Minimally invasive plate osteosynthesis in the treatment of multifragmentary fractures of the proximal tibia
Elsayed M. Mohamady Ibrahim, Hossam Elbegawy and Amr Elgazar

Background
Proximal tibia fractures with metaphyseal comminution present a difficult treatment challenge. Minimally invasive plate fixation (osteosynthesis) (MIPO) has theoretical advantages for the treatment of these injuries. This report presents the clinical results of the MIPO system for the treatment of a series of patients with complex proximal tibia fractures.

Patients and methods
Between March 2003 and February 2007, 28 consecutive patients with comminuted proximal tibia metaphyseal fractures with intra-articular extension were treated with MIPO in Benha Faculty of Medicine. The mean age of the patients was 37 years (range between 21 and 60 years). There were 22 closed fractures and six grade I open fractures (Gustilo Anderson classification).

Results
The average follow-up was 23 months (range 12–48). In 26 (92.8%) out of 28 patients, the fracture healed after the index procedure and had satisfactory results. One patient had a fair result because of valgus malalignment and replating was performed. One patient had a poor result because of deep infection and loosening. Postoperative fracture alignment was satisfactory in 26 out of the 28 cases and was maintained in all patients at union. There was no deep venus thrombosis or compartment syndrome.

Conclusion
The MIPO can be used safely to treat complex proximal tibia fractures without the need for additional medial stabilization. Surgeons attempting to use MIPO should familiarize themselves with the significant technical differences between these and traditional plating systems to ensure satisfactory results.

Keywords:
biological fixation, minimally invasive surgery, proximal tibial fractures

Introduction
Upper tibial plateau fractures with intra-articular extension represent a treatment challenge and range from low-energy injuries in osteopenic bone to high-energy trauma with severe soft-tissue damage. It is often difficult to determine as to which method of fixation is the best for any given fracture pattern. The fundamental principles that must be followed by the surgeons are: (a) reduction in the anteroposterior and lateral planes, (b) avoidance of varus, (c) avoidance of muscle and periosteal damage and (d) stable internal fixation. The goal is to achieve union and avoid complications. The concept of the principle of preservation of the blood supply and an atraumatic surgical technique led to development of biological fixation techniques. With the use of this treatment, lower soft-tissue complications and higher union rates have been found [1].

Open reduction and internal fixation has been used to overcome the limitations encountered in the treatment of upper tibial fractures with skeletal traction or cast immobilization. Plate osteosynthesis is known to be the standard treatment for many fractures. Early techniques emphasized a precise anatomic reduction and absolute rigidity of each cortical fragment to achieve maximal mechanical stability, thereby allowing fracture fragments to unite by primary or internal callus bone healing. However, the extensive operative exposure often results in devitalization of fracture fragments, stripping of periosteum as well as evacuation of osteogenic fracture haematoma. Problems with delayed union or nonunion, infection and implant failure are not uncommon. Therefore, biological plating techniques, with preservation of the osteogenic haematoma, avoidance of devitalization of the fracture fragments and preservation of endosteal blood flow in contrast to intramedullary nailing, could be the reasons for the earlier callus formation and fracture stability and hence a possible solution [2,3].

The aim of these techniques is to achieve axial alignment and stable fixation while preserving the fracture biological environment. Bone heals by both endosteal union and callus formation. The use of these methods has been reported to successfully decrease the incidence of fracture complications.
and has produced favourable results compared with earlier, less biologic approaches to plating [1,3–5]. Intramedullary fixation for the treatment of lower limb long bone diaphyseal fracture is a gold standard. However, fractures at the diaphysis metaphysis junction, or fractures that primarily involve the metaphysis, have been managed by a wide variety of implants [6].

In this study, we applied the lateral tibial head plate using the minimal invasive technique and the biological plating principle in selected fractures in which intramedullary nails may not be applicable. Biological fixation principles can be summarized as follows [7]:

1. Repositioning and realigning by manipulation at a distance to fracture site, preserving soft tissues (indirect reduction techniques).
2. Leaving comminuted fragments out of the mechanical construct, while preserving their blood supply.
4. Limited operative exposure.

Minimally invasive plate fixation (MIPO) is a method in which a percutaneously inserted plate is fixed at a distance proximal and distal to the fracture site by minimal exposure.

Patients and methods

Twenty-eight cases of comminuted fractures of the upper tibia were treated in Benha University Hospitals between March 2003 and February 2007. The duration of the follow-up ranged from 12 to 48 months. Only closed or grade I open fractures were included.

