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ORIGINAL STUDY

Grade 3C open femur fractures with vascular repair in adults

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Grade 3C open femur fractures are challenging injuries with higher rates of complications. This is a retrospective review of grade 3C open femur fractures with vascular repair between 2002 and 2012. Outcomes included initial MESS score, additional injuries, duration of operation, complications, secondary operations or amputations, and social life implications. Thirty-one of 39 total patients were selected for revascularization and fracture fixation based on soft tissue injury and MESS score. The intra-operative approach included temporary arterial shunt replacement, orthopedic fixation, arterial reconstruction venous and/or nerve repair and routine fasciotomies. An external fixation and reverse saphenous vein graft was used in a majority of the patients (respectively ; 93.5%, 90.3%). The mean follow up was 5.4 years (range 2.2-10). The decision to amputate versus salvage should be left up to patients and their care teams after discussing options and future possibilities rather than using a scoring system.

Keywords : open femur fractures ; Gustilo-Anderson ; grade 3C open fracture ; vascular injury ; saphenous graft ; ankle brachial index (ABI).

INTRODUCTION

Management of a severely injured extremity remains challenging for orthopedic surgeons. These injuries are associated with higher rates of secondary amputation, non-union, infection, multiple surgical interventions, occupational changes and psychological problems (*1-4*). Developments in orthopedic fixation, vascular and soft tissue repair have allowed more severely injured limbs to be salvaged over the last two decades (*5*). At the time of emergency presentation, an immediate decision is required regarding limb salvage versus amputation. Various scoring systems using a variety of components have been developed to assist surgeons in making a decision (*6-10*). In addition to scoring systems, patient characteristics, cultural beliefs and costs should be taken into consideration to make a true decision. Therefore, this study was designed to evaluate the surgical outcomes of grade 3C open femur fractures with vascular repair and the long term psychological effects of limb-threatening injuries.

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MATERIAL AND METHODS

An institutional review board (IRB) approval was obtained. The medical records of all adult femur fractures with vascular injury (Gustilo-Anderson grade 3C open femur fractures) treated at a single trauma center between 2002 and 2012 (*11,12*) were analyzed to classify the mechanism of injury, associated injuries, timing of surgery, treatment methods and complications as well as their initial mangled extremity severity scores (MESS) (*6,7*). Patients who underwent primary amputation or had a vascular injury with a closed fracture were not included in this study. Secondary operations for soft tissue coverage, graft thrombosis, infection, joint stiffness, non-union, malunion or amputation were analyzed. Patients who had more than 2 years of follow up were evaluated for the implications of the injury of their daily life. The SF-36 health survey questionnaire (*13*) was used to evaluate patients' daily life status, pain levels, employment status and symptoms of depression at least 2 years after the injury. An additional question was asked regarding whether they would have preferred first-day amputation rather than their present status.

RESULTS

Out of 39 Gustilo-Anderson grade 3C open femur fractures, 31 patients (28 male, 3 female) with a mean age of 36.2 (rage 17 to 56) were operated on for re-vascularization and fracture stabilization at their initial presentation to the emergency department. Primary amputation was performed in 8 (7 male, 1 female) patients with excessive soft tissue injury and with a MESS score of 10 or above. The most common mechanism of injury was motor vehicle accident with 16 (51.6%) patients, followed by shotgun injury with 10 (32.2%) patients, fall from a height with 4 (12.9%) patients and one patient with an industrial accident.

Associated injuries were reported very commonly. Head injuries and pulmonary contusions were the most common concomitant injuries, reported in 9 cases. Seven additional fractures (spine, tibia, humerus, and rib), 5 intra-abdominal solid organ (liver, kidney, spleen) and 2 genitourinary injuries were reported in the medical records (Table I).

Total sciatic nerve palsy was reported in 5 patients and peroneal nerve palsy was reported in 3 patients. The femoral artery was injured in 19 patients, while the popliteal artery was injured in 12 patients. Mean time to vascular repair was 10 hours (range 5 to 13) after the injury. Intra-operative approaches including temporary arterial

Table I. — Additional injuries

Additional Injuries	number of patients
Head Injury	9
Pulmonary Contusion	9
Additional Fracture	7
Intra-abdominal Solid Organ Hematoma	5
Genitourinary Injury	2

