by young men, even without a driving license. Our study showed a male predominance comparable to other studies.

Optimal management of complex floating knee injuries with extensive soft tissue damage necessitated aggressive physiotherapy and early mobilization to reduce the complication rate and obtain good functional results [15]. Several authors have reported good results after internal fixation of both tibial and femoral fracture sites [11,16,17].

The general concept in recent studies is that the best management for the floating knee is surgical fixation of both the fractures with intramedullary nails. Dwyer *et al.* [18] used combined modalities of treatment, with one fracture managed conservatively and the other surgically. They concluded that the external fixation of the fractured femur resulted in a decreased range of movement at the knee due to quadriceps muscle fixation. The treatment method for the tibia did not interfere with joint mobilization. Lundy and Johnson [19] recommended surgical stabilization of the fractures for early mobilization, which produced the best results. Theodoratos *et al.* [20] recommended intramedullary nailing as the best choice of treatment, except for grades IIIB and IIIC open fractures. Single-incision techniques for nailing of both the fractures have been recommended by several authors [21,22]. Ríos *et al.* [22] compared single incision versus traditional antegrade nailing of the fractures and found the former to have less surgical, anesthesia, and set up time with reduced blood loss.

Our management consisted of treating both the femoral and tibial fractures surgically, most of them (50%) by intramedullary nailing using an interlocking nail. With this management, we found the fracture union time and functional recovery was better than the other surgical modalities. This was in accordance with studies by Ostrum [23], who achieved excellent results with fixation of both fractures by intramedullary nailing. Both these authors used a retrograde nailing for the femur with safe time of set up and surgical and anesthetic procedures with less blood loss. However, we found that the retrograde nailing of the femur may interfere with late ligament reconstruction in the cases with associated ligament injuries that needed reconstruction, and, in these cases, antegrade femoral nailing may be used.

The reported rates of excellent and good results after surgical treatment for floating knee injuries ranged from 34.5 to 68.7% [13]. Nonetheless, some authors have reported that complications and mortality are high, regardless of the treatment regimen used [8]. In our study, the rate of excellent and good results after surgical treatment of floating knee injuries was 64.6%, whereas complication rate in different degrees was 50%.

Many studies [22,24] have shown that the incidence of knee ligament injuries in the floating knee was up to 50%, most of which were missed in the initial assessment. Meticulous examination of the knee at the time of injury is strongly advocated, although the practicality of this method is questionable, whereas rigid internal fixation allowed for thorough evaluation and treatment of the ligamentous structures of the knee and facilitated management of the soft tissue trauma. Szalay *et al.* [25] demonstrated knee ligament laxity in 53% of patients, whereas 18% complained of instability. Most of the patients with instability had a rupture of the anterior cruciate ligament with or without damage to other ligaments. They concluded that knee ligament injury was more common with floating knee injuries than with isolated femoral fractures and advocated careful assessment of the knee in all cases of fractures of the femur and floating knee injuries. In our study, we encountered six (17.6%) patients who had ipsilateral knee injuries (two patellar fractures, three anterior cruciate ligament tears, one posterior cruciate ligament tear). Primary ligament repair and the patellar fracture surgical stabilization were carried out under the same anesthesia. From this study, the presence of ligament injuries and their repair delayed rehabilitation and was complicated by deferent degree of knee stiffness; hence, its presence was a poor prognostic factor. The presence of knee ligament injuries was a significant indicator of poor or accepted final outcomes (P=0.008).

Several studies [26,27] have shown that significant indicators of poor outcome results of floating knee injuries are intra-articular involvement of the fractures, severity of skeletal injury, and severity of soft tissue injuries. Hee *et al.* [28] suggested a preoperative scoring system, which took into consideration the age, smoking status at time of injury, injury severity scores, open fractures, segmental fractures, and comminution to prognosticate the final outcome of these fractures.

The best results were seen when both fractures were treated by intramedullary nailing. We found that these patients returned to their maximum level of activity earlier than when the fractures were treated with other modalities because it was indicated in extra-articular fractures. The presence of intra-articular fracture was a significant indicator of poor or accepted final outcome (*P*=0.041). The five patients who had poor outcomes in our study were three patients with intra-articular fractures who had knee stiffness and two patients with open comminuted fractures that were complicated by deep infection and treated by bone transport and external fixation with muscle scarring and persisting pain. This shows that the poor prognostic factors were related to the type of fracture (open or closed, intra-articular fractures, severe comminution, knee ligament injuries). The associated injuries played a major role in the initial outcome of patients in our study with regard to delay in initial surgery, prolonged duration of surgery, anesthetic exposure and delay in rehabilitation. From our study, we found that floating knee injuries were complex injuries that needed careful assessment to detect poor prognostic factors (open, intra-articular, comminuted fractures, and knee ligament injuries) and associated injuries. This should be combined with thorough planning of surgeries, appropriated surgical fixation of the fractures and aggressive rehabilitation to improve outcome of these patients.

Conclusion

The floating knee injury is more complex than just ipsilateral fractures of the femur and tibia. The prognostic indicators of the final outcome are associated injuries and type of fracture (open, intra-articular, comminution, and knee ligament injuries). We recommend thorough initial assessment of patients with regard to life-threatening associated injuries, surgical fixation of both fractures (preferred by intramedullary nailing), and early aggressive postoperative rehabilitation to improve final outcome.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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