ABSTRACT

Purpose. To assess results of small wire external fixation using a ligamentotaxis technique for high-energy tibial plateau fractures.

Methods. Between April 2002 and May 2004, 38 consecutive patients aged 21 to 60 (mean, 32) years underwent small wire external fixation for high-energy tibial plateau fractures. 15 involved the right and 23 the left knee. 34 were closed and 4 were open injuries. Fractures were classified according to Schatzker’s staging system. After a minimal of 2 years’ follow-up (range, 24–42 months), each affected knee was evaluated using Rasmussen’s (1) 30-point clinical grading system and (2) radiological evaluation.

Results. There were 22 type-VI and 16 type-V Schatzker tibial plateau fractures. Complications consisted of: 2 superficial infections, 3 pin site infections, and 4 peroneal nerve palsies. No soft tissue necrosis or devitalisation occurred. The mean range of knee movement was 132°. The mean Rasmussen radiological score was 14 (range, 10–18): excellent in 6, good in 26, and fair in 6. The mean Rasmussen functional score was 26 (range, 17–30): excellent in 19 patients, good in 17, and fair in 2. Clinical results did not parallel the radiological results.

Conclusion. Small wire external fixation allows anatomical reconstruction of the articular surface, stable fixation of fracture fragments, early movement of the joint, and care of associated soft tissue injuries, without a high rate of complications.

Key words: external fixators; tibial fractures

INTRODUCTION

High-energy tibial plateau fractures are difficult to treat, as they entail articular depression, condylar displacement, dissociation of comminuted metaphysis from diaphysis, and open wounds or extensive closed degloving injuries.¹ Injury mechanisms involve a combination of axial loading and valgus forces.¹ The outcome is usually poor with high
rates of complications, such as: wound problems, infections, varus collapse, knee stiffness, and articular malreduction. The treatment goals are to anatomically reconstruct the proximal tibial articular surface, restore limb axial alignment, and fix metadiaphyseal comminution to allow early knee mobilisation and weight bearing, and minimise further morbidity to an already traumatised soft tissue envelope.

Whenever incisions are poorly placed and the dissection is extensive, open reduction and internal fixation using dual plating may compromise the soft tissue envelope and cause soft tissue necrosis and deep wound infections. Although such complications are salvageable with local or free flaps, knee function and movement remain limited.

Minimally invasive techniques using periarticular fine wires allow rigid fixation of small pieces of cancellous bone and intra-articular fractures, easy wound surveillance, early joint mobilisation and weight bearing, and minimal soft tissue disruption.

We therefore evaluated the clinical results of 38 patients with high-energy tibial plateau fractures treated with a small wire external fixator, using a ligamentotaxis technique and no additional stabilisation.

**MATERIALS AND METHODS**

Between April 2002 and May 2004, 38 consecutive patients (32 males) underwent small wire external fixation for high-energy tibial plateau fractures. Inclusion criteria were: age >18 and <60 years, reasonable general condition and no concomitant serious injuries. The mean patient age was 32 (range, 21–60) years. 15 injured the right and 23 the left knee. 34 were closed and 4 were open injuries. 12 patients had associated fibular head and neck fractures. Injury mechanism were: fall from motorcycle (n=20), motor vehicle accident (n=9), pedestrian being struck by motor vehicle (n=7), and fall from a height (n=2).

Anteroposterior radiographs were used to determine the extent of medial and lateral plateau involvement, whereas lateral radiographs were used to gauge the extent of posterior displacement of condyles, degree of articular comminution, and joint depression (Figs. 1 and 2). Fracture patterns were classified according to Schatzker’s staging system. The extent of articular condylar depression was measured either from the remaining intact articular surface or from a line drawn as an extension of the other tibial condyle to the point of maximum depression. Condylar widening (an indirect indicator of articular comminution) was measured in relation to the intact femoral condyle. Open fractures were immediately irrigated and debrided prior to definitive fixation. 11 of 34 closed fractures had severe soft tissue injuries (Fig. 3). These were defined as: communicating open wounds or in cases of closed fractures presence of a compartment syndrome, abrasion, contusion, crushing, or marked swelling. Such injuries did not affect the timing of percutaneous procedures, whereas limited open reduction was allowed only after such injuries resolved. Distal tibial pin or calcaneal traction was used for preoperative immobilisation. Prophylaxis with a cephalosporin antibiotic was used routinely.

