Original article

Results of ring (Ilizarov) fixator in high energy Schatzker type VI fractures of proximal tibia[☆]

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ABSTRACT

Background: High-energy fractures of proximal tibia (Schatzker VI) are associated with severe articular depression, separation of both condyles, diaphyseal comminution & dissociation with loss of integrity of the soft-tissue envelope. Complications of plating are well known since last 50 years in these difficult fractures. An alternative method was proposed by Ilizarov (ring fixator) and was adopted for the treatment of these complex injuries.

Aim of study: To analyse the results of patients who had ring fixator for the management of high-energy fractures (Schatzker VI) of the proximal tibia. **Material & Methods:** Fifteen patients (mean age of 36 years) with high-energy fractures of the proximal tibia (Schatzker VI) by the Ilizarov fixator and transfixion wires. Nine fractures were open and six patients had severe soft tissue injuries. Thirteen were treated by ligamentotaxis and percutaneous fixation. All were followed for a mean of 19.4 months. Using the criteria established by Honkonen & Jarvinen (1992), the outcome was analysed.

Results: Fourteen fractures united, with an average time to healing of 14.6 weeks and one took six months. 12 patients achieved full extension and 8 patients regained more than 110° of flexion. All knees were stable with one patient uniting in mild varus deformity. Normal walking was observed in nine patients and four had a mild limp. All but one knee had an articular step-off of less than 4 mm and all had normal axial alignment except one. The outcome suggested that seven knees were excellent, seven good and one as fair. There were no cases of postoperative skin infection or septic arthritis, but three cases had pin tract infection who were treated successfully.

Conclusion: The technique is well suited for the management of complex fractures of the proximal tibia (Schatzker VI) when extensive comminution at the fracture site and compromise of the soft tissue is present.

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1. Introduction

Complex proximal tibial fractures esp. tibial plateau are one of the most challenging problems in fracture surgery.^{1–3} In 1979 Schatzker et al. described six types of tibial plateau fractures based on anteroposterior radiographs.⁴ Schatzker type VI tibial plateau fractures are caused by severe high energy trauma. A transverse or oblique fracture of proximal tibia is present in addition to a fracture of one or both condyles of tibia and articular surfaces. The high energy causes severe bony comminution and soft tissue injury. These high energy injuries cause significant articular depression, condylar displacement, meta-diaphyseal fracture extension with

open wounds or extensive closed degloving injuries of the proximal tibia.⁵ Complications include severe soft tissue coverage problems, lower limb compartment syndrome, peroneal nerve injury, vascular injury and eventual knee arthrosis.⁶ These associated complications directly impact surgical decision making and prognosis.

The principles of treatment are anatomical reconstruction of the articular surface, restoration of the anatomical axis, fixation spanning the metaphyseal comminution and further minimization of secondary insult to an already traumatized soft tissue envelope.⁷ These objectives can be achieved with internal fixation or external fixation with or without limited open procedures and bone grafting or a combination of these methods. With extensive contusion or soft-tissue injury, a joint-bridging external fixator is recommended in order to provide sufficient stability for the recovery of the soft tissues. The concept of 'spanning' the knee joint was introduced in the 1990s.⁵ This concept evolved as proponents

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of indirect fracture reduction and biological fixation reported increased rates of success.⁸ With this method, the fractures are indirectly reduced with traction, and then maintained with either internal or external fixation before a knee spanning external fixator is finally applied. With the knee spanning external fixator, reduction of the intraarticular fragments is maintained.

Many problems encountered in management of such fractures has panacea in Ilizarov technique. It provides a method for closed reduction and fixation that does not necessitate excessive soft-tissue stripping.^{1,2,3,9–11} Combining this Ilizarov external fixation with minimal internal fixation provides better radiological and functional results.^{11,12} The aim of this study was to assess the clinical outcomes of Type VI tibial plateau fractures with severe soft tissue injuries treated with Ilizarov spanning fixator across the knee joint.

