Treatment of high-energy tibial plateau fractures using the Ilizarov circular fixator

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Background
We treated 30 patients with high-energy fractures of the tibial plateau using Ilizarov fixators and transfixion wires: 10 fractures were open and 20 patients had complex injuries. Of the patients, 15 were treated by ligamentotaxis and percutaneous fixation, eight by limited open reduction and seven by open reduction bone graft and screws. There is, however, no 'gold standard' procedure for this complicated and multidisciplinary condition.

Patients and methods
Between October 2007 and October 2010 we treated 30 consecutive patients with severe bicondylar fractures of the tibial plateau using Ilizarov fixators. Ten (33.3%) fractures were open. There were 10 Schatzker type V and 20 type VI fractures; 20 (66.6%) were comminuted. Thirteen patients (43.3%) had complex knee trauma, which describes injuries that include more than one of the functional compartments of the knee, such as the soft-tissue envelope, the ligamentous stabilizers and the bony structures of the distal femur and the proximal tibia.

Results
All fractures united within a mean duration of 14.4 weeks. The femoral fixator was removed at a mean duration of 6 weeks (4–7 weeks), and the tibial fixator was retained for a mean duration of 13 weeks (12–20 weeks). Full weight-bearing was allowed at a mean time interval of 14.4 weeks (12–24 weeks). The patients were followed up for a mean duration of 36.5 months (24–53 weeks). The results were assessed according to the criteria of Honkonen and Järvinen, which consider the subjective opinion of the patient, the clinical state, the function and the radiological assessment. Fifteen patients achieved full extension and the other 15 had an extension deficit of less than 6°. Ten patients had an extension lag of 6–10°, and five patients had a lag of more than 10°. On the basis of the clinical criteria 10 results were excellent, 10 were good, five were fair and five were poor.

Conclusion
Our study emphasizes the low morbidity associated with the Ilizarov method. No patient developed osteomyelitis or septic arthritis. This absence of infection and septic nonunion compares favourably with the results of other published studies on these complex injuries. The technique is well suited to the management of complex fractures of the tibial plateau when extensive dissection and internal fixation are contraindicated because of comminution at the fracture site and compromise of the soft tissue.

Keywords:
high-energy tibial plateau fractures, Ilizarov external fixator, ligament taxis

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Introduction

Ilizarov circular fixation is an ideal method of treatment for high-energy fractures when extensive dissection and internal fixation are contraindicated because of trauma to the soft tissue, deficiency of bone stock and bony comminution.

Bicondylar high-energy fractures are associated with severe articular depression, separation of both condyles, diaphyseal comminution and dissociation and loss of integrity of the soft-tissue envelope. They occur primarily in younger patients who usually have multiple injuries.

The most popular treatment has been open reduction and internal fixation with double plating [1–11]; however, this treatment is associated with many complications such as joint stiffness, malunion, skin loss, osteomyelitis, amputation and even death. The incidence of these complications has been reported to be as high as 50% in some studies [5,7,12–15], and the occurrence of postoperative skin infection and osteomyelitis have been reported as being 42 and 33%, respectively [16]. To reduce the incidence of such problems, minimal internal–external fixation through limited approaches has been attempted with satisfactory results [11,17–20].

An alternative method was proposed by Ilizarov [2,17,21], and we have adopted his techniques for the treatment of fractures and nonunion [22,23].

In this prospective study, we used this method for management of high-energy fractures of the tibial plateau.

Patients and methods

Thirty patients with high-energy fractures of the tibial plateau were treated using Ilizarov fixators and transfixion wires: 10 fractures were open, and 20 patients had complex injuries. Of the patients, 15 were treated by ligamentotaxis and percutaneous fixation, eight by limited open reduction and seven by extensive open reduction. All patients were followed up for at least 24 months.

All fractures united, with an average time to healing of 14.4 weeks. Fifteen patients achieved full extension and the other 15 achieved more than 110° of flexion. Twenty-two knees were stable. Fifteen patients walked normally and the rest with only a slight limp. All but two knees had an articular step-off of less than 4 mm and had normal axial alignment. There were no cases of postoperative skin infection, osteomyelitis or septic arthritis.

