Hybrid Thin Wire External Fixation: An Effective, Minimally Invasive, Modular Surgical Tool for the Stabilization of Periarticular Fractures

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High-energy periarticular fractures are challenging to orthopedic trauma surgeons. For many years, radiographs were crucial in assessing fracture severity and treatment decisions, thus influencing their final outcome.

Recently, however, studies have proven the crucial role of soft tissues in the biological process of fracture healing.1,2 A valid, comprehensive, integrated method of soft-tissue damage and fracture classification is not available. Therefore, to enhance fracture healing, minimally invasive surgical techniques must be developed to minimize additional damage to the soft-tissue fracture envelope.

The basic thin wire/ring Ilizarov external fixator has been used for fracture healing. Since its introduction, extensive basic research3-9 has laid the foundation for the development of hybrid external fixation systems that are modular, easy to apply, and allow early mobilization. The involved muscles recover and return to physiological function levels,2,10 casting doubt on the physiological validity of rigid, fracture-based attempts of classification.11

**SUPRACONDYLAR FEMUR FRACTURES**

Severe, high-energy, compound distal femur fractures with loss of medial buttressing and intra-articular involvement often are encountered in patients with multiple injuries. The extent of bone and soft-tissue involvement, critical to the healing of such injuries, is intimately related but difficult to assess. The intimate relationship of soft tissue and bone in allowing the critical function of early loading, which enhances fracture healing,1,2 requires minimal soft-tissue dissection.

Accepted fracture treatment methods,12-15 including closed antegrade intramedullary nailing, dynamic condylar screws and plate, blade plates, and suprandonyln intramedullary nails, require soft-tissue dissection and are difficult to implement in critically ill patients. Malunions, nonunions, infections, knee stiffness, and post-traumatic arthrosis have been reported. Present thinking links these results to soft-tissue dysfunction.

The use of a hybrid thin wire external fixator in such patients is modular, minimally invasive, and reduces the risk of infection in the immediate and late healing period (Figure 1). It prevents malunion and allows early loading and mobilization, but has a steep learning curve and requires an updated knowledge of surgical anatomy.

Compulsory daily pin care is necessary to prevent pin-tract infections.16 Unilateral cantilever external fixation frames are stiff in the axial plane,8 and these mechanical properties hinder fracture healing. The ring fixator, although stiff in the coronal and sagittal planes, allows continuous dynamic axial micro-movements, which promote bone healing.8,16-18 Therefore, the hybrid thin wire external fixation frame provides...
mechanical stability, even in severely compound, unstable femoral fractures (Figure 2).2,8,19

Clinical Study
Twenty-eight patients (23 males and 5 females) with severe distal femoral fractures were evaluated. Mean patient age was 34 years (range: 14-65 years). Twenty-four injuries were high-energy and 4 were low-energy. The high-to low-energy injury ratio was 6:1. Twenty-five fractures were comminuted and 6 had ipsilateral patellar fractures. The ratio of open to closed fractures was 3:1. No patient had associated nerve injuries; however, the femoral artery was lacerated in 3 patients.

Twenty patients had open fractures, 8 were critically ill with multiple injuries, and 9 had bilateral lower-limb injuries. Two patients with extensive soft-tissue injury around the knee underwent acute arthrodesis. No limbs were lost, and ambulation was permitted 48-72 hours postoperatively.

On admission, fractures were re-aligned and stabilized with a unilateral cantilever external fixator (Tubular external fixator; Mathys Ltd, Bettlach, Switzerland). The knee was bridged with the fixation frame in 12 patients due to severe periarticular injuries causing knee instability. Six patients were primarily stabilized with the hybrid thin wire external fixation frame, 2 had temporary skeletal transtibial traction for immobilization, and 1 was treated with open reduction and internal fixation by dynamic compression plate, which failed after 10 days.

The lacerated femoral arteries were repaired following initial emergency bone stabilization. All open fractures were surgically debrided, wounds were left open for drainage, and necessary soft-tissue cover (split skin grafts or tissue flaps) was performed 5 days later.

Within 10 days, the cantilever fixation frames were converted to hybrid thin wire external fixation frames, using the Schantz screws already in bone (Figure 2). Kirschner wires were advanced to the joint metaphysis, preserving knee stability through this distal three-dimensional K-wire/ring frame configuration, allowing removal of the knee bridging and commencement of active physiotherapy. Transfixing K-wires with olives were manipulated to push or pull fractured bone fragments into anatomical alignment.

These indirect reduction techniques, combined with ligamentotaxis, resulted in anatomical fracture reductions in 22 of 28 patients. In the most distal femoral ring, three transfixing K-wires were used for enhanced stability and fracture stabilization (Figure 2).

All fractures healed within an average 175 days (range: 100-365 days), and average hospitalization was 12 days (range: 5-28 days) (Figure 3). No fracture required bone grafting, and osteomyelitis was not reported.