1.1. Material and method

Fifteen patients were included in this prospective study conducted between 2011 & 2014. The study was approved by the regional ethical review. The average age was 36 years (range 18–65 yrs). There were thirteen male and two female patients. The mode of injury was road traffic accident in all cases. There were open fractures in 9 cases and closed fractures with large blisters in 6 cases. The open fractures were Gustilo–Anderson type I in 2 cases, type II in 5 cases, and type III in 2 cases.¹⁰ Six closed fractures had extensive closed soft tissue injuries (mostly type I & II Tscherne and Gotzen)¹³ (Table 1). All patients with presence of high-energy tibial plateau fractures (Schatzker VI), either closed or open in skeletally mature patients were included. Antero-posterior (AP) X-ray was used to determine medial and lateral plateau involvement with degree of articular comminution and lateral view x-rays were used to determine the extent of posterior displacement of condyles and joint depression (Fig. 1 a–e). Soft tissue condition had a crucial importance on our planning for the time of the operation. All patients were reviewed at a minimum of 12 months. The patients with open fractures (n=9) were operated within six days after primary wound irrigation, debridement and intravenous antibiotics; while 6 closed fractures were treated with an average of four days delay (range 3–6 days) in order to allow soft tissue edema to subside. In cases of extremely complex and unstable fractures (n=13), the frame was extended onto the distal femur which kept the knee joint in distraction.

1.1.1. Operation technique

The operation was done under spinal anaesthesia in radiolucent operating table. The fragments were aligned by simple manual traction by an assistant or by fracture table. The fracture reduction was visualized on both planes by the image intensifier. Fragments were held with patella holding forceps. Depressed articular fragments often necessitate elevation (2 cases). The failure to reduce the articular fragments often necessitates an open reduction. A small window was made over tibial cortex through a small incision on the anterior-medial aspect of the tibial

metaphysis. A bone elevator was introduced through the hole and fragments were elevated under image intensifier. Meniscal or ligament injuries were not addressed at this stage. After reduction of the condyles, counteropposed olive wires through the fragments were used to achieve interfragmentary compression. Three wires with an divergence of at least 60°, were usually required for stabilization of the condylar and metaphyseal fragments. The wires were placed at least 15 mm away from the joint surface to prevent synovial contact and to avoid septic arthritis in case of pin tract infection. The first 1.8 mm olive wire was inserted using image intensifier in a lateral to medial direction just anterior to the head of the fibula at the subchondral region of tibial plateau to provide interfragmentary compression. All wires were passed through safe zones. The first ring was fixed to the first wire with two fixation bolts and tensioned to create compression in between the articular fragments. Another olive wire was applied from medial to lateral on the distal side of the ring, and then a drop wire was inserted. This ring was then connected to one ring distally with four interconnecting rods. Care was taken to restore the mechanical axis in relationship to the condyles. The frame was extended as distractor onto the distal femur. The frame was fixed by two half pins between quadriceps and hamstring. The tibial and femoral rings were connected with connecting rods. The pin sites were dressed with povidone iodine solution soaked gauzes.

1.1.2. Post operative rehabilitation

For open fractures, either daily dressing or delayed primary closure or skin grafting was done depending upon the size of the wound. Postoperative care consisted of daily pin tract dressing. Check radiographs were done on the next day and adjustments of the fixator was done by the 3rd day. Parenteral antibiotics were given up to the third day for closed fractures and up to the eradication of infection or wound healing for open and infected fractures. Active and passive dorsiflexion exercises of the ankle were started on the second post operative day. To prevent equinus deformity of the ankle, the foot was kept in a neutral position by splinting. Isometric quadriceps exercises and hip raising exercises were permitted. All patients were allowed partial weight bearing as pain tolerated by the end of one week. Patients with open fractures were checked weekly in the outpatient department until wound healing. Thereafter, they were checked every 4 weeks (as patients with closed fractures) with check radiographs. The femoral frame was removed on an average 4.4 weeks after operation and knee ROM (range of Motion) exercises were allowed (Fig. 2 a–e). All patients were encouraged to partially weight-bear. After radiographic healing, frame dynamization was performed to decrease pin bone stresses and to transmit weight-bearing forces to the bone. Incomplete fracture healing was assumed when pain or subtle radiographic changes were present after frame dynamization. The frame was retightened to allow further consolidation. The external fixator was removed once radiographic evidence of union was established, and the fracture was clinically united. Clinically, healing was defined as the ability to bear full weight with a varus and valgus stress to the injured tibia without causing pain. All the fixators were removed as an outpatient procedure without anaesthesia. Walking cast was applied for 3–4 weeks. Physiotherapy was continued after removal of the cast to improve the range of knee motion. Radiographs were taken without cast and were allowed full weight bearing with follow-up at 3, 6 and 12 months.

