Minimally Invasive Orthopaedic Trauma Surgery
A Review of the Latest Techniques

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Traditional plate and screw constructs are placed under direct fracture exposure with anatomic reduction of fracture fragments. These techniques in the past have often required extensive periosteal stripping of bony comminution under direct visualization. The problems associated with this approach include the potential for delayed and non-union secondary to fracture site devascularization. In order to minimize these potential problems, orthopaedic surgeons have moved away from direct exposure of comminuted non-articular fracture segments and toward minimally invasive and bridge plating techniques for diaphyseal and meta-diaphyseal fractures. Along with this new surgical philosophy, a new series of implants has been developed in order to achieve these goals.

Minimally invasive surgery is currently a buzzword in all fields of surgery. However, it is actually a concept that has been used in orthopaedics for a long time. In his book in 1989, Mast highlighted the delicate balance between the degree of bony stabilization and surgical trauma imparted to the soft tissues. We have been using many types of limited or minimally invasive and biologically friendly techniques in orthopaedic surgery. These concepts have included use of the bridge plate, closed intramedullary nailing, external fixation, cannulated screws, and more recently percutaneous plating. The common denominator between all of these types of biological fixation is preservation of the soft tissue attachments to the comminuted fracture fragments. The tenants of fracture surgery still include an anatomic reduction of the articular surfaces, application of stable internal fixation devices, preservation of the blood supply, and early active pain-free mobilization of the limb. Advancements of these techniques and the development of newer implants that minimize vascular damage have contributed to the development of biologic internal fixation. By using indirect reduction, by using longer plates to improve the mechanical leverage, and by applying fewer screws to avoid unnecessary damage to the bone, fracture union rates have improved. In a diaphysis we are concerned about length, rotation, and mechanical axis, and in these regions we have used intramedullary nails to achieve the aforementioned goals. In the epiphyseal or articular regions, anatomic reduction is mandatory and here, commonly, plate and screw fixation is used to ensure stability.

Experimental Basis

The experimental basis for minimally evasive surgery is based on the work of Rhinelander, who showed that two-thirds of the blood supply to the bone is via the nutrient artery and one-third comes from the inflow of the periosteum. The newer plating methods championed by Farouk and Krettek spare the blood supply by limiting dissection of the periosteum. Cadaveric femurs underwent lateral conventional plate osteosynthesis (CPO) through a standard lateral approach on one side and minimally invasive plate osteosynthesis (MIPO) through two three-centimeter incisions on the contralateral side. Injection studies were performed bilaterally to identify the femoral perforating and nutrient arteries. The authors found that the MIPO specimens showed intact perforating and nutrient arteries, whereas the CPO specimens had a variable incidence of vessel disruption. The MIPO group demonstrated better periosteal perfusion in each of the cadavers and improved medullary perfusion in 70% of the MIPO specimens compared with the CPO specimens. In addition, Perrin has introduced limited contact plates or point contact PC fix plates to achieve these same goals. Minimal additional surgical trauma and flexible fixation allow prompt healing when the blood supply to bone is maintained. The biomechanical aspects principally address the degree of

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instability that may be tolerated by fracture healing under different biological conditions. The strain theory of fracture healing offers an explanation for the maximum instability that can be tolerated and the minimal degree required for induction of callus formation. The biological aspects of damage to the periosteal blood supply, cortical necrosis, and temporary cortical porosity help to explain the importance of avoiding extensive contact of the implant with bone.

**Indications**

The indications for minimally invasive fracture surgery include all fractures amenable to these techniques. Limited incision or biological plating is used for periarticular fractures with a metaphyseal/diaphyseal extension or those extraarticular fractures not amenable to intramedullary nailing. Furthermore, percutaneous plating is favored in situations where there has been a compromise in the soft tissue envelope secondary to the initial insult of the trauma. For example, compartment syndrome, contused skin, fracture blisters, or poor circulation.

Intramedullary nails, already biologically friendly, are now being placed through smaller skin incisions with specially designed insertion guides and reduction tools that allow for less exposure. The majority of long bone fractures and hip fractures treated with IM nails can be done in a percutaneous manner.