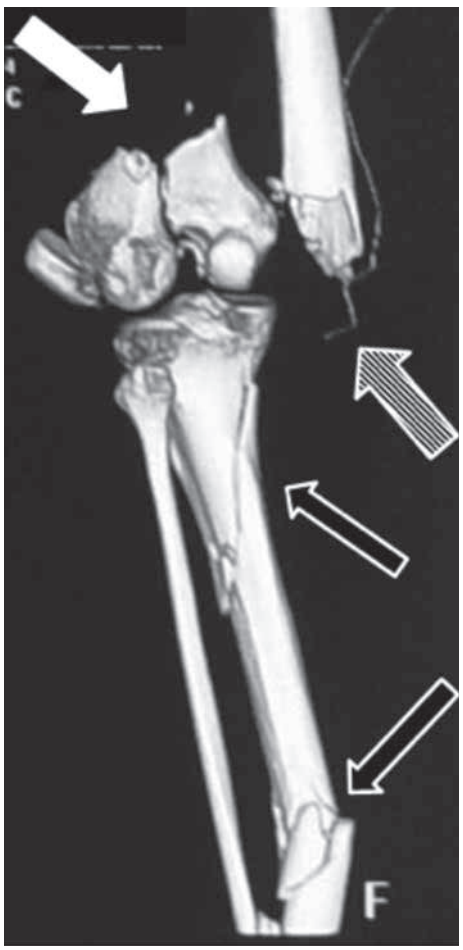


Fig. 1. — CT angiography shows comminuted distal femur T type intra-articular fracture (white arrow), Popliteal artery injury at the level of distal femur fracture (striped arrow), segmented tibia fracture (black arrow).

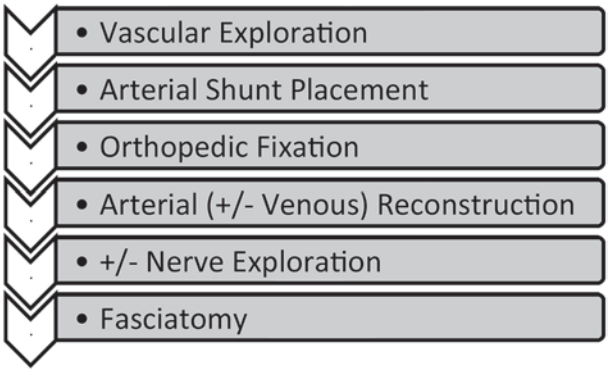
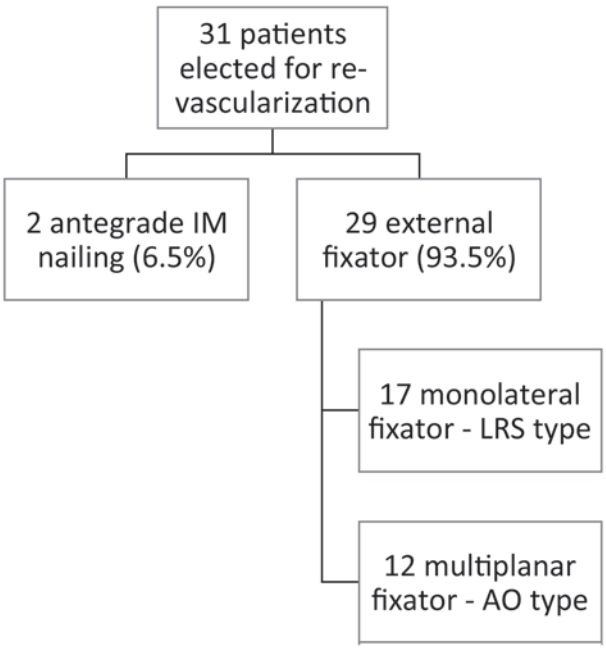


Fig. 2. — Perioperative approach algorithm

shunt replacement and orthopedic internal or external fixation are shown in Figures 2 and 3. Immediately after arterial shunt placement by vascular surgeons, external fixators were mainly used for temporary skeletal fixation in 29 patients (93.5%) including monolateral (n = 17) or multiplanar (n = 12) types. An antegrade intra-medullary nail was used in 2 patients (6.5%) with a lesser amount of soft tissue injury and single diaphyseal femur fracture as a definitive osteosynthesis (Table II).