Between October 2007 and October 2010, 30 consecutive patients with severe bicondylar fractures of the tibial plateau were treated using Ilizarov fixators (Table 1). They were reviewed for a minimum duration of 24 months. The level of function, clinical and radiological findings and patient opinion were assessed. Of the patients, 20 were males and 10 were females with a mean age of 39 years (18–69 years). Six patients were car drivers or passengers, 12 were pedestrians struck by motor vehicles and seven were motorcycle riders. Four patients had been injured as a result of a fall from a height and one patient had a crush injury caused by a collapsed wall. Ten (33.3%) of the fractures were open. There were 10 Schatzker type V and 20 type VI fractures; 20 (66.6%) were comminuted. Thirteen patients (43.3%) had complex knee trauma, which describes injuries that include more than one of the functional compartments of the knee [9,24], such as the soft-tissue envelope, the ligamentous stabilizers and the bony structures of the distal femur and the proximal tibia.

Ligament injuries were present in 13 (43.3%) of our patients, comprising five cases of isolated tears of the medial collateral ligament, one case of an isolated tear of the anterior cruciate ligament and seven cases of combined ligament injuries. Two patients (6.66%) sustained a fracture of the patella and 15 (50%) patients had associated major musculoskeletal trauma.

All patients were operated upon within the first 48 h. Fifteen patients underwent ligamentotaxis and percutaneous fixation of the fractures. Open reduction through a limited approach was used in eight patients, and an extensive exposure approach was used in seven patients. Eight patients required autogenous bone grafting. All patients received prophylactic antibiotics for 48 h after the operation and low-molecular-weight heparin from the time of hospital admission.

Operative technique

The fixator may be positioned irrespective of the state of the skin. After traction has been applied on the operating table, the fractures are reduced by open or closed means

Table 1 Details and results of 30 patients with fractures of the tibial plateau

Cases	Age (years)	Sex	Schatzker (1987) type	Multiple injury	Reduction	Fixation (weeks)		Full weight-bearing (weeks)	Follow-up (months)	Results
						Femoral	Tibial			
1	24	M	VI	No	C	7	14	17	29	Fair
2	47	M	VI	Yes	C	0	13	12	28	Excellent
3	45	M	V	Yes	O	7	13	15	53	Poor
4	40	M	V	No	O	5	12	14	29	Good
5	36	F	VI	No	O	6	13	15	31	Fair
6	30	M	VI	No	O	6	12	13	42	Good
7	29	M	VI	Yes	C	4	12	14	37	Excellent
8	33	M	VI	Yes	C	0	13	15	33	Fair
9	63	M	V	Yes	C	6	13	15	41	Good
10	31	M	VI	No	C	0	13	14	25	Excellent
11	34	F	VI	Yes	O	7	13	15	34	Fair
12	62	F	VI	No	O	6	16	16	52	Excellent
13	69	M	VI	Yes	C	0	12	13	44	Good
14	52	F	VI	Yes	C	0	12	14	33	Excellent
15	19	F	VI	No	C	6	13	13	37	Good
16	24	M	VI	No	C	6	12	13	42	Good
17	48	M	VI	Yes	C	6	20	24	40	Poor
18	32	M	VI	No	C	0	12	12	25	Good
19	23	M	VI	Yes	C	6	16	16	27	Excellent
20	47	F	VI	No	C	0	12	13	29	Excellent
21	56	M	VI	Yes	O	6	12	13	41	Good
22	31	M	VI	No	O	6	12	14	53	Poor
23	55	M	V	No	C	6	12	14	47	Poor
24	39	M	V	No	C	6	12	13	24	Poor
25	63	M	V	Yes	C	6	13	15	41	Good
26	31	M	VI	No	C	0	13	14	25	Excellent
27	34	F	VI	Yes	O	7	13	15	34	Fair
28	62	F	VI	No	O	6	16	16	52	Excellent
29	69	M	VI	Yes	C	0	12	13	44	Good
30	52	F	VI	Yes	C	0	12	14	33	Excellent

C, closed; O, open.

and stabilized with appropriate percutaneous wires. If an open operation is needed, the plateau is elevated, bone grafts applied and meniscal repair undertaken. Wounds may be left closed or open. A preassembled frame is then positioned, with an additional ring attached to the lower femur if the knee is still unstable. The knee hinge may be locked or left loose, as needed.