**Techniques**

The techniques involved in minimally invasive surgery may involve the use of standard plate and screw constructs. These plates can be pre-bent on bone models prior to surgery and then placed through small incisions sliding them down submuscularly, but extraperiosteally, followed by percutaneous placement of screws through image intensification (Fig. 1). In addition, new remodeled plates are pre-contoured to anatomically fit various regions of the extremities. Devices such as the fracture table, femoral distractor, or external fixator aid the surgeon in obtaining an indirect reduction and generalized alignment with respect to the mechanical and anatomic axes prior to placement of the implants. Finally, good radiographic visualization is imperative to be able to perform these procedures in an efficient and skilled manner. Image intensification with views at 90° to one another is mandatory. Percutaneous plating is achieved by obtaining

**Figure 1** A 45-year-old male with a distal fourth tibia-fibula fracture. A, Radiograph of injury; B, Pre-bent plate placed percutaneously reduces the fracture; C, Surgical incisions after all screws have been placed.
an indirect reduction prior to placement of the plate. Several small incisions are made outside the zone of injury. The plate is pre-contoured and slid into its position, which is confirmed by x-ray image intensification, and either clamped or K-wired in place. Next, screws are placed through several small incisions without disruption of deep periosteum (Fig. 1).

The LISS plate is a new generation of implant designed to treat meta-diaphyseal fractures. It is a locking plate designed to be an internal/external fixator by the screws locking to the plate.\textsuperscript{18-21} Angular stability is increased, thus enhancing anchorage into metaphyseal bone, which may improve fixation strength in osteoporotic bone. Insertion and placement of the implant is performed via small incisions by submuscularly sliding the plate along the bone. Screw placement is performed via an attached targeting jig. The screws are self-drilling, self-tapping, locking screws, which are placed in unicortical fashion.

**Femur**

In the hip region, the PCCP is a newly designed hip implant that allows for percutaneous placement and minimal additional muscular trauma for inter-trochanteric hip fractures (Fig. 2A).\textsuperscript{22,23} Again, the wire is placed under image intensification into a center-center position within the head. The plate is slid in a submuscular position and clamped to the bone through stab incisions and all the screws are placed to target devices (Fig. 2B). Implants of older design work well with a percutaneous technique. A dynamic condylar screw

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**Figure 2** A. PCCP hip fixation device. B. Intra-operative photograph demonstrating placement through minimal incisions.

**Figure 3** A 71-year-old female who sustained a supracondylar periprosthetic femur fracture. A. Fixation with a DCS screw and long side plate placed submuscularly; B. Skin incisions; C. AP radiograph at 8-months follow up; D. Lateral radiograph at 8-months follow up.
can be used for periprosthetic or distal femur fractures, in which a small incision is made into the distal segment. The lag screw is drilled and placed into the distal fragment. The side plate is then slid submuscularly and attached distally over a guide wire onto the lag screw and clamped through stab incisions to the femoral shaft (Fig. 3). Results reported in the literature with minimally invasive techniques about the proximal femur are encouraging. Kinast compared two groups of patients, both treated with a 95° condylar blade plate.24 One used standard open plating techniques and the other minimally invasive with no stripping and percutaneous plate placement. The authors found a six week decrease in the healing time. The nonunion rate decreased from 16.6% to 0%. They had a lower infection rate and there was no difference in functional results. In the distal femur, Krettek reported on the use of minimally invasive osteosynthesis with distal femur fractures using a percutaneously placed retrograde plate.16 He reported on 16 patients with 18 distal femur fractures, 5 were OTA 33-A's and 13 with OTA 33-C's. The mean ISS score was 19. The average follow-up was 33 months. All patients healed by 3 months and only 1 patient healed with a valgus malunion of greater than 10°.