Table II. — Fixation devices used at initial surgery



Radical wound debridement and irrigation was performed after vascular repair in all patients. Reverse saphenous vein grafts were used in all popliteal artery injuries and 16 of the femoral artery injury

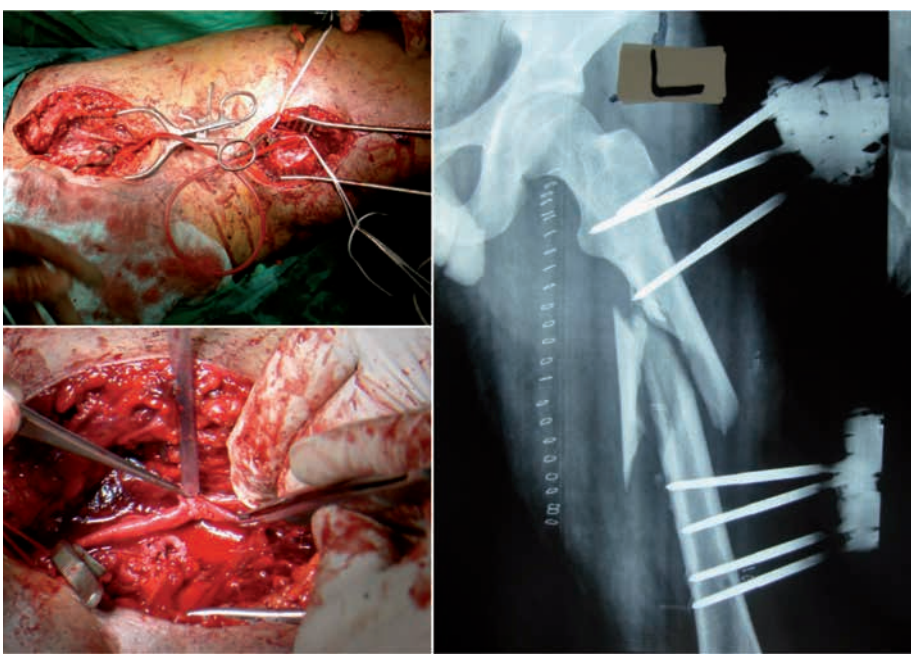


Fig. 3. — Perioperative approach (Top Left - arterial shunt replacement, Right – temporary external fixation, Bottom Left – definitive arterial repair with a reverse saphenous vein graft).

cases. Primary end-to-end anastomosis was performed in 3 patients with femoral artery injury. Sciatic nerve exposure was performed in 2 patients who had a shotgun injury and sciatic palsy. None of the nerve injuries necessitated any surgical treatment. Routine anterolateral and posteromedial fasciotomies of the leg were performed in all cases.

None of the patients need free or rotational flaps. Split thickness skin grafting was performed in 8 cases to cover the fasciotomy regions and in 2 patients to cover the primary wound caused by the primary injury and debridement. On the first postoperative day, 5 patients underwent a thrombectomy procedure and 1 patient underwent a new reverse saphenous vein replacement due to perfusion problems. Overall, 4 (13.7%) patients needed secondary amputation.

Out of 29 patients who underwent temporary external fixation, one patient died during the surgery because of pulmonary comorbidities, 4 patients underwent a secondary amputation (3 above knee, 1 below knee joint), 11 patients were converted to a circular external fixator and 8 patients were converted to an intramedullary nail. Permanent external fixation was achieved in 5 patients in the first surgical intervention (Fig. 4).

The mean follow up was 5.4 years (range 2.2-10). Mean number of procedures was 2.7 (range 1-6), including the first day surgery, debridements, vacuum dressing placements, fasciotomy closures and all procedures performed later (Fig. 5). Partial sensory improvement was noted in 2 patients but no motor recovery occurred in any of the patients who had a nerve injury.

Osteomyelitis was the most common complication in 5 (16.6%) patients, followed by non-union in 3 patients (Fig. 6), malunion in 2 patients, and knee stiffness in 2 patients. The overall orthopedic complication rate was 42.9%.

According to the SF-36 health survey questionnaire the mean physical health summary was 42, which is below average for the general population ; the mean mental health summary was 32.5, which is well below average for the general population. Anxiety or depression was reported in 18 (59.4%) patients.

DISCUSSION

Grade 3C open femur fractures carry a great risk of limb loss in addition to high mortality and also have significant psychosocial effects on patients.

