

## External fixation followed by delayed interlocking intramedullary nailing in high velocity gunshot wounds of the femur

Femurun yüksek hızlı ateşli silah yaralanmalarında eksternal fiksasyonu takiben ertelenmiş intramedüller kilitli çivileme

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### BACKGROUND

High velocity gunshot-related fracture is associated with massive soft tissue damage and severe comminution at the fracture site. This unique type of open fracture presents a serious challenge to the orthopedic traumatologist.

### METHODS

The study was conducted prospectively involving patients who presented to the Accident and Emergency Department of the Bone and Joint Surgery Hospital Srinagar (India), from January 2005 to March 2007, with a history of high velocity gunshot wounds to the femur. Initial stabilization with external fixation was followed by delayed interlocking intramedullary nailing. The patients were followed for an average period of 26 months (range, 15-39 months).

### RESULTS

All the patients were males, with an average age of 37 years (range, 22-52 years). Twenty-four (65%) were type IIIA, 11 (30%) were type IIIB and 2 (5%) were type IIIC. All the fractures united in good alignment in an average time of 24 weeks.

### CONCLUSION

External fixation as a primary modality of treatment provides more than adequate stabilization to facilitate nursing, good wound care and physiotherapy. A staged protocol of primary temporary fixation by unilateral external fixation followed by delayed reamed intramedullary interlocking nail seems to be an effective method of treatment for high energy gunshot femoral fractures.

**Key Words:** External fixation; femoral fractures; gunshot wounds; interlocking nail; staged treatment.

### AMAÇ

Yüksek hızlı ateşli silah yaralanmaları ile ilişkili kırık, kırık bölgesinde masif yumuşak doku hasarı ve ciddi parçalanma ile birliktedir. Bu özel açık kırık tipi, ortopedi uzmanları için ciddi bir sorundur.

### GEREÇ VE YÖNTEM

Bu prospektif çalışma, Ocak 2005 ile Mart 2007 tarihleri arasında yüksek hızlı ateşli silah yaralanmasıyla femur bölgesinde oluşan yara öyküsü ile Srinagar'da (Hindistan) kemik ve eklem cerrahisi hastanesinin kaza ve acil servisine başvuran hastalarla yapıldı. Eksternal fiksasyon ile gerçekleştirilen ilk stabilizasyonunu takiben ertelenmiş intramedüller kilitli çivileme yöntemi uygulandı. Hastalar, ortalama 26 aylık bir periyot (dağılım, 15-39 ay) boyunca takip edildi.

### BULGULAR

Bütün hastalar, erkekti ve yaş ortalaması 37 (dağılım, 22-52 yaş) idi. Kırıkların 24'ü (%65) tip IIIA, 11'i (%30) tip IIIB ve 2'si (%5) de tip IIIC idi. Bütün kırıklar, ortalama 24 haftalık bir sürede düzgün bir şekilde kaynadı.

### SONUÇ

Primer tedavi yöntemi şeklinde uygulanan eksternal fiksasyon, hemşirelik, iyi yara bakımı ve fizyoterapiyi kolaylaştırmaya yönelik yeterli stabilizasyondan daha fazlasını sağlamaktadır. Unilateral eksternal fiksasyonla gerçekleştirilen ilk geçici fiksasyonu takiben ertelenmiş intramedüller ayarlı kilitli çivi uygulanması şeklindeki aşamalı protokol, yüksek enerjili ateşli silah yaralanmaları ile oluşan femur kırıklarında etkin bir tedavi yöntemi gibi görünmektedir.

**Anahtar Sözcükler:** Eksternal fiksasyon; femur kırıkları; ateşli silah yaralanması yaraları; kilitli çivi; aşamalı tedavi.