All patients received first aid with a thorough examination to identify associated injuries. Patients were subjected to routine preanaesthetic investigations and additional investigations when indicated. Standard anteroposterior and lateral radiographs were taken, and the fracture was classified according to the AO group classification.

The leg was immobilized in a posterior plaster splint. Strict limb elevation was performed with additional chymotrypsin trypsin tablets to reduce the overall inflammatory response. Many of the patients with other bony or soft-tissue injuries were treated appropriately.

The anteroposterior and lateral radiographs were evaluated for the extent of comminution and the likely length of the plate was calculated.

Operative technique

Surgery was performed under regional anaesthesia and with a tourniquet in the supine position. A small incision was made on the upper end of the fractured comminuted area without disturbing the soft-tissue envelope of the fractured fragments. The incision was extended right up to the bone with the periosteal tube opened. A submuscular tract was made along the surface where the plate was be placed and extended across the fracture to the other side. The plate used depends on the anatomy and location of the fracture. L or T Buttress plates were used for proximal metaphyseal-diaphyseal fractures. Once the tract was made, an appropriate length plate was selected ensuring that a hold of at least six to eight cortices was obtained on either side of the fracture. A contoured plate was made to slide along the previously created tract. With the plate in situ and some traction provided manually, the alignment was checked using the standard anterior superior iliac spine – centre of the patella – second toe guide line. A radiograph was taken to check the alignment radiologically and also to confirm that the length of the plate is appropriate. The plate was fixed at the upper end with 6.5 mm cancellous screws. Initially, only one screw was passed, maintaining plate bone contact and the alignment, and then the remaining screws were passed. With the fracture reduced by indirect means without dissecting the fractured area by gentle external manipulations, the distal end of the plate was identified. The plate was fixed distally with percutaneously inserted 4.5 mm cortical screws or through a small incision. The alignment was checked throughout the procedure. The use of bone holding forceps was avoided. Careful handling of the soft tissues and judicious use of the retractors are essential. No primary bone grafting was carried out irrespective of the comminution (Fig. 1).

After the operation, the limb was elevated, and ankle and knee range of motion was started once pain subsided. Toe-touch weight bearing was allowed initially, with full weight bearing only with good clinical and radiological evidence of progressive fracture healing. In patients with multiply injuries, the protocol was adapted to treat the associated injuries.
Results
Twenty-eight patients were operated upon. The mean age of the patients was 37 years (Table 1). The youngest patient was a 21-year-old man and the oldest was a 60-year-old man. Overall, 71.5% of the injuries (20 cases) were because of a road traffic accident (Table 2). Most of the patients involved in high-velocity accidents were between 31 and 50 years of age. There were 22 closed fractures and six grade I open fractures (Gustilo Anderson classification). Seven patients had an associated injury resulting from the same trauma. The injuries were a fracture of the radius and ulna, Hoffa’s fracture, fracture of the ribs, fracture of the pubic rami and contralateral fracture of the tibia. Two patients had a head injury.

The average injury–surgery interval was 10.75 days, with 50% cases operated within 9–14 days of the injury (Table 3). The average operative time was 98 min. The operative time was later reduced as experience was gained during the study. Healing of the fracture occurred with the formation of callus. All fractures achieved union. Fifty percent of the patients showed union between 14 and 18 weeks, whereas 42.8% showed union between 19 and 23 weeks (Table 4). The average period of union was 17.63 weeks. One patient showed delayed union (> 7 months). Union in this patient was achieved through protected weight bearing in a cast after 10 months. The overall knee range of motion averaged 105° (range 0–135°) at the latest follow-up. The average time taken for full weight bearing was 19.6 weeks (Table 5). It was more for cases with bilateral limb injuries. Overall, 85.7% of the patients achieved full weight bearing by 23 weeks. The average length of hospital stay was 20 days. A fair result was achieved in one patient in the form of a valgus malalignment, and replating was performed 2 weeks after the operation. Deep infection developed in one patient (3.6%) with a poor result. This patient had a type C closed fracture and developed wound drainage 7 days after the operation; wound cultures indicated *Staphylococcus aureus*. The patient underwent extensive irrigation and debridement with antibiotic beads. A gastrocnemius rotational flap was used. Hardware was removed as it was found to be unstable. Later, total knee replacement was performed. None of the patients required bone grafting. No deep vein thrombosis or compartment syndrome was encountered.