Coronal and saggital and 3-dimensionally
reconstructed computed tomography (CT) scans (Fig. 4) revealed the precise location and degree of articular depression and incongruity and determined intact regions of the plateau upon which to build a stable construct and insert wires.

The patient was positioned on a radiolucent operating table. Knowledge of neurovascular anatomy was a prerequisite for pin placement using the circular frame. Fine wires were placed through safe tissue corridor. The principle of ligamentotaxis was used to achieve metaphyseal reduction. Concomitant soft tissue injuries such as meniscal, cruciate, or collateral ligament injuries were left alone at this stage, and the knee was spanned by the fixator. Two to three 1.8-mm wires were inserted through the femoral condyles at the level of superior pole of patella and were tensioned to an adequately sized ring placed parallel to the knee joint axis. A second ring was placed in the tibia, just distal to the metaphyseal component of the fracture and the wires were tensioned on it. Threaded rods were then used to connect these 2 rings (spanning the knee joint). Closed reduction was performed using the principle of ligamentotaxis. An articular incongruity of ≥3 mm indicated indirect or direct (if indirect failed) open reduction. In the course of indirect open reduction, the fractures site was left undisturbed; through a 3-cm incision just lateral or medial to the tibial crest, the crushed metaphyseal component was lifted to restore the articular surface. The defect so created in the metaphyseal region was buttressed with bone grafts. In direct open reduction, limited incisions using submeniscal exposures were made to elevate depressed articular surface. Full thickness flaps were

Figure 2  (a) Anteroposterior (AP) and (b) lateral radiographs of a 60-year-old man with type-VI tibial plateau fracture with extension of fracture in the metadiaphyseal region. (c) Axial and (d) coronal computed tomographic scans showing complex nature of the fracture lines. (e) AP and (f) lateral radiographs 3 months after surgery, just prior to fixator removal. (g) AP and (h) lateral radiographs after 30 months showing reduction of tibial plateau articular surface and union of fractures.
raised without undermining the subcutaneous tissue and fascia, so as to avoid skin necrosis. Bone grafting was done through submetaphyseal cortical windows at the inferior margins of the fractures using curved impactors.

After achieving adequate reduction, 2 to 4 counteropposed olive wires (1.8-mm Kirschner wires with 4-mm beads located eccentrically in the wires) were placed in the juxta-articular bone supporting the soft cancellous bone fragments, parallel to the knee joint, each was tensioned to 30 kg and attached to the proximal fixation ring. The juxta-articular pins were placed at least 15 mm away from the joint surface to prevent synovial contact. Each wire was positioned centrally in the midportion of each condylar fragment and perpendicular to the major fracture lines, so as to act in a lag fashion and provide maximal intercondylar compression.

This ring was placed at the level of fibular head, which was used as a buttress plate when intact. By placing an olive wire through fibular head obliquely into the lateral condyle and tensioning it, the fibular head was compressed into the lateral condyle. Wires were then attached and tensioned to this ring. The distal ring was placed just proximal and parallel to the ankle joint. Fixator rings should allow 1.5 cm of clearance over the anterior crest of the tibia and 3 to 4 cm of clearance around the posterior calf to accommodate postoperative swelling. Care was taken to restore the mechanical axis in relationship to the condyles.

Isometric quadriceps exercise and hip raising exercises were started from postoperative day 1. The femoral ring was removed at 3 weeks and knee mobilisation initiated. Weight bearing status was touch down initially, then advanced to partial when callus was noted on radiographs. Serial radiographs were taken at 2-week intervals to detect any deviation of the mechanical axis during external fixation. Adjustments were made to realign the extremity and to add compression to small areas of bony comminution. Active compression of the rings consolidated the metaphyseal comminution and achieved greater cortical contact and stability, thus avoided bone grafting. Radiographic healing was defined as obliteration of the major fracture line in both views. Clinically, healing was defined as the ability to bear full weight with a varus and valgus stress to the injured tibia without pain.