Gunshot-related fracture is a unique type of open fracture presenting a serious challenge to the orthopedic traumatologist. More than 75% of all injuries in modern wartime are localized to the extremities, and more than one-third of these injuries are accompanied by bone fractures.<sup>[1]</sup> High velocity gunshot injuries result in massive soft tissue damage and severe comminution at the fracture site. The heat generated in a bullet when it is fired does not render the fracture sterile.<sup>[2,3]</sup> Early stabilization of the wounded extremity decreases pain and shock and diminishes the possibility of injury to the soft tissues, vessels and nerves from bone fragments.<sup>[4]</sup>

Immediate fixation with interlocking intramedullary nail has been shown to produce favorable results in low-to-mid velocity gunshot wounds.<sup>[5-7]</sup> Massive soft tissue and bone damage caused by high velocity gunshot injuries mandates meticulous repeated surgical debridement to achieve the best possible infection control and reconstruction. Little has been reported regarding the management of high energy fractures.<sup>[4]</sup>

The aim of this article was to present our experience with the use of external fixation followed by delayed interlocking intramedullary nailing in femoral fractures caused by high velocity gunshots.

## MATERIALS AND METHODS

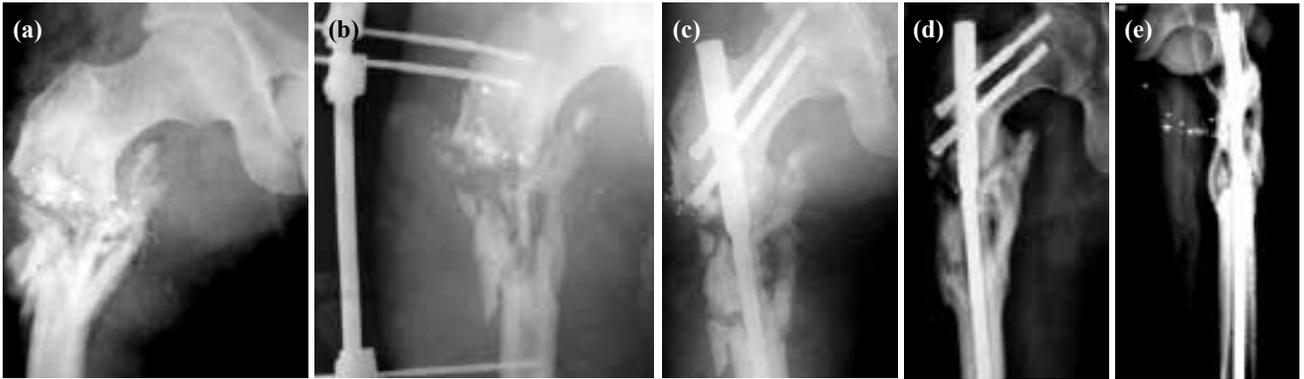
This study was conducted prospectively involving patients who presented to the Accident and Emergency Department of the Bone and Joint Surgery Hospital Srinagar (India) with a history of high velocity gunshot wounds of the femur. The hospital is a tertiary care referral center specifically catering to patients who require orthopedic management. Due to the ongoing war in Kashmir for the last two decades, this institution has evolved to resemble a military hospital.

From January 2005 to March 2007, 41 patients presented to this hospital with a history of bullet injuries to the femur fired from high velocity military rifles. Four patients (2 lost to follow-up and 2 with associated spinal injuries) were excluded. All the patients were males with an average age of 37 years (range, 22-52 years). The left femur was involved in 16 and the right in 21 patients. Seventeen (46%) were proximal one-third, 12 (32%) were middle one-third and 8 (22%) were distal one-third fractures. Using the Gustilo-Anderson classification, 24 (65%) were type IIIA, 11 (30%) type IIIB and 2 (5%)

type IIIC.<sup>[8]</sup> Grade 3 to 4 comminution was present in all fractures (Winquist and Hansen).<sup>[9]</sup> Concomitant abdominal and chest injuries were present in 9 (24%) patients. Upper extremity injuries were present in 5 (13.5%) cases (2 with both forearm bone fractures, 1 intercondylar fracture of distal humerus, 2 humeral shaft fractures). Nerve injury was present in 6 (16%) patients (1 sciatic, 5 peroneal). Two patients had associated femoral artery injury.