### Table 1 Age and sex distribution of patients

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Male</th>
<th>Female</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>21–30</td>
<td>2</td>
<td>4</td>
<td>21.5</td>
</tr>
<tr>
<td>31–40</td>
<td>8</td>
<td>4</td>
<td>42.8</td>
</tr>
<tr>
<td>41–50</td>
<td>4</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>51–60</td>
<td>2</td>
<td>1</td>
<td>10.7</td>
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### Table 2 Mechanism of injury

<table>
<thead>
<tr>
<th>Mechanism of injury</th>
<th>Number of cases (%)</th>
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<tbody>
<tr>
<td>RTA</td>
<td>20 (71.5)</td>
</tr>
<tr>
<td>Assault in fight</td>
<td>6 (21.5)</td>
</tr>
<tr>
<td>Fall</td>
<td>2 (7)</td>
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RTA, road traffic accident.

### Table 3 Injury surgery interval

<table>
<thead>
<tr>
<th>Injury surgery interval (days)</th>
<th>Number of cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–8</td>
<td>10 (35.7)</td>
</tr>
<tr>
<td>9–14</td>
<td>14 (50)</td>
</tr>
<tr>
<td>&gt;15</td>
<td>4 (14.3)</td>
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### Table 4 Period of radiological union

<table>
<thead>
<tr>
<th>Period (weeks)</th>
<th>Number of cases (%)</th>
</tr>
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<tbody>
<tr>
<td>14–18</td>
<td>14 (50)</td>
</tr>
<tr>
<td>19–23</td>
<td>12 (42.8)</td>
</tr>
<tr>
<td>24–28</td>
<td>1 (3.6)</td>
</tr>
</tbody>
</table>

### Table 5 Time at which full weight bearing was achieved

<table>
<thead>
<tr>
<th>Period (weeks)</th>
<th>Number of cases (%)</th>
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<tbody>
<tr>
<td>14–18</td>
<td>14 (50)</td>
</tr>
<tr>
<td>19–23</td>
<td>10 (35.7)</td>
</tr>
<tr>
<td>24–28</td>
<td>3 (10.7)</td>
</tr>
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### Table 6 Functional outcome

<table>
<thead>
<tr>
<th>Rating</th>
<th>Number of cases (%)</th>
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<tbody>
<tr>
<td>Excellent</td>
<td>14 (50)</td>
</tr>
<tr>
<td>Good</td>
<td>12 (42.8)</td>
</tr>
<tr>
<td>Fair</td>
<td>1 (3.6)</td>
</tr>
<tr>
<td>Poor</td>
<td>1 (3.6)</td>
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Final results
The long-term final results were rated using a point system for pain, function, work ability, joint movement and radiological and gross appearance. Overall, 92.8% of the patients (26 cases) showed an excellent to good outcome (Table 6).

One out of 27 fractures healed in 6° of varus. In the remaining cases, assessment of the fractures in terms of valgus/varus deviation indicated a correct alignment (Figs 2–4).

Discussion
The management of complex multifragmentary upper tibial fractures remains a problem for orthopaedic surgeons. These fractures have been treated using conservative methods earlier in the form of casts or traction, but yielded poor results with respect to joint motion and prolonged recumbency. Closed methods also have limitations in the treatment of bilateral extremity fractures and in individuals with multiply injuries [8,9].

Conventional plating in which the fragments of the broken bone are put together like a jigsaw, irrespective of the soft tissue attachments, also lead to several complications, especially with bilateral approaches [10–12]. Irrespective of treatment, the reported complications include...
the following: wound breakdown, deep infection (2.8–80%), deep vein thrombosis (3.6–10%), compartment syndrome, nonunion, myositis ossificans, peroneal palsies, hardware failure and arthrofibrosis [13–15].

As no current method satisfactorily circumvents these limitations, alternative approaches have been explored to minimize these complications. Currently, minimally invasive techniques are gaining favour among orthopaedic surgeons, and there have been reports of patients with upper tibia fractures being treated exclusively using this technique [16–18]. The MIPO system includes a precontoured, anatomically shaped plate that can be inserted using a minimally invasive technique.

We studied the application of conventional nonlocking plating using indirect reduction and biological fixation principles. Indirect reduction is technically challenging. Early postinjury surgery, careful planning, intraoperative fluoroscopic monitoring and accurate contouring of the plate are essential to avoid malalignment and implant impingement because of high application of the plate. We used the AO 4.5 mm lateral tibial head buttress plate because the implant had a strong straight stem for the insertion of cortical screws and a flared metaphyseal portion for the insertion of multiple 6.5 mm cancellous screws and only fine intraoperative contouring was required. The implant was also strong and there was no implant failure in any of our patients. The minimally invasive technique allowed the use of a longer plate. A long plate has several advantages. It distributes the stress over a longer length of bone, allows screws to be inserted at the most desirable intact bone away from the fracture site.
site and facilitates better alignment of the distal and the proximal intact fragment. In addition, our minimally invasive plating technique allowed us to successfully treat fractures extending into or close to the joints. Screws can be inserted at different angles or inserted using the lag screw principle to induce interfragmentary compression. This cannot be achieved with the use of an intramedullary nailing device.