1.1.3. Assessment

All patients had record of the clinical & subjective assessment, level of function and radiological assessment according to the criteria established by Honkonen & Jarvinen.¹⁴ All patients were

Table 1
Number of patients with Grades of fractures with time to union.

S No	Grade	No of patients	Time to union (weeks)
1	I ^a	2	12
2	II ^a	5	14.6
3	III ^a	2	20
4	I ^b	2	13
5	II ^b	4	14

^a Open fractures (Gustilo/Anderson).

^b Closed fractures (Tscherne/Goetzen).

Fig. 1. a) Preoperative X-ray (AP & Lat views) showing Type VI fracture of tibial plateau in a 44 year old male patient. b) Immediate post-operative (AP & Lat views) showing reduced fragments with Ilizarov frame in situ. c) Two months post-operative (AP & Lat views) showing healing fracture with congruent articular surface. d) One year follow up clinical photo showing good function (Squatting). e) One year follow up clinical photo showing outcome without any varus deformity.

asked to record their symptoms esp. frequency and importance. The symptoms were pain during activities, swelling, stiffness, weakness, limping, giving way and crepitus. The severity was assessed by multiplying the frequency of symptoms by the grade of importance to the patient. All patients were clinically assessed with extension lag (in degrees), flexion range (in degrees) and thigh atrophy (in cm). These parameters are graded from excellent to poor. The final score was the lowest grade found in any of the four tests. Functional assessment was done by assessing the walk, stair climbing, squatting, jumping and duck-walking. The final score was the lowest found on these five tests and graded as excellent to poor. Radiological grading was done by assessing the plateau tilt, varus/valgus tilt, articular step off, condylar widening and degeneration (relative narrowing of the joint). The radiographs were assessed in both antero-posterior and lateral planes. 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. Local step-off was measured whenever there was an intact part of the articular surface. The normal alignment of the plateau was measured on the radiograph of the uninjured knee. Condylar widening was estimated in comparison with the width of the ipsilateral femoral condyles. Post-traumatic arthritis was recorded as narrowing of the joint space compared with the uninjured knee.

2. Results

The mean interval between the injury and application of the Ilizarov ring external fixator was 5.6 days (range 3.5–10 days) in

our hospital. The external fixator was tolerated for the entire treatment period in all cases. Average partial weight bearing walking was allowed by 5.5 days (range 4–7 days) and average full weight bearing was allowed by 17.4 weeks (15–25 weeks). The mean hospital stay was 5.4 weeks (range 2–18 weeks). All fractures healed, with an average time of treatment with the frame for 14.6 weeks (range 12–25 weeks) (Table 2). All but two fractures were united within four months. Eleven patients required additional casting and four patients did not require any other form of supports. In one patient, fracture took longer than 6 months to heal. Two patients had pin track infection. All pin track infections healed by regular dressing without requiring wire removal. One patient had united in varus (10°), but was asymptomatic. One patient required muscle flap procedure for soft tissue coverage and two patients required split thickness skin grafting.

