Treatment of Complex Proximal Tibia Fractures With the Less Invasive Skeletal Stabilization System

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Objective: Proximal tibia fractures with metaphyseal comminution present a difficult treatment challenge. The Less Invasive Skeletal Stabilization (LISS) internal fixator system has theoretical advantages (minimally invasive fixed angle construct) for the treatment of these injuries. This report presents clinical results of the LISS system for treatment of complex proximal tibia fractures and illustrates the unique properties of the system.

Design: Prospective clinical trial.

Setting: Level I trauma center.

Patients: Twenty-eight consecutive patients with comminuted proximal tibia metaphyseal fractures (41A3, 41C2, or 41C3) treated with LISS plates.

Outcome Measurements: Healing, fracture alignment, infectious and implant-related complications, and functional outcome based on the Lower Extremity Measure (LEM).

Results: Average follow-up was 23 months (range 12–48). Thirty-seven of 38 patients healed their fracture after the index procedure. The other healed after implant removal without the need for further fracture repair. Postoperative fracture alignment was satisfactory in 37 of the 38 cases and was maintained in all patients at union. There were no infectious complications. The average LEM score was 88.

Conclusions: The LISS internal fixator system can be used successfully to treat complex proximal tibia fractures without the need for additional medial stabilization. Surgeons attempting to use fixed angle internal fixation plating systems should familiarize themselves with the significant technical differences between these and traditional plating systems to assure satisfactory results.

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Proximal tibia fractures with metaphyseal comminution present a difficult treatment challenge. Techniques of open reduction with internal fixation (ORIF) employing a traditional lateral plate and screw construct for these injuries offer little resistance to varus deformity. Augmentation of such constructs with either a medial plate[1] or medial external fixation[2–4] has been advocated to improve stability. These methods increase associated morbidity and have the potential to devitalize bone,[2,5,6] particularly when exposure is obtained through a single midline incision.[4] Hybrid external fixation for these injuries is associated with malunion, pin tract complications, decreased knee range of motion, and poor patient satisfaction.[7–9] Intramedullary nailing has also been advocated;[10] however, this technique is frequently complicated by valgus or apex anterior angulation and residual displacement at the fracture site[11,12] and is not applicable in cases with intra-articular comminution.

Biologic fixation, a term for which the definition continues to evolve, represents an attempt to preserve blood supply and enhance fracture healing to reduce the incidence of nonunion and infection. Techniques of biologic fixation have led to the current expanding use of minimally invasive percutaneous plating. Although sufficient data to support the widespread implementation of, and specific indications for, these techniques is not available, a growing body of biomechanical and clinical data shows great promise.[13–15]

The Less Invasive Skeletal Stabilization (LISS) system for the tibia has features that make it well suited for the treatment of complex proximal tibia fractures. All screws lock into threaded holes in the plate, providing a fixed-angle construct that can theoretically resist varus collapse. The insertion technique is optimized to allow percutaneous submuscular fixation that minimizes soft-tissue disruption and maximizes healing potential. The purpose of this investigation was to examine these theoretical advantages by reviewing the results of using this single lateral, fixed-angle plate construct for treatment of patients with comminuted proximal tibia fractures with attention to healing, ability to maintain alignment, and complications and to illustrate the unique properties and potential pitfalls of the system.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

Criteria for inclusion were adult patients with comminuted metaphyseal fractures of the proximal tibia (OTA 41A3, 41C2, and 41C3 [with metaphyseal comminution]) treated with a laterally placed fixed-angle plate (LISS; Synthes, Paoli, PA). Between November 1998 and January 2003, 34 consecutive patients met the inclusion criteria at our Level I trauma center, Barnes-Jewish Hospital, St. Louis, Missouri. Six of these patients were excluded; two died in the early postoperative period and four were lost to follow-up. The remaining 38 patients were studied.

Patient Characteristics

Twenty-three of the patients were men and 15 were women. Their mean age was 53 years (range 19–85 years). When classified according to the Orthopaedic Trauma Association,[16] there were 18 type 41A3, 12 type 41C2, and 8 type 41C3 fractures. There were 31 closed injuries and, according to the grading system of the Gustilo and Anderson[17] and Gustilo et al,[18] 2 Grade I, 2 Grade II, and 3 Grade IIIA open fractures. Two patients were treated with temporary external fixators prior to definitive internal fixation.