Major ligament tears are repaired directly when indicated. Cruciate reconstruction is carried out as a secondary procedure. Early mobilization of the knee is encouraged, and the use of femoral stabilization allows a degree of early weight-bearing. The femoral fixator is removed after 6 weeks and the tibial at 12 weeks if the fracture has united. Full weight-bearing is allowed 2–4 weeks later (Figs 1–3).

Results

All fractures united within a mean duration of 14.4 weeks. The femoral fixator was removed at a mean duration of 6 weeks (4–7 weeks), and the tibial fixator was retained for a mean duration of 13 weeks (12–20 weeks). Full weight-bearing was allowed at a mean duration of 14.4 weeks (12–24 weeks). The patients were followed up for a mean duration of 36.5 months (24–53 months). The results were assessed according to the criteria of Honkonen and Järvinen [25], which consider the subjective opinion of the patient, the clinical state, the function and the radiological assessment (Tables 2–5).

Subjective analysis

The patients were asked to record the frequency and importance of each symptom, the severity of which was then calculated by multiplying the frequency by the grade of its importance to the patient (Table 2). Using these parameters, the results were calculated to be as follows: 10 excellent, 10 good, five fair and five poor (Table 1).

Clinical evaluation

The methods of grading the clinical examination are given in Table 3. The final clinical score was the lowest grade found in any of the four tests used.

Fifteen patients achieved full extension and the other 15 had an extension deficit of less than 6°. Ten patients had an extension lag of 6–10°, and five patients had a lag of more than 10°. Fifteen patients achieved a flexion of more than 110°, and five of these patients were able to flex the knee to more than 130°. Thigh atrophy of more than 1 cm was observed in only one patient.

At follow-up, 30 knees were either fully stable or slightly unstable. Of the 13 knees with ligamentous injuries, five were stable, seven were slightly unstable and one was unstable.

Excellent or good results were observed in patients with isolated tears of the medial collateral ligament, five of whom had undergone a primary repair. The worst results were observed in two patients with combined ligamentous injuries (Table 1) despite primary repair. On the basis of the clinical criteria, 10 results were excellent, 10 were good, five were fair and five were poor.

Functional results

Many of our patients had sustained multiple injuries but we concentrated our attention on the disability caused by the tibial condyle fracture.

The final score was the lowest grade found in any of the five tests used (Table 4). Fifteen patients could walk

Figure 1

(a) Image of a preoperative leg with bullae (a 47-year-old male patient, a manual worker). (b) Preoperative radiographs of a type VI fracture of the tibial plateau. (c) Postoperative radiographs showing simple tibial fixation with counteropposed olive wires. (d) Postoperative image of the leg with the femoral extension frame. (e) Follow-up images showing good function. (f) Last follow-up radiographs showing an excellent result.

Figure 2

(a) Preoperative radiographs of an open Schatzker type VI fracture (a 30-year-old male patient, a security officer). (b) Preoperative image of an open fracture (GIII). (c) Postoperative image showing the frame. (d) Postoperative radiographs at 1 month showing good alignment. (e) Follow-up image with good functions. (f) Follow-up radiographs after 6 months showing good alignment. (g) Last follow-up images after 3 years showing good function.

normally the other 15 had a slight limp. None of the patients used walking aids. All patients were able to squat, although with some difficulty. Ten patients could squat normally, and a limitation of squatting to less than 90° was observed in another 10 patients. Fifteen patients could climb stairs normally, 15 could do so with only slight difficulty and three could climb only one step at a time. Jumping and duck walking were very difficult to assess, especially in patients with other impairments of physical activity; however, these activities were not important in grading the functional score. There were 10 excellent, 10 good, five fair and five poor results.