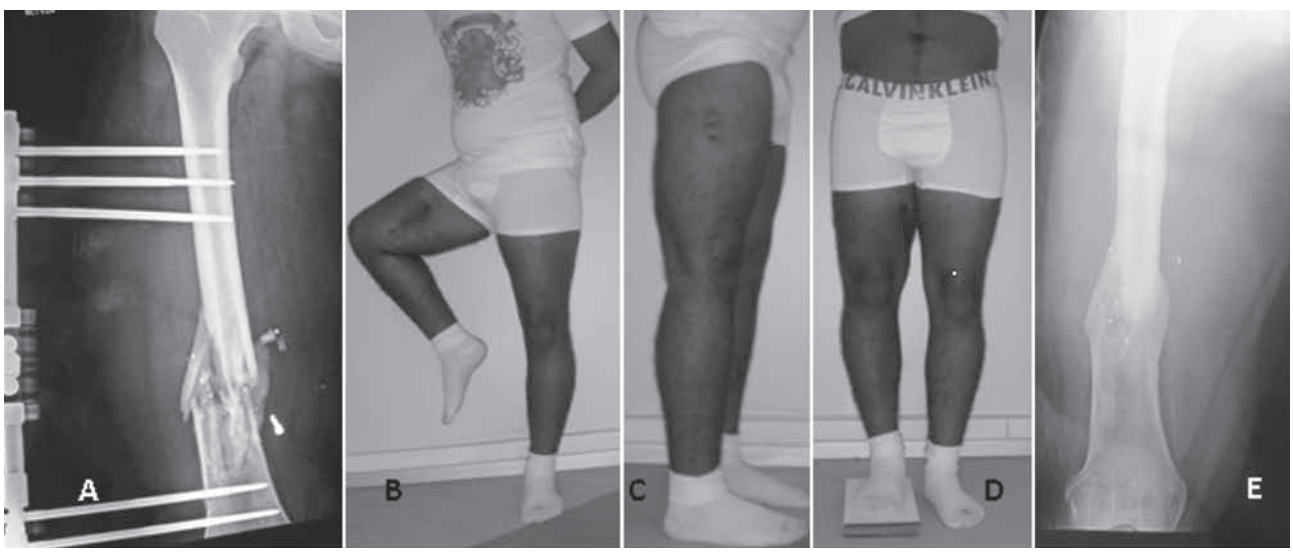


Fig. 4. — Femur diaphysis fracture with a femoral artery injury. A. Temporary external fixation with a mono-lateral fixator. B-C-D-E. Third year follow-up.

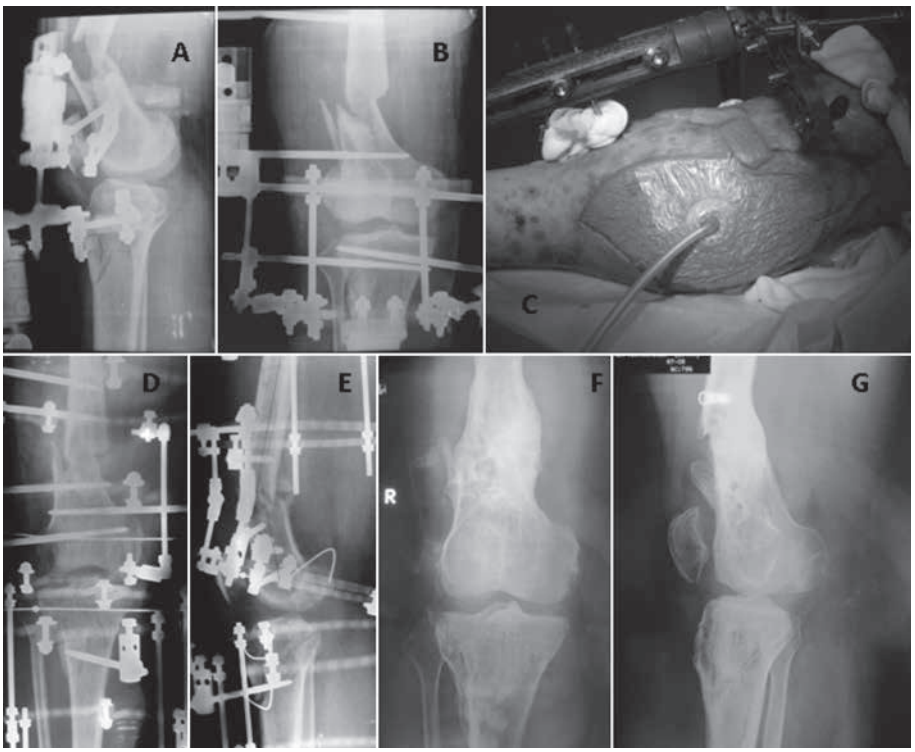


Fig. 5. — Distal femur and proximal tibia fracture with a popliteal artery injury. A-B. Temporary fixation at initial presentation. C. VAC (Vacuum assisted closure) dressing for fasciotomy wounds. D-E. Fixation converted to circular external fixator after 2 weeks. F-G. Fourth year follow-up.