A total of 14 patients regained functional use of the knee joint, without pain or instability and improved quality of daily living. Mean flexion of 110° (range 70° – 130°) was achieved in 15 patients at a mean follow up of 19.4 months. In fractures treated with knee distractor ($n=13$) the average knee flexion achieved was 108° (range 70° – 130°). 2/15 patients were able to flex the knee to 130° and 6/15 patients upto 120° . Three patients had 5° lack of extension (range 0° – 8°). Thigh atrophy of more than 1 cm was noted in only one patient. Normal walking was observed in nine patients and four had a mild limp. None of the patients used any walking aid. Squatting was normal in 10 patients. Limitation of squatting was observed in three patients. 8/15 patients could climb stairs normally. Overall, there were seven excellent, seven good and one fair result (Table 3). Residual knee laxity was observed in two

Fig. 2. a) Preoperative X-ray (AP & Lat views) showing Type VI fracture of tibial plateau in a 45 year old female patient. b) Six weeks post operative AP X-rays showing the healing fracture of right knee. c) Clinical photo showing removal of femoral pins and weight bearing at 8 weeks. d) Clinical photo showing full extension with the frame at 2months post operative period. e) One year post operative AP & Lat view X-ray showing the healed fracture at follow-up.

Table 2

Details of 15 patients with their outcome in Schatzker VI fractures.

SL No	Age	Sex	Side	Soft tissue status	Fixator (weeks)		Full wt Bearing (wk)	Follow-up (months)	Time to union (wk)	Range of Motion (degrees)	Outcome	Complication
					Femoral	Tibial						
1	36	M	L	Blister	No	12	15	24	14	120	Excellent	No
2	39	M	R	Open	4	13	16	18	15	120	Excellent	No
3	53	M	L	Open	6	16	20	30	24	70	Fair	Stiffness
4	63	M	L	Blister	4	13	17	18	16	100	Good	Pin tract infection
5	48	F	R	Open	4	14	17	18	15	120	Excellent	Pin tract infection
6	44	M	L	Blister	4	13	16	24	13	130	Excellent	No
7	37	M	R	Open	4	14	17	16	14	100	Good	Varus deformity
8	27	M	L	Open	6	18	22	16	16	100	Good	No
9	50	M	L	Blister	No	12	15	15	13	120	Excellent	No
10	25	M	R	Open	4	16	17	20	14	120	Excellent	No
11	60	M	L	Blister	4	13	17	18	13	100	Good	No
12	45	F	R	Open	4	14	17	18	15	120	Good	No
13	42	M	L	Blister	4	13	16	24	13	130	Excellent	No
14	33	M	R	Open	4	14	17	16	12	100	Good	No
15	31	M	L	Open	6	18	22	16	12	100	Good	No

Table 3
Outcome analysis.

SL No	Subjective Outcome	Clinical Outcome	Functional Outcome	Radiological Outcome
1	Good	Excellent	Excellent	Excellent
2	Good	Excellent	Excellent	Excellent
3	Poor	Fair	Fair	Poor
4	Fair	Good	Good	Fair
5	Good	Excellent	Good	Excellent
6	Excellent	Excellent	Excellent	Excellent
7	Fair	Good	Good	Fair
8	Fair	Good	Good	Fair
9	Good	Excellent	Excellent	Excellent
10	Good	Excellent	Excellent	Excellent
11	Fair	Fair	Good	Good
12	Good	Good	Good	Good
13	Excellent	Excellent	Excellent	Good
14	Fair	Good	Fair	Fair
15	Fair	Good	Good	Good

patients, but no patient complained of functional instability of the knee.

A varus tilt of 10° was noted in one patient on AP radiographs. On lateral radiographs the plateau tilt of less than 6° was noted in two patients. Only one patient had a step of less than 4 mm on the articular surface. On comparing with the uninjured knee the tibial varus tilt was observed in two patients. Condylar widening was noted in 7 patients and none were more than 6 mm. No patients had post traumatic degeneration. Radiologically, 6 were excellent, 4 were good and 4 were fair.