Implants

Less Invasive Stabilization System plates and screws (Synthes) were used in all patients including 9 5-hole plates, 21 9-hole plates, and 8 13-hole plates. The titanium plate is attached to an outrigger that aligns a drill sleeve with each hole in the plate. This allows percutaneous fixation of all but the proximal portion of the plate to bone. The LISS system utilizes locking screws that attach securely to threaded holes in the plate, providing a fixed-angle internal fixator that can theoretically resist varus collapse of unstable proximal tibia fractures.

Surgical Technique

General Principles

1. The fixed angle nature of the locking screws does not allow compression or reduction of bone to plate with tightening of screws. Gaps between bone and plate will remain after screws are tightened (Figs. 1A, B). Such gaps between plate and bone may be necessary to obtain proper fracture alignment because the plate cannot be bent to accommodate individual variations in tibial anatomy.
2. Fracture reduction should be obtained prior to screw placement. Alignment will be maintained even if the plate does not precisely fit the bone (Figs. 1C, D).
3. Screws are self-drilling and should be placed unicortically, especially in dense cortical bone of the tibial shaft. If bicortical placement is attempted and the tip of the screw contacts the far cortex and does not advance, then the near cortex will be stripped.
4. Bending of the plate causes inaccurate aiming of the screws through the outrigger and is contraindicated.

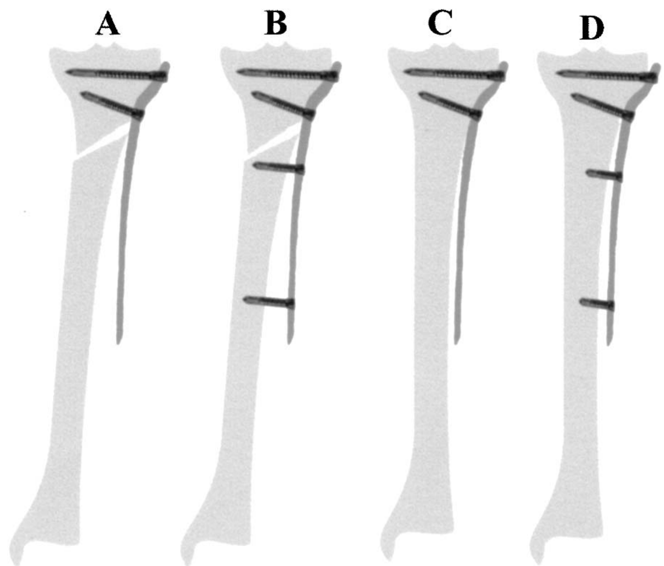

FIGURE 1. A, LISS plate applied to the proximal fracture fragment without proper fracture reduction. B, Fixation of the LISS plate to the distal fragment does not compress bone to plate, fracture malaligned. C, LISS plate applied to proximal fragment after proper reduction. Note: plate is not in contact with the distal fragment. D, Fixation of plate to distal fragment does not compress bone to plate, reduction maintained.

Patient Positioning

Patients are positioned supine on a radiolucent table. A tourniquet is applied to the proximal thigh and the limb prepared and draped in the standard sterile fashion. Open fractures are irrigated and debrided.

Approach

A curvilinear incision is made over the proximal lateral tibia. The skin incision is approximately 6 cm in length for extra-articular fractures and is extended as needed to provide exposure of the articular surface for intra-articular fractures. The fascia of the iliotibial band is divided longitudinally parallel to its fibers starting at the Gerdy tubercle and extended proximally. Dissection is extended distally through the fascia of the tibialis anterior muscle, and a small portion of the muscle is elevated off the proximal lateral tibia. A submeniscal arthrotomy is made for intra-articular fractures.

Periarticular Reduction

When the fracture involves the articular surface, the articular segment is reduced anatomically and held provisionally with Kirschner wires (K-wires). In 7 cases, interfragmentary

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lag screws were placed to stabilize either the articular fracture (n = 4) or the tibial tubercle fragment (n = 3) prior to plate insertion (Fig. 2). Based on preoperative planning, care is taken to place these screws in positions that do not interfere with LISS screw placement.