Radiological assessment

It is almost impossible to measure the sinking of the tibial plateau in bicondylar fractures [26] as plain radiographs do not distinguish between a local defect and depression of the whole condyle.

Tilting of the plateau was measured in the frontal plane by drawing a line between the deepest points of the weight-bearing area of the two condyles. The angle between that line and the long axis of the tibia was recorded. Twenty patients had no tilt at follow-up, five had a tilt of less than 6° and five had a tilt of 6–10°. Local step-off was measured whenever there was an intact part of the articular surface. All except two patients had a step-off of less than 4 mm.

The normal alignment of the plateau was measured on the radiograph of the uninjured knee. In 10 injured knees, the alignment remained normal and only two showed a deviation of more than 5°.

Figure 3

(a) Radiographs showing a bicondylar tibial plateau with metaphyseal comminution (a 31-year-old male patient, a lecturer). (b) Preoperative images of the knee and leg. (c) Postoperative radiographs showing good alignment. (d) Postoperative image showing the frame. (e) Follow-up radiograph after frame removal. (f–h) Images showing good wound healing and good function with excellent results after 2 years.

Table 2 Scales used to assess the subjective results of fractures of the tibial plateau

Frequency of symptoms[a]	1 None	2 Slight	3 Moderate	4 Very high	5 Extremely high
Never	1	–	–	–	–
Monthly	2	4	6	8	10
Fortnightly	3	6	9	12	15
Weekly	4	8	12	16	20
Daily	5	10	15	20	25

Importance of symptoms: 1–5, excellent; 6–10, good; 12–15, fair; 16–25, poor.
[a]Pain during various activities, swelling, stiffness, weakness, limping, giving way and crepitation.

Condylar widening was estimated in comparison with the width of the ipsilateral femoral condyles. Widening was present in ten knees and was more than 6 mm in only two of these.

Post-traumatic arthritis was described as narrowing of the joint space on comparison with the uninjured knee. Subchondral sclerosis was not taken into consideration because it can be attributed to fracture healing. Assessment of post-traumatic arthritis was considered preliminary because of the short duration of follow-up. There were 10 excellent, 10 good, five fair and five poor results.

The results were similar for both Schatzker type V and type VI fractures. We found no significant correlation between the type of fracture and the clinical, functional and radiological results. The subjective result was better in type VI fractures ($P = 0.076$). Whether the fracture was comminuted or compound did not affect the result. As regards ligament injuries, isolated lesions of the medial collateral ligament had the best prognosis.

Complications

There were no intraoperative injuries to the nerves or major vessels. One patient with a comminuted fracture required management in a functional brace for delayed union. Two patients developed deep vein thrombosis and two developed pulmonary embolism. All patients were

Table 3 Grading of the clinical criteria of fractures of the tibial plateau[a]

	Stability
Extension lag (deg.)	
1 – None	1 Normal
2 – 1–5	
3 – 6–10	2 Mediolateral: stable in extension, 5–10° instability in flexion. Anteroposterior: grade I instability, Lachman or drawer test.
4 – >10	
Flexion range (deg.)	3 Mediolateral: 5–10° instability in extension. Anteroposterior: grade II instability.
1 – >130	
2 – 110–129	
3 – 90–109	
4 – <90	4 Mediolateral: >10 instability in extension. Anteroposterior: grade III instability.
Thigh atrophy (cm)	
1 – None	
2 – >0–1	
3 – >1–3	
3 – >3	

[a]1, excellent; 2, good; 3, fair; 4, poor.