Despite the fact that fracture gaps were often visible after the indirect reduction technique, fracture union was not delayed. Preservation of osteogenic haematoma, avoidance of devitalization of fracture fragments and preservation of endosteal blood flow affected by reaming and nail insertion in intramedullary nailing could all be the reasons for strong callus formation and fracture stability.

In general, the wound complication rate with the use of the percutaneous technique was low [4,19,20]. This was because of minimization of skin trauma as a result of large surgical incisions with a traditional open technique. A bone graft was not required in any of our closed fractures and many authors do not recommend the use of a bone graft in closed fractures in similar studies [4,10,12]. However, few papers have been published on percutaneous plating for high-grade open fractures (Gustilo IIIb and c) and the role of a primary bone graft remains uncertain [5].
We believe that a good result in limb length restoration was achieved because of early surgery within the first 2 weeks of the percutaneous technique. By operating within the first 48–72 h, intraoperative manual traction can distract the fragments to restore limb length. One of our patients initially required revision for valgus malreduction. We subsequently refined our technique by inserting the most proximal screws of the contoured plate subarticulatively parallel to the knee joint under an image intensifier. The knee, together with the proximal fragment and the preliminary fixed plate, was then manipulated to ensure that the plate was parallel to the long axis of the tibia before distal fixation. If parallelism could not be achieved, the plate was withdrawn and recontoured.

In the present study, all fractures achieved union. Overall, 93.75% of patients showed an excellent to good outcome, with the time to full weight-bearing union averaging 17.63 weeks. The length between the period for full weight-bearing union averaging 93.75% of patients showed an excellent to good outcome, which delayed mobilization.

Helfet et al. [4], in their study of upper tibial fractures treated with MIPO, found no loss of fixation or evidence of hardware failure. There were isolated cases of delayed union, deformity and superficial cellulitis. All 20 patients achieved union.

Radziejowski et al. [21], in their study of 22 cases of proximal tibial fractures, also obtained good results, with union occurring in 12–24 weeks.

Johner and Wuhrs [22] reported a significant increase in complications as progressively higher energy fractures were treated with open reduction and conventional internal fixation. The rate of complications increased from 9.5% for torsional fractures to 48.3% for comminuted fractures. Similarly, the infection rate increased from 2.3% for torsional fractures to 10.3% for comminuted fractures. Also, nonunion was two-fold more common and infection five times more likely when open fractures were treated with open plating.

Thus, the results of the present series in the treatment of high-energy upper tibial fractures are better than those achieved with the use of conventional plating techniques. MIOP is a logical choice in the treatment of periarticular multifragmentary fractures. Equally good results in terms of union and early mobilization can be obtained. The potential disadvantages of a laterally inserted implant that have been described by Krettek et al. [1] include the following: (a) devitalization of the fracture because of elevation of muscles from bone; (b) potential injury to the superficial peroneal nerve; (c) increased risk of developing compartment syndrome; and (d) difficulties in the placement of the implant into confined spaces. However, none of the above-mentioned disadvantages was found in this study. It could be argued that, as the MIPF technique causes limited surgical trauma to the surrounding soft tissues and the healing process, the presence of the above-mentioned disadvantages appears to have been minimized.

The potential advantages of MIPO are as follows: (a) it is a simple technique and easy to perform, (b) there is no need for additional expensive instrumentation, (c) improved rates of fracture union can be obtained, (d) there is a decrease in the infection rate, (e) there is decreased need for bone grafting, (f) it is an ideal technique for the treatment of patients with multiply injuries, (g) early mobilization of the extremity is possible and (h) there is decreased incidence of refracture after plate removal.

It is noteworthy that none of our patients developed deep vein thrombosis. It could be argued that, using this technique, the surgical trauma to the surrounding tissue and vessels is limited and thus leads to better muscular function and blood flow.

Conclusion

Indirect reduction and minimally invasive percutaneous fixation appear to be valuable in the management of various diaphyseal–metaphyseal fractures even with intra-articular extension.

The key to success includes early surgery, preservation of the biological healing potential and careful attention to surgical details.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References