After radiographic healing, frame dynamisation was performed by loosening proximal and distal rings 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 dynamisation. The frame was retightened to allow further consolidation. Two patients required bone grafting to achieve union.

Further procedures, adjustment of frames, time during fixation, time to union, and complications were recorded. At the final follow-up (minimum of 2 years), patients were evaluated using the Rasmussen 30-point clinical grading system and the Rasmussen radiological evaluation of the knee.9

The relationships between knee scores and factors such as age, fracture side and type, gender, preoperative and postoperative fracture depression and displacement, bone grafting in the depressed segment, and the immobilisation period were analysed using the Chi squared test. A p value of <0.05 was considered statistically significant.

RESULTS

There were 22 type-VI and 16 type-V Schatzker tibial plateau fractures. The mean interval between injury and surgery was 5 (range, 0–22) days. Impending compartment syndrome (n=6) was the most common cause of delay in surgery. No patient required blood transfusion. The mean hospital stay was 9 (range,
4–29) days. The mean interval between surgery and full weight bearing was 3.7 (range, 3.3–5.2) months. The mean follow-up period was 32 (range, 24–41) months.

There was no non-union, septic arthritis, myositis ossificans, overt pulmonary embolism or deep venous thrombosis. Neither was there soft tissue necrosis or devitalisation. Complications included superficial infection (n=2), pin-site infection (n=3), and peroneal nerve palsy (n=4).

The respective mean values for fracture depression and displacement were 8.6 (range, 4–18) mm and 12.3 (range, 5–31) mm preoperatively and 1.8 (range, 0–8) mm and 2.4 (range, 0–6) mm postoperatively, as assessed by condylar widening. In 2 patients, the correction of fracture depression at the final follow-up was lost by about 3 mm.

The mean Rasmusson radiological score was 14 (range, 10–18): excellent in 6, good in 26, and fair in 6. Although varus or valgus instability was noted in 10 patients, none of them complained of functional instability. The mean range of knee movement was 2º (range, -4º–8º) of extension to 134º (range, 90º–140º) of flexion. Knee movement was significantly more improved in patients starting mobilisation within 3 weeks compared to those starting later ($\chi^2=10.556, p=0.001$). Four patients complained of an occasional ache on exertion. 36 of 38 patients could walk normally outdoors for at least one hour. The remaining 2 described decreased walking capacity (about half an hour), one of them needed to change his occupation.

The mean Rasmussen functional score was 26 (range, 17–30): excellent in 19, good in 17, and fair in 2. Residual condylar depression contributed to less-than-excellent functional results. Functional results were significantly correlated to condylar depression ($\chi^2=8.686, p=0.003$), but not to residual condylar separation ($\chi^2=2.171, p=0.141$), final radiological scores ($\chi^2=1.782$ with Yates correction, $p=0.182$), and patient age, gender, fracture type and side, and preoperative fracture depression and displacement. The absence of any bone graft in a fracture with a depressed component was significantly associated with less-than-excellent results ($\chi^2=9.47, p=0.02$).

**DISCUSSION**

Treatment of high-energy tibial plateau fractures remains controversial. Traction and cast bracing provides poor results.$^{10}$ Open reduction and internal fixation with double plating requires large amounts of soft tissue mobilisation and stripping to achieve satisfactory results. This devitalises soft tissue and hinders wound healing. A 23% infection rate was reported with dual plating of bicondylar fractures.$^{11}$ An 87.5% deep infection rate and 100% complication rate were reported with dual plating for comminuted or bicondylar fractures.$^{12}$ Hybrid fixation using lateral open reduction and internal fixation combined with unilateral external fixation does not address medial condylar comminution, because of the larger diameter of half pins and poor purchase in metaphyseal bone.$^{13}$ Limited internal fixation or lateral open reduction and internal fixation alone incompletely address the metaphyseal dissociation, resulting in collapse beneath the unsupported plateau.$^{14}$ Knee spanning external fixation does not allow early range of movement, impairing articular fracture healing.$^{15}$ Less-invasive stabilisation systems confer a higher risk of implant-associated pain than conventional plates.$^{16}$