Initial assessment included thorough physical evaluation, followed by appropriate radiological examination. Tetanus prophylaxis was administered to the patients on admission. A combination of parenteral antibiotics (cefazolin and amikacin/tobramycin) was administered in all the patients empirically and continued for 4-5 days. Immediate irrigation and thorough soft tissue debridement was followed by axial alignment and initial stabilization with external fixation on the day of admission (Figs. 1a-b, 2a-b). Vascular reconstruction and external fixation were done in a single setting in two patients. Patients were encouraged to perform active and passive assisted exercises in bed and ambulate as soon as possible without bearing any weight on the injured limb. Repeated debridements (1 to 5; average, 3), delayed primary closure, and skin and soft tissue reconstruction were done in the day care operation theater as required in each patient before definitive treatment. Meticulous pin site care and daily antiseptic dressings of the wounds were performed. In cases where wounds did not granulate satisfactorily, culture sensitivity was established and specific antibiotic therapy was instituted.

Patients were readmitted and prepared for definitive procedure (interlocking nail). The average delay to reach the hospital was 8.4 hours (range, 2-16 hours) and average delay between external fixation and interlocking was 26.7 days (range, 17-37 days). External fixation was converted to closed interlocking intramedullary nail in all patients under fluoroscopic control. Excision of pin tracts with washout was done in all the patients. Twenty-five (68%) patients underwent statically locked reamed interlocking nail using the largest possible nail size. Statically locked reconstruction nail was used in 12 (32%) patients to fix subtrochanteric fractures (Figs. 1a-e). The distal tip of the nail was cut to fix two supracondylar fractures. Patients were ambulated on the second postoperative day and discharged with instructions to use two crutches/walker and to avoid bearing weight on the extremity until there was radiographic evidence of early bridging callus; at that point, the



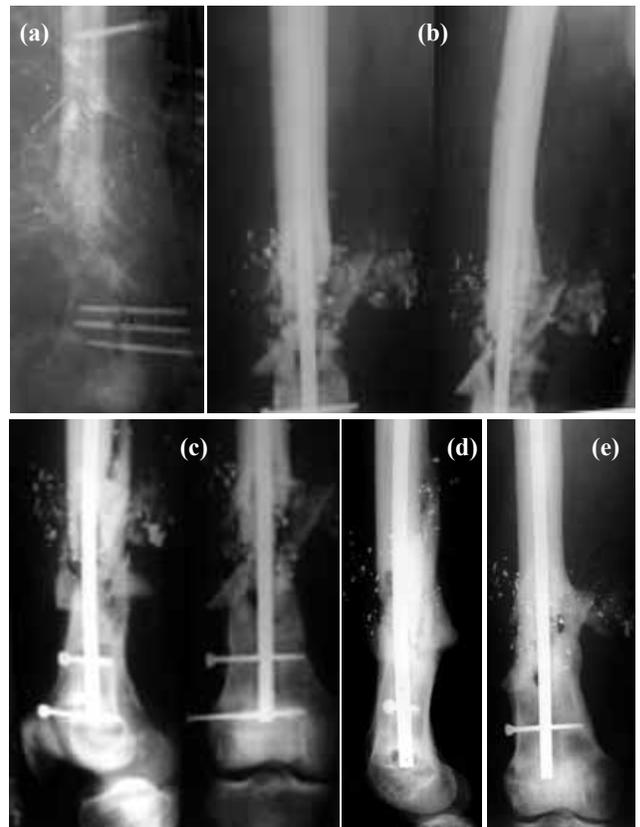
**Fig. 1.** (a-e) Subtrochanteric fracture (a) stabilized initially by external fixation (b) and later fixed by reconstruction nail (c); union of the fracture (d, e).

patients were allowed to bear progressively more weight as tolerated. Full weight-bearing was allowed only after the clinical and radiological union. Static interlocking nailing was converted to dynamic nailing in 5 (13.5%) of the 37 patients. The average hospital stay from admission through external fixation and initial discharge was 4.2 days (range, 2-7 days) and that of second admission through interlocking and final discharge was 2.9 days (range, 2-4 days). The patients were followed for an average period of 26 months (range, 15-39 months). The complications encountered during the healing period until completion of the treatment were recorded.