3. Discussion

Decision making in the management of tibial plateau Schazker type-VI fractures with extensive soft tissue injury relates to the longterm outcome.¹⁵ Surgery is indicated in such fractures with metaphysis-diaphyseal dissociation.¹⁶ In this series, 60% patients had open fractures and 40% had significant closed injuries to the soft tissue. Joint spanning circular fixation (Ilizarov frame) provides adequate healing of soft tissue injuries especially ligament injuries. In the present series, despite the severe articular comminution, spanning of fixator across the joint allowed adequate rest to the tissues and a satisfactory functional outcome was achieved. It has been reported that the healing of the articular surface is adequate when the articular congruity is maintained. Intra-operative imaging helps in providing congruous reduction although it is difficult to achieve anatomical reduction by closed methods. Instability of the knee after these fractures is a major cause of a poor result.^{15,17–19} Whether it is due to ligamentous laxity or bone deformity is debatable.^{18,20} 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, but many believe that operative repair should be undertaken.^{19,20} In this series, the ligament injuries were not primarily assessed. Ilizarov circular fixation allowed both early movement and early weight-bearing and none of the patients had signs of instability.

Open reduction and internal fixation is not indicated in the presence of fracture blisters or extensive subcutaneous haemorrhage and bruising. Literature review suggests increased rates of infection in 23–80% patients with complex proximal tibial fracture.^{21–24} Morandi et al. showed decreased rate of complications with external fixation in such fractures.²⁵ The percutaneous wires could be used to avoid additional devitalisation of the bone since the periosteal and endosteal blood supply do not undergo a secondary insult. Olive wire acts as lag screws and compress the fragments against the condyle. They hold the fragments against vertical shear and creates a relatively stable joint surface configuration.²⁶ Small tension wire helps to hold the small

fragments.²⁷ Mechanical axis of lower limb can be maintained and monitored by adjustment of the frame. Spanning the knee with the external fixators also prevents wire migration into the knee joint. Two patients required open reduction with elevation of the tibial plateau.

Early range of motion in such fractures has been well established,¹⁶ but early loading of such fractures has generally been avoided because the reduction may be lost, resulting in depression of the joint surface or a progressive deformity. However, early weight bearing could stimulate bone healing and muscular strength could be regained early for a better functional outcome.²⁵ The Ilizarov tibio-femoral frame allows early weight bearing. In this series, it was observed that minimum of six weeks was required for soft callous formation. The early signs of healing due to early weight bearing confirm the already established theory.²⁸ Multiple studies of treatment of complex fractures of the tibial plateau with circular wire external fixation reported that the mean time to union varies between 24–26 weeks.^{29–31} Kumar & Whittle reported an average of 173 days i.e. 24.71 weeks (7.14–59.28 weeks) for fracture union.²⁹ Behrens & Searls showed average union time of 186 days i.e. 26.57 weeks.³⁰ Tucker et al. showed that all of the fractures healed without bone grafting with the time to union ranging from 12 to 47 weeks (mean 25.6 weeks).³¹ All the patients in the current series healed earlier than the reports published.

Our study emphasises 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 other published studies on these complex injuries.^{32,33} The functional outcome of tibial plateau fractures managed with Ilizarov fixator were reported as excellent to good in 76–89%.^{34–36} In this series, excellent to good function was achieved in 96.7% patients. Knee stiffness is a common problem after tibial plateau fracture surgery.^{9,37} Knee stiffness has been defined as flexion of less than 100° and an extension deficit of less than 5°. Excellent to good results have been achieved with ring fixators and the results in the present study compare favourably with these.^{9,38}

The limited size of the study sample was a limiting factor. The other limitation was defining the articular incongruence with CT scans and the follow-up CT scans.

4. Conclusion

The Ilizarov technique is a safe and effective method associated with low morbidity in fractures of the proximal tibia. Early and definite fixation is achieved with the Ilizarov technique, allowing early partial weight bearing, and the compliance is good. Removal

of the femoral ring especially after six weeks does not disturb knee function and also encourages fracture healing. All patients had fracture union within four months of Ilizarov application. This method of treatment for such fractures is highly recommended.

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Conflict of interest

None.

Contributions of each author

1. Ujjwal K. Debnath – Collect data, write manuscript, edit manuscript.
2. Dipak K. Jha – Senior author, Collect data.
3. Prasanta K. Pujari – Collect Data.

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