Closed reduction or limited open reduction using small tensioned wires prevents further iatrogenic soft tissue injury and minimises additional devitalisation of the bone and periosteal and endosteal blood supply. It offers superior juxta-articular, metaphyseal purchase, fixes small cancellous osteoporotic fracture fragments, and allows for early range of movement and weight bearing. This reduces hospital stays and costs. The olive wire provides superior reduction and interfragmentary compression of metaphyseal fracture components and facilitates fine adjustment of rotational deformity.

Early weight bearing stimulates fracture healing by axial micromotion without shear. Simultaneous distraction on both sides of the joint helps to achieve a ligamentous reduction. Small wire external fixation combines the benefit of traction, external fixation, and limited internal fixation, whilst allowing accessibility to the soft tissue for wound checks, pin care, dressing changes, measurement of compartment pressure, and monitoring of neurovascular status. Thus, it is indicated in periarticular fractures with metaphyseal/subchondral comminution that precludes routine plate and screw stabilisation. It is also indicated in plateau fractures that present with diaphyseal-metaphyseal comminution and major extension into shaft region, as well as in complex fractures with soft tissue–associated compartment syndrome and loss.

A mechanically stable and adjustable ring fixator can span across a fracture gap in cases with comminuted or minimal bone loss. Compression can be directed across the site of bone loss or fracture gap without additional bone grafting. Rotational and translational deformities can be corrected as consolidation progresses.$^{1}$
more isotropic mechanical properties in bending, non-linear axial rigidity, and the ability to create configurations for complex corrections.17

When surgery is performed early, anatomical reduction and ligamentotaxis are more easily achieved, with the extent of open surgery minimised. Small wire external fixation is the only viable option for early surgery, whenever severe soft tissue injuries are present. In cases of delay, patients must be maintained in calcaneal or tibial pin traction to avoid additional trauma and reduce swelling and soft tissue compromise.

In each of 12 patients, only 2 olive wires were used for repair of the articular surface. At the final follow-up, in 2 of them the correction achieved perioperatively was lost by 3 mm (depression). Therefore, a 2-wire construct was inadequate18; for which at least 3 or more out-of-plane wires are recommended. Full ring stabilisation is preferable to monolateral shaft stabilisation because the cantilever loading is accentuated when a proximal ring is attached to a solitary diaphyseal bar, and the monolateral construct cannot easily dynamise the fixator.18

Adequacy of reduction is the most important factor to predict outcome. Intra-articular comminution with depression is difficult to treat; even if accurate anatomical reduction is obtained, late collapse and deformity on weight bearing precludes good functional results.8

Most meniscal lesions have been reported to be peripheral, in the red-on-red zone, and may heal without intervention.14 Most cruciate, meniscal injuries should be addressed at the second stage, once the fracture consolidates and a good range of movement is established. It is futile to address meniscal pathologies simultaneously, at the expense of a knee compromised for primary range of movement.

Range of knee movement was better in patients starting mobilisation before postoperative week 3. Longer immobilisation attained a mean range of movement of 14° less than that achieved by earlier mobilisers.19

We enjoyed a short learning curve on the use of these frames. Results improved with experience, careful preoperative planning, and thorough knowledge of neurovascular anatomy. Good intra-operative radiographs are needed to decrease the incidence of malreduction while learning.

Pin tract infection is a potential problem despite the use of small wires. To avoid the disastrous complication of septic arthritis, we recommend placing wires at least 15 mm away from the joint surface, monitoring the status of pin sites (especially at juxta-articular locations), and removing any pin revealing features of infection.

**CONCLUSION**

Small wire external fixation offers a promising alternative treatment for high-energy tibial plateau fractures. It allows anatomical reconstruction of the articular surface, stable fixation of fracture fragments, early rehabilitation of the joint, and care of associated soft tissue injuries, without a high rate of complications. It is not recommended for all intra-articular tibial fractures.

**REFERENCES**

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