Fracture Reduction and Plate Insertion

Once the articular fragment and/or tubercle are reduced and at least provisionally stabilized, attention is turned to reduction and fixation of the articular segment to the shaft segment. The appropriate length LISS plate that provides at least four screws in the distal fragment is selected and assembled to the radiolucent outrigger. The plate is then guided through the surgical incision between the tibialis anterior muscle and the periosteum along the lateral tibia. The majority of the distal portion of the plate is placed percutaneously without direct visualization. The distal portion of the plate can often be palpated anteriorly (adjacent to the anterior crest of the tibial shaft), and this helps guide alignment in the sagittal plane. The plate can be clamped to the proximal fragment across the proximal tibia using a large periarticular reduction clamp. Anteroposterior (AP) and lateral fluoroscopic radiographs are used to confirm satisfactory positioning of the plate and satisfactory alignment of the fracture. If necessary, the reduction is adjusted indirectly under fluoroscopic guidance with manual forces and/or percutaneously placed reduction clamps. The LISS system push-pull reduction instrument can also be used to make minor adjustments to the varus-valgus alignment of either the proximal or distal fracture fragments. Two millimeter K-wires are placed through the outrigger into the proximal and distal fragments to maintain the position of the outrigger/plate construct relative to bone.

Plate Fixation

Once satisfactory alignment of the fracture and positioning of the plate is confirmed, the plate is secured to the proximal and distal fragments with 5.0-mm self-drilling, self-tapping locking screws (Fig. 3). On average, 4 screws were used in the proximal fracture segment (range 3–6 screws) and 5 in the distal segment (range 3–9 screws). Preoperative planning and templating determined screw lengths. Alternatively, a guidewire placed through each drill hole and checked for proper length using fluoroscopy can be used for indirect length measurements. It is important to irrigate through the insertion sleeve during screw insertion to avoid heat necrosis of bone. The screws should be placed unicortically, especially in the denser cortical bone of the shaft, to avoid stripping the near cortex. However, the thin cortical bone proximally can allow bicortical screw placement, which may be desirable to stabilize the medial fragment when treating bicondylar fractures. When using longer plates, careful soft-tissue dissection is required during distal screw insertion to avoid injury to neurovascular structures.

FIGURE 2. Preoperative and 18-week postoperative radiographs illustrating lag screw fixation of the tibial tubercle fragment independent from the LISS construct.

Closure

The outrigger is disassembled from the plate after removal of K-wires. The wound is irrigated. The iliotibial fascia and wound are closed over a drain in standard fashion.

Postoperative Care

Immediate active assisted range of motion of the knee (intra-articular fractures) or active and active assisted range of motion of the knee (extra-articular fractures) is begun on the first postoperative day. Patients with intra-articular fractures are kept toe-touch weight bearing for 8 to 12 weeks, and patients with extra-articular fractures were kept toe-touch weight bearing for 6 to 8 weeks. Thereafter, weight bearing is advanced based on tolerance and radiographic evidence of fracture healing.

Follow-up and Outcome Measures

The average follow-up was 23 months (range 12–48 months). Anteroposterior and lateral radiographs were obtained postoperatively and at follow-up visits. Fracture alignment was determined in a blinded fashion on each of these radiographs by making goniometric measurements as de-

FIGURE 3. Preoperative and 34-week postoperative radiographs illustrating LISS fixation of a comminuted tibial plateau fracture.

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scribed by Freedman and Johnson.[11] Briefly, the AP radiographs were used to determine coronal plane deformity (varus and valgus) by measuring the angle between the long axis of the shaft and a line drawn perpendicular to the articular surface of the proximal tibia. The lateral radiographs were used to determine sagittal plane deformity (flexion and extension) by measuring the angle between the long axis of the shaft and a line drawn perpendicular to the articular surface. Normal frontal plane alignment was defined as 0°, and normal posterior tilt (apex anterior angulation) of the articular surface relative to the shaft in the sagittal plane was defined as 8°.[19–22] Change in alignment was defined as greater than a 3° change in angular measurements between the postoperative and follow-up radiographs. Malalignment was defined as 10° or more of angular deformity. Rotational alignment was measured clinically at follow-up visits with normal rotation being equal to the contralateral side. Union was defined as pain-free full weight bearing in the absence of tenderness or motion at the fracture site with the presence of bridging callus across at least one cortex of the fracture site on each the AP and lateral views. Nonunion was defined as absence of progressive fracture healing for 3 consecutive months extending beyond 6 months from injury. Functional outcome was measured using the Lower Extremity Measure (LEM) obtained at the last follow-up visit or via telephone interview.