Table 4 Grading of the functional results of fractures of the tibial plateau[a]

Walking	1 – Normal
	2 – Slight limp
	3 – Severe limp or stick
	4 – Wheelchair
Stair climbing	1 – Normal
	2 – Impaired
	3 – One at a time
	4 – Unable
Squatting	1 – Normal
	2 – Impaired
	3 – <90°
	4 – Unable
Jumping	1 – Normal
	2 – Impaired
	3 – Only with the aid of the uninjured leg
	4 – Unable
Duck walking	1 – Normal
	2 – A few steps
	3 – One step
	4 – Unable

[a]1, excellent; 2, good; 3, fair; 4, poor.

Table5 Grading of the radiological criteria of fractures of the tibial plateau[a]

Plateau tilt (deg.)	1 – None
	2 – 1–5
	3 – 6–10
	4 – >10
Varus/valgus tilt (deg.)	1 – None
	2 – 1–5
	3 – 6–10
	4 – >10
Articular step-off (mm)	1 – None
	2 – 1–3
	3 – 4–6
	4 – >6
Condylar widening (mm)	1 – None
	2 – 1–5
	3 – 6–10
	4 – >10
Degeneration (relative narrowing of the joint space)	1 – None
	2 – <50%
	3 – >50%
	4 – Obliterated

[a]1, excellent; 2, good; 3, fair; 4, poor.

administered low-molecular-weight heparin from the time of admission. An impending anterior compartment syndrome was recognized in three patients who then underwent successful fasciotomies.

There were no skin sloughs or severe wire tract infections. No patient developed osteomyelitis or septic arthritis. None of the patients required removal of the fixator before healing of the fracture. We did not encounter significant stiffness of the ankle or the hind foot because we took great care in placing the wires and paid particular attention to the maintenance of mobility of these joints.

Discussion

An open wound is present in 33.3% of Schatzker type IV, type V and type VI fractures, and 66.6% of the remaining fractures are associated with significant closed injuries to the soft tissue [27]. In our series, 33.3% of fractures were open and 66.6% revealed damage to the soft-tissue envelope of the joint. Careful management of the soft-tissue injury is vital and the use of the Ilizarov system facilitates this [21,28,29]. The presence of fracture blisters or extensive subcutaneous haemorrhage and bruising does not hinder percutaneous placement of the wires, which avoids additional devitalization of the bone as the periosteal and endosteal blood supply are not further damaged. Small tensioned wires allow capture of small bone fragments and olive wires can compress the condylar fractures as would lag screws. Maintenance of the mechanical axis can be continually monitored by adjustment of the frame.

Fifteen patients required open reduction with elevation of the tibial plateau. Use of Ilizarov fixation allows the choice of any incision, without particular concern for the state of the skin as internal fixation is not used.

Instability of the knee after these fractures is a major cause of a poor result [6,10,30–35]. Whether it is due to ligamentous laxity or bone deformity is debatable [31,36]. There is no general agreement as to whether the repair of associated ligament injuries at the time of the fixation of the fracture is necessary; however, many believe that operative repair should be undertaken [24,36,37].

The tibiofemoral circular fixation provides adequate bracing for any form of management of ligament disruption. Analysis of our patients confirmed that isolated injuries of the medial collateral ligament have a better prognosis compared with all other isolated or combined knee ligament injuries associated with fractures of the tibial plateau [36].

Ilizarov circular fixation allows both early movement and early weight-bearing. The value of early movement has been well established [38–41]; however, early loading of fractures of the tibial plateau is generally avoided because of the concern that the reduction may be lost, resulting in depression of the articular surface or a valgus deformity.

Early weight-bearing, however, stimulates bone healing and allows retention of muscular strength [26,42,43].

The Ilizarov tibiofemoral frame allows adequate initial weight-bearing.

Conclusion

Our study emphasizes the low morbidity associated with the Ilizarov method. No patient developed osteomyelitis or septic arthritis. This absence of infection and septic nonunion compares favourably with the results of other published studies on these complex injuries [1,15,27,44]. The technique is well suited to the management of complex fractures of the tibial plateau when extensive dissection and internal fixation are contraindicated because of comminution at the fracture site and compromise of the soft tissue.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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