### RESULTS

All the fractures united in an average time of 24 weeks (16-34 weeks) (Figs. 1d, e, 2d, e). Union was declared when the patient was able to bear weight without pain or walking aid and formation of good callus. The wide range of fracture consolidation is due to the diversity of the injuries (bone and soft tissue damage). All the fractures healed in good alignment with no significant (more than 1.5 cm) limb length discrepancy in any patient. Bone grafting was done in three patients who did not show adequate consolidation at 24 weeks. Superficial wound infection was seen in five patients who were managed with appropriate oral antibiotics and serial debridements. No case of deep vein thrombosis or pulmonary embolism was seen. No deep wound or severe pin tract infection, which would mandate relocation of the pins or even removal of the implant, was seen in any patient. Knee stiffness was a major complication seen in 16 (43%) patients. Average flexion at the knee was 115 degrees (range, 80-130 degrees) and at the hip was 125 degrees (range, 100-130 degrees). All eight patients with fracture of the distal third of

the femur united with stiffness at the knee with average flexion of 79 degrees (range, 80-100 degrees). The stiffness in these patients was attributed to the extensive soft tissue damage with adhesions of the quadriceps muscle to the femur. Despite vigorous physiotherapy, manipulation under anesthesia (5 patients) and quadriceps plasty (2 patients), movement at the knee did not improve to a significant level. The other patients with joint contractures were those who



**Fig. 2.** (a-e) Supracondylar femoral fracture Stabilized initially by external fixation (a) and latter fixed by Interlocking nail (b, c), union of the fracture (d, e).

had associated systemic and multi-extremity injuries and could not cooperate with the rehabilitative protocol. In the six patients who had nerve injury, four peroneal palsies resolved completely and two had partial recovery (1 peroneal and 1 sciatic). Knee pain was seen in five patients, which resolved after the removal of the implant. All the patients except one (with sciatic nerve injury) were able to stand and walk without assisted support. However, the patients with stiffness at the knee were not able to squat, sit cross-legged or genuflect during their prayers.

## DISCUSSION

The incidence of bullet wounds in civilian trauma has increased in many parts of the world. The orthopedic surgeon is frequently involved in the management of these patients because of the high rate of gunshot wounds to the extremities.

A high velocity missile is defined as one leaving the muzzle at a velocity of more than 600 meters/second (2000 feet/second). Rifles that are capable of firing a projectile at a speed of more than 2500 feet/second are considered as the most powerful firearm and have an increased capacity to wound as compared to their lower velocity counterparts (hand gun, pistol).

Fracture of the femur caused by high velocity gunshot is an orthopedic challenge. Multi-organ injury, sometimes combined with delayed referral, further compounds the problem. High energy injuries with severe comminution at the site of the fracture and massive soft tissue damage demand more aggressive treatment. Early aggressive and serial debridements of the osseous and soft tissues, early stabilization of the fracture and intensive rehabilitation are key points in the treatment of high energy gunshot wounds. A well-planned approach to initial care may optimize later reconstructive efforts by reducing risk of infection and additional injury to the damaged tissues.<sup>[10,11]</sup> External fixation allows simple and quick bone stabilization, good wound care and early mobilization of the patient, but is not convenient for a long period, and stabilization is required in a secondary phase of treatment.<sup>[7]</sup> Initial temporary fixation by external fixation followed by Ilizarov ring fixation has shown good results in high energy gunshot wounds.<sup>[4]</sup> However, frequent need to relocate the pins and poor patient acceptability of the frame are the disadvantages.

Interlocking intramedullary nailing using closed technique has greatly improved the surgeon's abil-

ity to treat these difficult fractures. There has been a consensus that immediate intramedullary interlocking nailing carries significant advantages in low-to-mid velocity gunshot wounds of the femur.<sup>[5,6,12]</sup> In our institution, low-to-mid velocity gunshot wounds are stabilized by early interlocking intramedullary nail, when reported within six hours. A staged protocol of external fixation followed by interlocking intramedullary nail is used to treat low-to-mid velocity gunshot femoral fractures in those who present after a delay of six hours. However, the principles of treatment in high energy gunshot wounds continue to be of crucial importance.

Immediate intramedullary interlocking nail has shown good results with shorter hospital stay and a significant decrease in hospital expenses. Nevertheless, immediate intramedullary interlocking nailing is not the treatment of choice under all circumstances and can not be performed on hemodynamically unstable patients. Mass disasters tend to overwhelm the capacity of the hospitals to cope with the massive and relatively unexpected patient load. In such situations, to facilitate the care, operating time takes prime importance.

The present study was performed to determine whether or not staged treatment using immediate external fixation with later conversion to interlocking intramedullary nail is a valuable treatment strategy for high velocity gunshot femoral fractures.