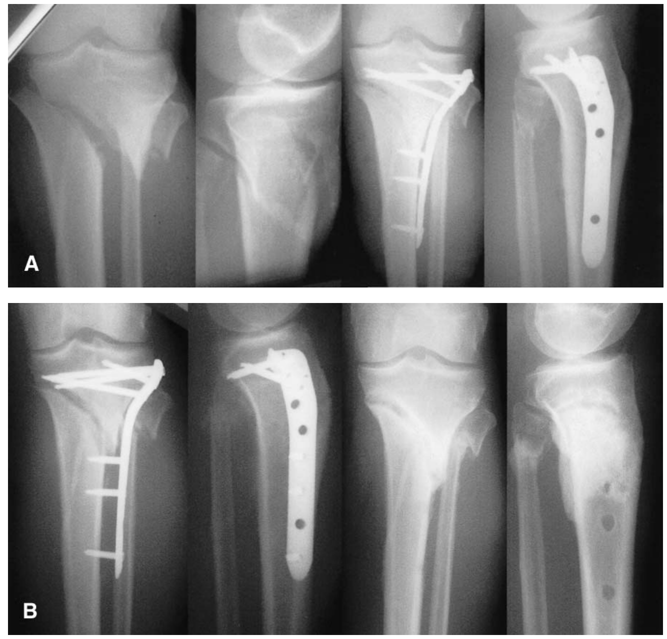

FIGURE 4. A, Injury and immediate postoperative radiographs. B, Nine weeks postoperatively, the plate/screw construct has loosened from the distal fragment, leading to implant removal. This patient healed his fracture after 4 additional weeks of cast immobilization. Final radiographs at 34 weeks from the index procedure show solid union.

RESULTS

Fracture Healing

All patients healed their fracture after the index procedure except one. This patient had implant loosening evident 9 weeks postoperatively. Radiographs revealed that the plate/screw construct had loosened from the distal fragment. Clinically, the patient was progressing toward union. His implants were removed electively, and he was treated with cast immobilization for 4 additional weeks. The fracture united without need for further repair (Fig. 4). There were no nonunions.

Complications

One of the patients with a type 41C3 fracture developed symptomatic posttraumatic knee arthritis. She underwent total knee replacement with implant removal 20 weeks after the index procedure. There were no wound, infectious, vascular, or neurologic complications. Compartment syndrome was diagnosed in four patients, two preoperatively and two after LISS plate placement. All were successfully treated with fasciotomy. Two patients complained of implant-related pain at the proximal portion of the plate. In one of these cases, the pain resolved after implant removal, and in the other, the symptoms were not severe enough to warrant implant removal. No other patients required reoperation.

Fracture Alignment

The postoperative fracture alignment was satisfactory (less than 10° of malalignment in both the coronal and sagittal planes) in 37 of the 38 cases. One patient was malaligned in apex posterior angulation (11° less than the normal 8° of posterior tilt). More critical evaluation of alignment revealed 2 additional patients were in valgus (6° and 7°, respectively) and 2 in apex anterior angulation (7° and 9° greater than the normal 8° of posterior tilt, respectively). No patients had rotational malalignment. Fracture alignment was maintained in all patients at union.

Functional Outcome

Data for the LEM was available for 16 patients. The average LEM score was 88 (range 55–100, SD 11). Only 2 patients had LEM scores less than 80. One (LEM = 55) was a workman's compensation case for which the symptoms were out of proportion to physical and radiographic findings. The other (LEM = 76) had multiple other upper and lower extremity injuries that complicated completion of the LEM questionnaire. Among the remaining patients, 5 had scores between 80 and 90, 3 between 90 and 95, and 6 greater than 95.

DISCUSSION

Complex proximal tibia fractures including those with metaphyseal comminution present a difficult treatment chal-

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lenge. Complications of treatment and associated injuries have led to several approaches with little consensus on optimal management. Closed treatment has been associated with a propensity for varus malunion.[23] Unstable proximal metaphyseal tibia fractures with concomitant lateral plateau fractures may be treated with a single lateral plate.[24] However, this construct offers little resistance to varus deformity, and significant soft-tissue complications have been reported when treating these high-energy fractures with traditional ORIF techniques.[5,25–31] External fixation for these injuries has been associated with minor pin tract complications in up to 100% of cases,[9] and more serious complications such as septic arthritis of the knee and osteomyelitis in up to 20%.[8,9,29] Furthermore, external fixation for proximal tibia fractures can inhibit knee motion and is associated with poor patient satisfaction. The LISS system, with its fixed-angle design and associated minimally invasive technique, has the potential to reduce many of the aforementioned potential complications.