**Tibia**

Minimally invasive techniques have been used in the proximal tibia as well. Once again, for tibial plateau fractures, the high-energy Schatzker type V’s and VI’s, anatomic articular reconstruction is mandatory. These techniques are beneficial in cases in which the fractures are extraarticular, but too proximal to nail. The concepts remain the same. A lateral incision is made. The plate is slid below the anterior tibialis muscle, bypassing areas of fracture and comminution, and stabilized with screws proximal and distal to the fracture (Fig. 4).20,25 Egol and colleagues reported on 24 Schatzker type V’s and VI’s, all treated using the LISS plate and compared this with a laboratory experiment, which compared the LISS to a double plating construct.26 These investigators found that 22 of the 24 fractures healed at 3 months and 2 required supplemental bone grafting. There were no infections and the range of motion of the knee was 1° to 110° degrees of flexion. Furthermore, the biomechanical aspect of the study showed that the unilateral locked plate was a stable construct when compared to the double plating construct, which had historically been used to treat these injuries.

The distal tibia is in a subcutaneous region, which makes plating and open surgery in this region more risky. Often the fibula can be used to gain length and indirectly reduce the tibia fracture. Once again pre-bent plates or contoured plates can be slid along the anteromedial border of the tibia with screws placed subcutaneously (Fig. 5). Articular splits can be stabilized with cannulated screws (Fig. 5). Helfet and associates reported on 20 patients who underwent percutaneous plating of the distal tibia.4 All patients healed at 11 weeks and good functional results were seen in all. However, four patients in the series healed in a malunion of greater than 10°. These patients all underwent treatment with tubular plates. These investigators have recommended against using one third tubular plates in this region.

**Pelvis and Acetabulum**

Gaining popularity, iliosacral screw fixation affords a minimally invasive avenue for stabilization of some complex pelvic ring injuries27-32 (Fig. 6). The technique is technically demanding and requires good image intensification as well as the ability to anatomically reduce the sacroiliac joint or sacral fracture. This can be accomplished via traction, Schanz pins, or indirect reduction of the back by anterior symphysisal plating. One must understand the anatomy of the pelvis as well as the contraindications to this technique, which include the presence of a dysmorphic pelvis, physician unfamiliarity, and the inability to visualize under fluoroscopy secondary to contrast material, obesity, or bowel gas.
Anterior pelvic fixation can be performed via percutaneous methods, retrograde pubic rami screws are currently being placed to minimize the approaches needed for anterior pelvic ring fixation (Fig. 7). Once again, it requires physician comfort and good image intensification.

**Spine**

Vertebral compression fractures are a source of pain and morbidity in the elderly. Some of these patients are too frail to undergo traditional fusion surgery for multilevel fractures. The advent of vertebroplasty or kyphoplasty provides a minimally invasive technique for treatment of these fractures with reduction and stabilization through minimal incisions under fluoroscopy. The injection of polymethylmetacrylate (PMMA) is often a final attempt at therapeutic treatment of complications due to such fractures. Vertebroplasty involves injection of cement under high pressure via one or both pedicles, thus filling and stabilizing the vertebra without reduction of the fracture. Extravertebral cement leakage is a common complication; an intact posterior wall normally

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**Figure 5** A 49-year-old male who sustained a distal tibia fracture with intra-articular extension. A. CT scan reveals intra-articular extension; B. AP radiograph; C. Plate slid through a small distal incision above the periosteum; D and E. Percutaneous clamp placement aids in reduction of the fracture; F. Percutaneous screw placement; G. Final radiograph at 6 months demonstrating healing.
prevents cement leakage into the epidural space. Kypho-
plasty involves transpedicular inflation of balloon tamps,
thus creating a cavity which is then filled with PMMA under
low pressure. Restoration of vertebral height is possible and
the potential for extravertebral cement leakage lessened.

Summary
Computer assisted fluoroscopic surgery is at the fore-
front of the ability to continue and pursue minimally
invasive surgical options in orthopaedic surgery. Many
systems afford the surgeon three-dimensional views and
biplanar imaging for placement of orthopaedic implants
in difficult areas.

The current literature regarding these techniques is
limited. The indications are poorly defined. The common
thread of all techniques, however, is the preservation of
the soft tissue attachments and the biology of the frac-
ture hematoma. Currently we are using first generation
implants. It appears that malalignment is the biggest
problem with any of these techniques and long-term
prospective studies will be required to evaluate whether
or not these theoretical advantages become clinically
viable and functional for patient care.

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