Wiss et al.<sup>[13]</sup> reported 100% fracture healing and zero incidence of deep wound infection in 56 patients treated by reamed intramedullary interlocking nail after a post injury delay of 10-14 days. Similar good results were reported by Hollman and Horowitz<sup>[14]</sup> after delayed reamed intramedullary interlocking nailing. Bone et al., Nowotarski et al. and Marc Bergman et al. showed a significant decrease in the number of pulmonary complications and decrease in the cost of hospitalization in patients undergoing early instead of delayed femoral stabilization.<sup>[15]</sup> Stephen et al. reported a significant decrease in respiratory complications, osteomyelitis and health care costs in patients in whom femoral fractures were stabilized immediately.<sup>[16]</sup>

The concept of a staged approach with temporary external fixation has gained in popularity for complex periarticular fractures, compartment syndrome and polytrauma patients.<sup>[17]</sup> External stabilization is followed by open reduction, limited open reduction and internal fixation.<sup>[18]</sup>

We report results of a staged treatment (external fixation followed by reamed intramedullary interlocking nail) in a series of 37 high velocity femoral fractures. All fractures healed in good alignment with no significant limb length discrepancy. After initial stabilization, the patient is discharged and treated in the outpatient department, which reduces the number of days spent in the hospital. The average hospital stay at each admission was 4.2 days (range, 2-7 days) and 2.9 days (range, 2-4 days), which is less when compared with other studies.<sup>[4,5,7]</sup> There were only two cases of vascular injury after high velocity gunshot injury in our study. Fast stabilization of the femur with external fixation and immediate vascular reconstruction is a definite advantage of the procedure. Delayed conversion to interlocking nail did not affect the vascular repair. Superficial wound infection was seen in five patients; no deep wound infection was seen in any of our patients.

Debridement is done as per the principles of war surgery. Copious irrigation with normal saline is combined with the removal of debris and excision of wound margins and all devitalized tissues. Marginally viable tissue may become necrotic later. Serial debridements are carried out until all the devitalized tissue is removed and there is no evidence of infection. We recommend administration of combination of prophylactic antibiotics in all cases for 4-5 days, and modification as per the culture sensitivity. Nerve injury is an important complication because of its effects on daily life and long-term sequelae.<sup>[12]</sup> Peripheral nerve injury is seen in 1-2% following blunt traumas and increases to 9% in gunshot injuries.<sup>[12,13]</sup> Nerve injury was present in 6 (16%) of our 37 patients, among which four resolved completely and two had partial recovery, although no exploration was performed. Knee stiffness was a major complication seen in 16 (43%) patients, especially in those with fracture of the distal third of the femur. The stiffness in these patients is explained by the extensive soft tissue damage with adhesions of the quadriceps muscle to the femur. The other patients with joint contractures were those who had associated systemic and multi-extremity injuries and could not cooperate with the rehabilitative protocol. Knee pain was seen in five patients, which resolved after the early removal of the implant. Implant failure after intramedullary interlocking nailing has been another complication in patients having grossly unstable fractures, which was not seen in any of our patients. Premature full weight-bearing should be strongly discouraged

until there are signs of radiological union. Pin tract infection, though uncommon in our series, is another important complication seen with the use of external fixation. We recommend early relocation of the pin and excision of the pin tract with appropriate use of antibiotics.

Our study is unique in that the use of external fixation as a prime modality of treatment makes the patient able to ambulate and perform range of motion exercises with the advantages of decreased operating time and decreased blood loss. The soft tissue injuries and associated wound contamination in high velocity gunshot wounds are so severe that in these cases, the pin sites do not represent a significant additional source for infection. The small bacterial inocula inherent to the pin sites are often not sufficient to overcome host defenses to cause deep septic complications. External fixation provided more than adequate stabilization to facilitate nursing and good wound care and to perform physiotherapy. Simultaneously, the temporary fixation does not increase local complications, and quality of definite osteosynthesis (reamed intramedullary interlocking nailing) is not impaired.

In conclusion, a staged protocol of primary temporary fixation by unilateral external fixation followed by definitive osteosynthesis using largest diameter reamed intramedullary interlocking nail seems to be an effective method of treatment for high energy gunshot femoral fractures.

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