Management of comminuted tibial plateau fractures with external fixator using ligamentotaxis principle

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Received 15 January 2012
Accepted 26 February 2012

Egyptian Orthopedic Journal 2014, 49:167–173

Background
The treatment of proximal tibial fractures is often challenging, and internal fixation is occasionally associated with problems in wound healing due to frequently coexisting soft tissue injuries.
Objective
This study evaluated the performance of an external fixator in the treatment of different types of proximal tibial fractures by ligamentotaxis principle.
Materials and methods
Between March 2002 and June 2007, 50 proximal tibial fractures in 48 patients were treated with Ilizarov external fixator in Benha University and health insurance hospitals. The mean age was 39 years (range 19–57 years), and the mean follow-up period was 36.5 months (range 24–50 months).
Fracture categorization was performed according to AO/ASIF; closed reduction was performed most often by closed means in 26% of cases or through miniopen incision in 74% of cases. Clinical and functional evaluation of patients in the tibial plateau group was performed using the Knee Society clinical rating score.
Results
The overall functional outcome of treatment of comminuted tibial plateau fractures treated by indirect reduction and ring fixator in this study was excellent in 18 cases, good in 22, fair in eight cases, and poor in two cases. All fractures in this series eventually healed.
Conclusion
Ring frames provide mechanical stability of the comminuted tibial plateau fracture. The excellent stabilization of fracture allows early ambulation of the patient with partial weight bearing; even in comminuted fractures, there is beneficial biologic influence of the early weight bearing on osseous healing.

Keywords:
tibial plateau fractures, external fixator, ligamentotaxis principle

Egypt Orthop J 49:167–173

1110-1148

Introduction

Treatment of high-energetic proximal tibial fractures is often challenged by severe fracture comminution. The goals of treatment are restoration of joint congruity, normal alignment, joint stability, and a functional range of knee motion. Closed management of these injuries has proven ineffective, and therefore is not usually recommended [1,2]. Open reduction of the fracture allows a good control of the articular surface, but combined to dual plating requires extensive dissection of soft tissues, with a consequent increase in the risk for deep infection and necrosis [3–6]. To avoid these common difficulties, several new concepts have been developed. These include techniques of percutaneous intra-articular fragment manipulation, percutaneous plates, and the ring and hybrid external fixators [7–10]. Several previous reports have shown the advantages of external fixation using ligamentotaxis principle, such as a low infection rate, easy postoperative alignment adjustments, free range of motion (ROM), and early weight bearing [11–14].

Imaging studies

Initial radiographs should include anteroposterior, lateral, 15° caudal, and two oblique views. These five radiographs are known as the knee trauma series [15]. A 10–15× caudally tilted plateau view is used to assess articular step off because of the 10–15-degree posterior slope of the tibial articular surface [16].

A significant amount of additional information is gained using CT scan and MRI especially when dealing with high-grade fractures.

Patients and methods

Fifty cases of recent intra-articular and periarticular tibial plateau fractures in 48 patients were treated by closed reduction using the ligamentotaxis principle and external fixator during the period between March 2002 and June 2007. The mean age was 39 years (range 19–57 years). The number of male patients was 40 and of female patients was eight.

 DOI: 10.4103/1110-1148.145405

The mechanism of injury was a result of high-energy trauma in 46 patients (92%) of 50 plateau fractures.

Of the 50 patients with tibial plateau fractures, 22 had associated injuries. The most common associated injuries in this series were distal and proximal femoral fractures.

Tibial plateau fractures were classified according to the criteria of Schatzker *et al*. [5] as type V 11 fractures (22%) and type VI 39 fractures (78%). Type V fractures are bicondylar fractures, whereas type VI fractures are bicondylar plateau fractures with associated fractures of the proximal tibial metaphysis or the shaft (tibiometaphyseal dissociation).

The fractures were also classified using the AO/ASIF classification. There were total articular type C fractures [type C1 12 cases (24%), type C2 18 cases (36%), and type C3 20 cases (40%)].

There were 41 closed fractures (82%) and nine open (18%) fractures.

Preoperative assessment

All patients were assessed clinically and radiologically by different means.

Timing of surgery

The timing of definitive fixation was variable depending on the magnitude of injury. Delay ranged between few hours and 21 days (average 7 days).