Patients were evaluated using the anatomical and functional scale described by Neer et al.20 The distribution of functional results included 6 excellent, 11 satisfactory, 6 unsatisfactory, and 5 failures. All unsatisfactory results and failures were in patients with ankylosis or severely limited knee range of motion. These included patients who also had patellar fractures and 1 patient who sustained a periprosthetic fracture after total knee replacement (TKR) performed 8 years earlier.

Treatment
Due to the high risk of infection and further damage to soft tissues, severely compound, open supracondylar fractures are more safely managed by external fixation.21 The associated loss of knee movement range following three-dimensional external fixation in the thigh has been reported by Arazi et al22 and Marsh et al.23 It is caused by adhesions developing from the extensive soft-tissue injuries present in these patients and from healing of the local inflammatory process between the fixation wires, quadriceps muscles, and fracture callus. It is an acceptable shortcoming for the uneventful healing of these severe injuries.

External fixation preserves the soft-
tissue envelope with minimal damage, thus enhancing fracture healing by ligamentotaxis, reduced blood loss, and early mobilization. The hybrid thin wire external fixation frame allows controlled axial micromovements through the affected bone, which is critical for optimal fracture healing. This surgical method is an option for experienced surgeons for the reconstruction of severe, compound, high-energy supracondylar femur fractures.

**TIBIAL PLAFOND (PILON) FRACTURES**

Tibial plafond fractures involve both compartments of the ankle—the tibiotalar and inferior tibiofibular joints (Figure 4). These fractures present a challenge to the treatment and reconstruction of the distorted anatomy because soft-tissue edema develops quickly around the affected joints, forming blisters and skin slough. The limited nature of the soft-tissue envelope has contributed to the high rate of wound complication after classic open reduction and internal fixation. Soft-tissue slough often leads to deep infection, which may result in below-the-knee amputation.24-26

Minimally invasive techniques using external fixation systems allow fracture stabilization until tissue swelling subsides without any soft-tissue stripping. The severity of injury and the accuracy of reduction influence bone healing and joint function. Three-dimensional periartricular fracture fixation with one ring and three K-wires with olives for joystick push-pull maneuvers allows precise indirect fracture fragment reduction (Figure 5).

Ligamentotaxis can be used for indirect fracture reduction and distraction osteogenesis, and early joint movements, which minimize joint stiffness, can be implemented.24,27

Numerous studies reporting poor results of open reduction and internal fixation of such fractures25,26,28,29 have contributed to its classification as a surgical challenge. This challenge is increased in high-energy injuries. Bone et al.30 reported good to excellent ankle function in 75% of patients with long-term external fixation of open or comminuted tibial pilon fractures.

In our series, fracture consolidation was achieved in 41 (95%) of 43 fractures (Figure 6). Average time to union was 171 days (range: 100-720 days). Good functional ankle range of motion was achieved in 84% of fractures (3 patients had bilateral fractures). Primary ankle fusion due to severe bone and soft-tissue loss was performed in 1 patient. The hybrid thin wire external fixator allowed free mobilization of the ankle while maintaining stability at the fracture site, and is a safe treatment method with fewer complications than internal fixation.30

**SUPRACONDYLAR AND DISTAL HUMERAL FRACTURES**

High-energy injuries cause extensive combined bone and soft-tissue damage. These tissues often are more extensively devitalized, contaminated, or both, with many being open (Gustillo 3C or 3B). This precludes the safe use of internal fixation for stabilization.7,31-33 Ipsilateral damage and fracture of the humerus, proximal radius, and ulna combine to form “a floating elbow.” These highly unstable fractures require immediate stabilization to prevent aggravation of the associated soft-tissue damage and to allow early reconstruction of any neurovascular damage.

A modular hybrid ring (thin wire) tubular fixation frame allows quick and safe fracture stabilization and bone fragment realignment without additional disruption of the involved soft tissue. Thus, the necessary mechanical stability for an optimal function of the biological healing process is achieved.7,8,33-35

In a consecutive series of 16 patients, of whom 12 had sustained high-energy open fractures of the supracondylar or distal humerus, all were treated by early stabilization with a hybrid ring tubular external fixation frame. Active movements of the elbow and shoulder were started 24 hours after stabilization.
Patients were encouraged to increase the use of the affected joint to the limit of pain. All 16 fractures united between 48 and 362 days (average: 153 days). Delayed unions developed in 2 patients and were treated by alternating distraction compression periods in the frame.\textsuperscript{26,27}

Functional results, assessed by the presence or absence of pain, range of elbow motion, and return to previous activities, were excellent and good in 7 (44\%) and fair in 5 (31\%) patients with high-energy fractures. One patient requested arthrodesis because of extensive tissue loss.

**SUMMARY**

Hybrid thin wire external fixation is an effective, minimally invasive treatment for the stabilization of periarticular, supracondylar, and pilon fractures. The extent of bone and soft-tissue loss, high risk of infection, and further damage to the soft tissues precludes open reduction and internal fixation as a safe treatment method. External fixation preserves the soft-tissue envelope with minimal damage and allows fracture stabilization, early loading, and mobilization, which promote bone healing.

**REFERENCES**


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