In the current series, the use of the LISS plate system for treatment of complex proximal tibia fractures resulted in an excellent union rate. All but one patient healed their fracture after the index procedure, and this patient healed after implant removal without need for additional surgical fracture repair. There were no cases of varus collapse. This represents an advantage over traditional lateral plating systems, which offer little resistance to varus deformity. In fracture patterns with metaphyseal comminution, adjuvant medial neutralization plating has been advocated to increase the stability of traditional lateral plates.[1] Application of a medial plate requires either a separate medial incision or unacceptable soft-tissue compromise if applied via a single midline approach. When inserted through a separate medial incision, the saphenous vein and nerve, the medial collateral ligament, and the pes anserine tendons are at risk for injury. When treating high-energy injuries, the additional soft-tissue dissection required for medial stabilization can increase the risk of wound complications and delay fracture healing.[2,4,6,25,28,32–34] Based on the results of the current study, the fixed angle nature of the LISS construct seems to obviate the need for additional medial stabilization and therefore reduces the risk of injury to the medial soft tissues.

Medial external fixation is another option to augment a lateral plate construct and has been advocated to improve stability. This has been referred to as substitution,[3] internal splinting,[1] and composite fixation.[3,35] Ries and Meinhard reported on six cases of proximal tibia fractures treated in this manner.[4] All six fractures healed with no report of knee pain or ligamentous laxity. However, 33% developed an infectious complication (1 superficial pin-tract infection and 1 deep infection). Bolhofner presented a series of 41 extra-articular comminuted proximal tibia fractures without knee joint involvement treated with a lateral plate and medial external fixator construct.[2] He reported a 5% incidence of deep wound infections, a 12% incidence of pin-tract infections, and a 7% incidence of delayed union. The high union rate, absence of wound complications, and lack of infectious complications in the current study using the LISS system compares favorably with the results of traditional lateral plating supplemented with medial external fixation.

Only 1 fracture in this series was malreduced (>10° malalignment). However, more critical evaluation showed 4 additional fractures with angular deformity between 5° and 10° from normal. This compares favorably with the incidence of malalignment reported after intramedullary nailing of proximal tibia fractures, up to 59%.[11,12] Comparison to traditional plating techniques is more difficult. Although a great deal of data is available regarding the management and outcomes of tibial plateau fractures, there is a limited amount specifically addressing alignment after treatment of complex, metaphyseal, proximal-third tibia fractures with traditional ORIF. In a study of malunion of tibial shaft fractures treated with ORIF by Milner et al,[36] 29% of fractures healed with coronal angulation greater than 5° and 43% healed with sagittal angulation greater than 5°. However, only 4% involved the proximal third of the tibia, and the results for this subgroup were not presented. Bolhofner reported a 2% malunion rate (1 patient with 6° varus) among 41 extra-articular proximal-third tibia fractures treated with indirect reduction, lateral plating, and medial substitution external fixation.[2] The incidence of malalignment in the present study also compares favorably with results after treatment with external fixation. Marsh et al[37] presented a series of 21 complex tibial plateau fractures treated with monolateral external fixation and limited internal fixation and reported a 14% rate of malalignment (2 patients in 8° varus and 1 with 10° valgus). Weigel and Marsh[38] presented a 5-year follow-up after treatment of 24 high-energy tibial plateau fractures with limited internal fixation and a monolateral external fixator. In the radiographic analysis, they reported 18 fractures had <5° of angulation, 5 had between 6° and 10° of angulation, and 1 had 12°.

Obtaining proper alignment is technically demanding with the LISS system. To obtain optimal alignment when using the LISS system, it is important to understand that the unique properties of this fixed-angle plate and screw construct affects fracture alignment differently than traditional plating systems. Traditional constructs reduce bone to plate with the tightening of screws where the alignment of the fracture reduction is largely determined by the plate contour (Fig. 5). If necessary, traditional plates can be bent to provide satisfactory reduction once bone is reduced to plate. Insertion of fixed-angle screws does not reduce bone to plate with screw tightening. Therefore, because all screws in the LISS system are locking screws, satisfactory alignment must be obtained independent of the relative contour of the bone and plate. If the bone is properly aligned without being completely in contact with the plate, then the fixed angle screws should be inserted to maintain this