Surgical technique

Patients were operated under traction on a fracture table to assist fracture reduction. The use of a fracture table also facilitated 360° visualization using an image intensifier and allowed for use of the circular fixator without impingement of the rings on the table.

The objectives of treatment in tibial plateau fractures were to reduce the condyles to one another underneath the femoral condyles, to avoid tilt, and to avoid widening. Anatomical reduction of the joint surface is a secondary goal that is often accomplished percutaneously or through limited approaches based on the plane of the fracture line. Extensile approaches have never been performed. The shaft is aligned and stabilized beneath the reduced condyles using the fixator without an open approach.

The surgical technique for applying the fixator involves positioning the patient supine under general or regional (spinal) anesthesia with biplanar fluoroscopic control. Condylar fragments were always reduced and stabilized after frame application. Condylar reduction was performed through ligamentotaxis between the femoral and tibial parts. The femoral ring was applied either temporarily or permanently according to the fracture situation or stability to treat ipsilateral distal femoral fracture (Figs 1–3).

Postoperative care

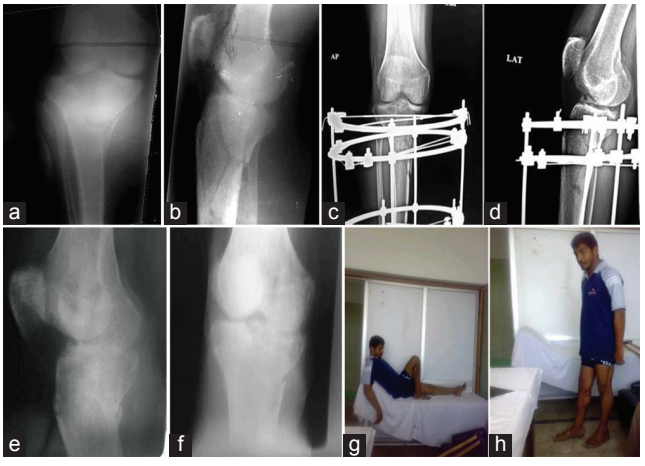
Intravenous antibiotics, third-generation cephalosporin, were given for 48 h postoperatively.

Early ROM of the knee as tolerated began on postoperative day 2; in across the knee frames ROM was delayed for 6 weeks. Early ROM should not be at the cost of producing proximal wire inflammation.

Postoperative weight bearing was individualized according to the fracture pattern, the technique used, and the presence of associated injuries. Patients with stable injuries (mostly C1 and C2 fractures) were allowed early ambulation with toe-touch partial weight bearing following frame application. Weight bearing was advanced as tolerated, depending on the fracture pattern, until the patient can bear full weight. Patients with marked articular comminution were kept nonweight bearing for 4–6 weeks, and may be longer, followed by progression to full weight bearing by 8–12 weeks. Joint distraction commonly deferred weight bearing until removal of the distraction.

Weight bearing was not permitted while the fixator spanned the joint. Associated injuries, at occasions, necessitated nonweight bearing. Wire tension was

Figure 1

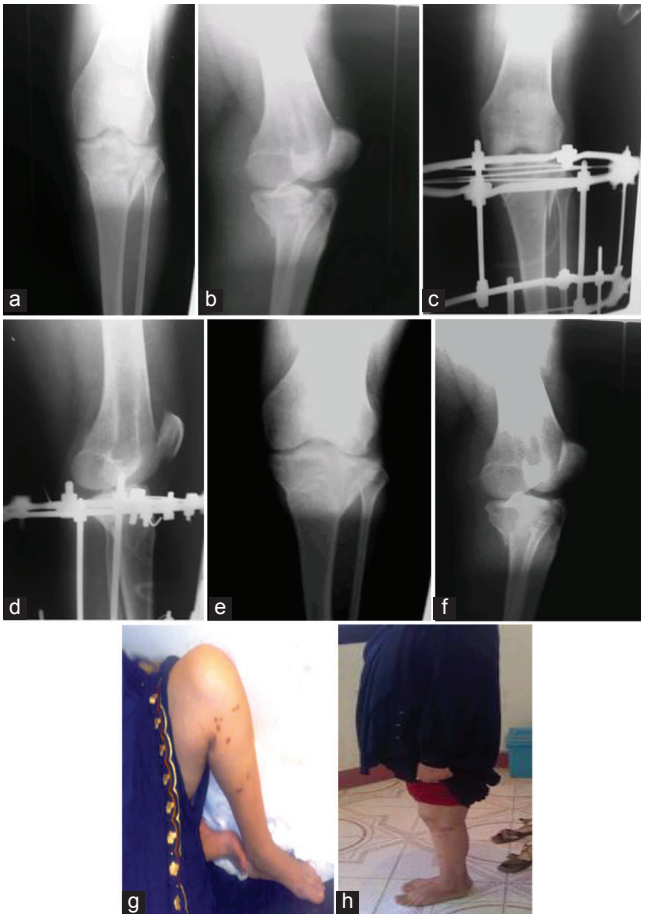


A 27-year-old man had sustained comminuted fracture of his right tibial plateau (Schatzker type VI, AO/ASIF type C1). (a, b) Preoperative radiograph. (c, d) Postoperative radiograph. (e, f) Radiograph after healing. (g, h) Patient after healing.

Figure 2

A male patient aged 45 years was admitted with an isolated closed Left tibial plateau fracture (Schatzker type VI). (a, b) Preoperative radiograph. (c, d) Postoperative radiograph. (e, f) Radiograph. after healing. (g, h) Patient after healing.

Figure 3



A female patient aged 32 years with comminuted left tibial plateau fracture [Schatzker type V, AO/ASIF (type C1)]. (a, b) Preoperative radiograph. (c, d) Postoperative radiograph.

checked at follow-up visits and retensioned with simple manual wire tensioning as necessary. Follow-up radiographs were performed at every 3 weeks postoperatively. Additional active compression and fixator dynamization after 3 months postoperatively occurred for some patients to enhance union.

Fixators were removed after clinical and radiographic evidence of fracture healing. Before the fixator pins were taken out, loosening of the frame or removal of the connecting rods were performed; thereafter, fracture consolidation was tested manually or the patient was asked to walk. Absence of springing on manipulation or pain on walking indicates full clinical union. Frame removal was commonly performed in the outpatient clinic.

Patient follow-up

Patients returned for follow-up visits nearly every month for the first 6 months and every 3 months thereafter until the end of first year, and then every 6 months. The average follow-up for patients in this study was 36.5 months (range 24–50 months).

The quality of reduction was assessed using the final intraoperative or initial postoperative radiographs. Serial radiographs were made thereafter and were evaluated for secondary fracture displacement, loss of fixation, articular/metaphyseal union, mechanical axis deviation, and development of malunion/nonunion.

Results

All fractures in this series eventually healed; no abnormal motion or pain occurred with stress of the fracture after loosening the frame. The average time of healing period was 14.4 weeks. The mean follow-up period was 36.5 months (range 24–50 months).

Clinical and functional evaluation of patients in the tibial plateau group was performed using the Knee Society clinical rating score.

Clinical and functional results

Pain

In all, 14 (28%) cases had no pain; 26 (52%) cases had mild pain, eight (16%) cases had pain on stairs only, and two cases (4%) had pain (mild) while walking or on stairs.

Walking

Normal walking was noted in 29 cases; 14 patients were using walking aids during the final follow-up period.

Stair climbing

In all, 28 cases could normally climb stairs, 20 cases had difficulty down, and two cases had difficulty both up and down.

Range of movement

A total of 23 patients achieved full extension, and 23 had an extension deficit of less than 10° and four had more than 10°. All patients were able to squat, although with some difficulty. The flexion range of movement (arc of motion) was more than 120° in 17 cases (34%), in six cases (12%) was 110°, in seven (14%) cases between 100 and 105°, and in four cases (8%) was less than 90°. The average ROM was 110°.

Stability

Varus and valgus stress were applied.

Only two were symptomatic but without functional handicap. Anterior laxity on the drawer and Lachman tests was noted in one patient. The rest had mediolateral laxity.

Knee scores

In 1989, the Knee Society published its revised Knee Rating System (Table 1). This system has been used in several series [10,12,13,17].