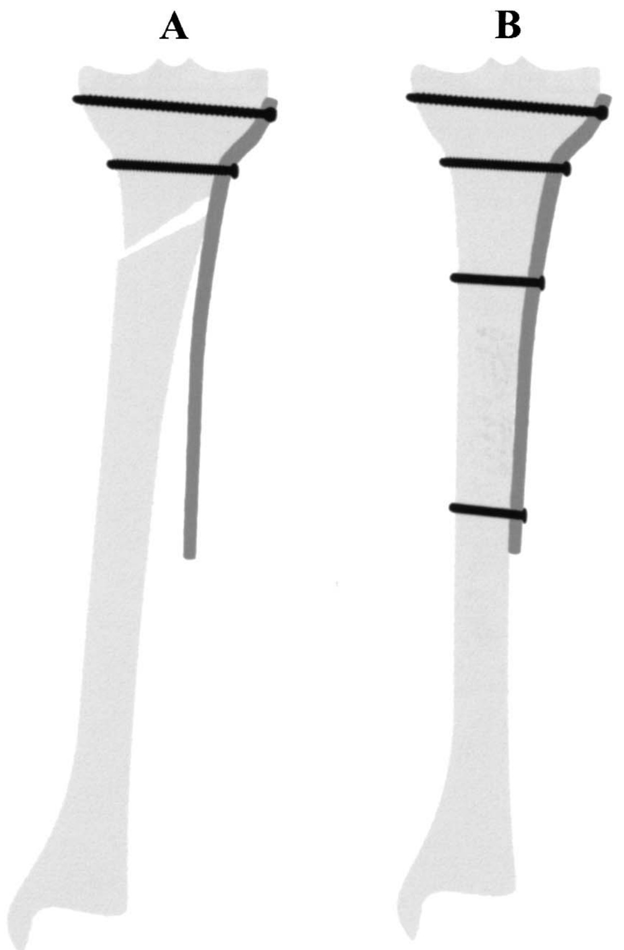

FIGURE 5. Traditional plate and screw construct. Tightening the screws compresses plate to bone. Reduction is influenced by plate contour.

alignment (Figs. 1C, D) because reducing the bone to the plate with clamps or other instruments will only introduce malalignment.

Critical evaluation of the one fracture with implant failure in this series illustrates an important concern when using the LISS system. The screw closest to the fracture site in this case may not have had good purchase in bone (Fig. 4). The locking nature of the screws makes it difficult to determine if screws are firmly attached to bone because all screws securely tighten to the plate. The familiar feel of a good or poor "bite" in bone is absent with this system. Only three screws were used in the distal fragment in this case. Based on this case, and the manufacturer's recommendations, we now use at least four screws in the distal fragment, especially if the fracture involves the diaphysis. Furthermore, the simple oblique pattern of this particular fracture may have been better suited to traditional plate and lag screw fixation because interfragmentary compression cannot be accomplished through the plate in the LISS system. Lag screws, if indicated, must be placed prior to LISS plate fixation.

One patient in our series developed early posttraumatic knee arthritis that required total knee replacement. This patient had a severely comminuted intra-articular fracture component. We found that the LISS system was not ideal for supporting such comminuted or depressed lateral articular fractures. The system provides two proximal screws that each angle slightly away from the articular surface. This configuration supports the medial side from collapsing into varus, but it is difficult to get these screws proximal enough to support the lateral subchondral bone. In cases that require implants to support the subchondral bone, other implants should be considered.

The factors contributing to the two postoperative cases of compartment syndrome are uncertain. Each of these patients had high-energy injuries and may have gone on to compartment syndrome regardless of the mode of treatment. Alternatively, the additional trauma of plate fixation may have contributed. Any plate will cause increased compartment volume and, when associated with fascial closure, an increased compartment pressure. The potential for LISS plates to be fixed away from the bone could further increase both the volume and pressure. The association between compartment syndrome and use of the LISS system deserves further study. We recommend that all patients with high-energy tibia fractures be carefully observed for symptoms and signs of compartment syndrome.

CONCLUSION

In conclusion, the LISS internal fixator system can be used successfully to treat patients with complex proximal tibia fractures without the need for additional medial stabilization. Surgeons attempting to use fixed-angle internal fixation plating systems should familiarize themselves completely with the significant technical differences between these systems and traditional plating systems to assure satisfactory results, especially with regard to obtaining proper fracture alignment. We find that comminuted metaphyseal proximal tibia fractures with either simple or no articular extension are suited for treatment with the LISS system. When complex articular fractures exist, other plate and screw constructs may be preferable.

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