Table 1 **Knee rating system**

	Points
Pain	
None	50
Mild or occasional	45
Stairs only 40	40
Walking and stairs 30	30
Moderate	
Occasional	20
Continual	10
Severe	0
Range of motion	
5° = 1 point	25
Stability (maximal movement in any position)	
Anteroposterior (mm)	
<5	10
5–10	5
10	0
Mediolateral	
<5°	15
6–9°	10
10–14°	5
15°	0
Subtotal	–
Deductions (minus)	
Flexion contracture	
5–10°	2
10–15°	5
16–20°	10
>20°	15
Extension lag	
<10°	5
10–20°	10
>20°	15
Alignment	
5–10°	0
0–4°	3 points each degree
11–15°	3 points each degree
Other	20
Total deductions	–
Knee score (If total is a minus number, score is 0)	–
Function	
Walking	
Unlimited	50
>10 blocks	40
5–10 blocks	30
<5 blocks	20
Housebound	10
Unable	0
Stairs	
Normal up and down	50
Normal up; down with rail	40
Up and down with rail	30
Up with rail; unable down	15
Unable	0
Subtotal	–
Deductions (minus)	
Cane	5
Two canes	10
Crutches or walker	20
Total deductions	–
Functional score	–

Discussion

The treatment of proximal tibial fractures is often challenging, and internal fixation is occasionally associated with problems in wound healing due to frequently coexisting soft tissue injuries.

Open reduction and internal fixation still remain the treatment of choice for low-energy tibial plateau fractures. Application of these techniques, however, in high-energy fractures with significant tissue dissection and double buttress plating has resulted in a substantial number of devastating complications such

as loss of reduction, joint stiffness, ankylosis, malunion, nonunion, skin loss, and wound infection.

An open wound is present in 30–35% of Schatzker type IV, type V, and type VI fractures, and 86% of the remaining fractures are associated with significant closed injuries to the soft tissue [18]. Indirect reduction with limited internal fixation prevents soft tissue complications and works well for simple fracture patterns but still does not address the issue of dissociation of the metaphysis from the diaphysis.

Marsh *et al.* [17] reported 21 complex plateau fractures in 20 patients treated with closed reduction, interfragmental screw fixation, and a unilateral half-pin fixator. They concluded that external fixation with limited internal fixation is a satisfactory technique for the treatment of selected complex fractures of the tibial plateau.

Circular and hybrid fixators facilitate a better overall reduction and interfragmental compression. The use of olive wires offers a unique adjustability of the fixator system, capable of reducing and maintaining small intra-articular fragments, correcting angular deformities [19,20].

Ring-tensioned wire frames provide mechanical stability of the fracture comparable with dual-plating internal fixation [1,10] and superior metadiaphyseal purchase and support compared with hybrid frames with half pins or screws [20–23].

The major problems of the skin wound, fracture blisters subcutaneous hemorrhage, or extensive bruising must be overcome before any conventional surgery is undertaken.

However, they are not obstacles for the safe application of the technique. Small pin circular fixators can be placed irrespective of the skin condition. Any additional bone necrosis is minimized because the periosteum and endosteum are not further damaged. Finally, the circular fixator is a four-dimensional apparatus that takes into consideration the variables as they arise. Unsatisfactory alignment of the limb and redisplacement of the fracture are not uncommon complications after internal fixation.

A potential disadvantage of indirect reduction and external fixation is decreased accuracy of reduction of the articular surface compared with that obtained with open reduction. Koval and Helfet [15] demonstrated the difficulty in obtaining and assessing reduction of depressed fragments with indirect techniques and fluoroscopic visualization. The articular surface in some of our patients was imperfectly reduced (average residual displacement, two millimeters), and intraoperative fluoroscopy and postoperative radiographs may have led to an underestimation of the degree of residual displacement that was present. It is also clear that there was a relationship between the more comminuted (type C3) articular fractures and the development of post-traumatic osteoarthrosis as well as the clinical result represented by the Iowa knee score. We cannot be certain whether these poorer results were related to the severity of the articular injury or to the quality of the difficult reduction, but we believe that the former factor is more important (the worse the initial articular comminution, the worse the outcome).

The follow-up period in this study was 36.5 months; the longest follow-up reported in similar series was by Kumar and Whittle [12] for plateau (3.5 years).

The average knee ROM in this study was 110.35°. The mean ROM reported by Guadinez *et al.* [8] was 85°, by Morandi and Pearse [24] was 113°, by Watson *et al.* [14] was 106°, by Stamer *et al.* [13] was 107°, and by Murphy *et al.* [25] was 103°. Marsh *et al.* [17] stated that knee immobilization for 6 weeks did not appear to adversely affect the ultimate knee ROM. Lansinger *et al.* [26] also noted that tibial plateau fractures tolerated immobilization for as long as 6 weeks without adverse consequences. In this study, long immobilization had led to fair or even bad results.

Ligament injuries were not directly addressed during management of plateau fractures. This is because it is the primary goal of these techniques to avoid any further soft tissue disruption and restore normal skeletal architecture.

In this study, the results were assessed according to the scoring system proposed by Honkonen and Järvinen [27] and the Knee Rating System. Both systems are simple, easy to apply, and assess knee function using the most important tests. The functional results were: 18 excellent (36%), 22 good (44%), eight fair (16%), and two bad (4%).

In this study, there was a direct correlation between the magnitude of soft tissue injury and the final outcome. All patients with no or minor soft tissue injury (Tscherne grade 0–I) were rated as excellent with only one good result. This agrees with the findings of Tscherne and Lobenhoffer [6] that distally threaded unreamed humeral nailing demonstrated a high satisfactory rate and should be considered as palliative treatment for the patients with pathological humeral shaft fractures due to metastatic disease. It provides immediate stability and pain relief, short operative time, no blood loss, and avoids complication of distal locking screws.

Recovery is relatively impaired in multiply injured patients and in patients with complex knee trauma, open injuries were responsible for 45% of the unsatisfactory results.

All patients having their fractures fixed within the first 24 h had excellent outcome. All cases who ended up with a less than excellent results had a delay of 1 week or more.

Patients in whom articular fixation was supplemented by minimal invasive osteosynthesis were more prone to have excellent results, except one case that was compound fracture grade IIIB.

Moore *et al*. [28] reported a 23% rate of infection in association with bicondylar fractures after ORIF; they noted difficulty in wound closure and subsequent dehiscence in eight of 11 knees that had been treated with double plating. Mallik *et al*. [29] found infection complicating four of five bicondylar fractures that had been treated with plates, and Young and Barrack [30] reported deep infection with seven of eight fractures that had been treated with double plates. Given their devastating nature, one of the goals of management must be to keep the incidence of these complications absolutely low as possible. This side of the balance must be given heavy consideration. Pin tract infection was the commonest complication in our study. It occurred in 18 cases (36%) and was mostly in the form of simple superficial infection that respond to local antiseptic measures, systemic antibiotics, or sometimes pin removal. A common finding in all patients with high-grade infection was a fixation period of more than 3 months. This rate is comparable with that in other reported series on the use of the Ilizarov fixator in general and in series dealing with its use in high-energy tibial fractures in particular.

Increased skin tension was due to improper pin placement or failure to release the surrounding soft tissues. Similarly, pins traversing large quantities of soft tissues, such as those in the proximal thigh or those traversing the calf muscles, seemed to be more problematic than those in more subcutaneous locations as noted by Montgomery [31].

Neurovascular injuries as sequelae of percutaneous wires/pins have been reported by some authors, although not met within the current study. Peroneal nerve palsies following plateau fractures were reported with variable incidences of 3–6% sometimes over 10%, but it is sometimes impossible to know whether it is caused by the injury or by the operation. Mikulak *et al*. [21] had two postoperative palsies that recovered completely.

Post-traumatic arthritis was recorded as joint space narrowing; subchondral sclerosis was not taken into consideration because it can be attributed to fracture healing. We cannot be certain whether poorer results were related to the severity of the articular injury or to the quality of the difficult reduction, but we believe that the former factor is more important (the worse the initial articular comminution, the worse the outcome).

There were three cases (6%) of delayed union (>6 months). Weiner *et al*. [23] had six cases (12%) of delayed union, and Dendrinos *et al*. [32] had one case.

No cases of articular nonunion were encountered. Kumar and Whittle [12] had one case of nonunion and Morandi and Pearse [24] had three cases. The case of nonunion occurred in a patient with a severely comminuted tibial plateau fracture with a comminution along the whole proximal third of the tibial diaphysis in the sagittal and coronal planes; after 8 months without evidence of diaphyseal union, patient had not come for follow-up and further management.

In all, four cases developed stiffness with a total arc of motion of less than 90°. These patients had concomitant knee injuries.

Conclusion

Ring frames provide mechanical stability of the comminuted tibial plateau fracture. The excellent stabilization of fracture allows early ambulation of the patient with partial weight bearing; even in comminuted fractures, there is beneficial biologic influence of the early weight bearing on osseous healing.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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