Historically, these high energy injuries have been reported to result a higher rate of amputation (78%) (*3*). Developments in orthopedic fixation, vascular surgery, wound care and the effectiveness of antibiotics have improved the outcomes of such injuries. Although there is no study in the recent literature assessing grade 3C femoral fractures for comparison, our study found a 17% primary amputation rate on the first day of injury and a 13.7% secondary amputation rate. Soni *et al* (*5*) recently reported a 16.6% amputation rate for Gustilo 3C lower extremity fractures.

The treatment of these high energy injuries requires an early decision between amputation and salvage, which still remains a difficult dilemma for surgeons. There are significant risks of surgery to attempt limb salvage. The possible need for multiple operative procedures and prolonged rehabilitation should be considered.

Diagnosis of vascular injury is can be difficult. Careful physical examination and suspicion of vascular injury are the most important steps. Early diagnosis is vital. The ABI (ankle brachial index) is one of the most effective and reliable tools to screen for vascular problems (*14-16*). When the ABI is less than 0.9, the sensitivity is 95% and specificity is 97% for a major arterial injury (*15,16*).

Multiple injury scores have been published to assist surgeons in making this decision over the last three decades (*6-10*). MESS is the simplest and seems to be the most applicable. Such scoring systems could be beneficial but they have been shown not to be good predictors of limb salvage or amputation (*17-20*). Differences in severity of the injury and cultural beliefs make the scoring systems difficult to use. The MESS was not shown to be helpful in guiding the decision between an amputation and a salvage procedure in this study. Patient age and

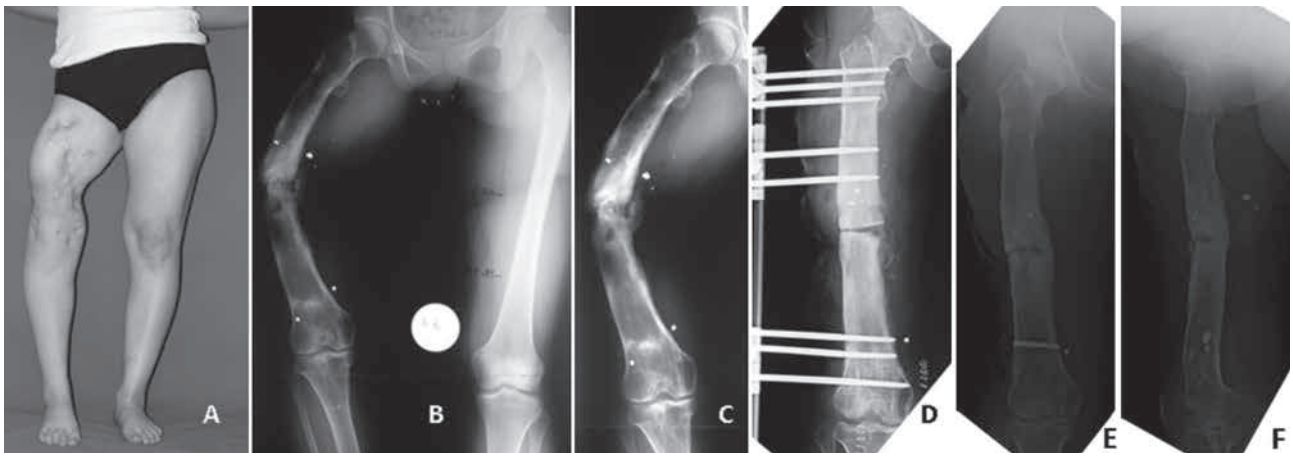


Fig. 6. — Femur diaphysis fracture with a femoral artery injury. A-B-C. Non-union of the fracture. D. Resection of non-union sides and application of mono-lateral external fixator. E-F. Last radiologic control (3 years after initial injury).

ischemia time were not found to be relevant. A MESS score of 8, while being associated with a higher amputation rate, was not predictive that amputation was necessary. In our series the time to vascular repair was sometimes over 10 hours. Although that seems to be a disadvantage for the MESS, it did not change salvage procedure decision making.

Amputation has a great impact, especially in countries with low socio-economic levels. The LEAP (Lower extremity assessment project) study showed that outcomes often are more affected by patient economic, social and personal resources than by the initial treatment choice. Only 34% of LEAP patients achieved normal physical scores of the general population and 58% were working at the same place as before the injury (*4*). Patients in our study reported 59.4% anxiety or depression, compared to the 19% severe depression rate found in LEAP patients (*4*).

Nerve and muscle are the tissues most sensitive to ischemic injury. Kinosha *et al* (*21*), using a rat model, demonstrated that neural blood flow was severely impaired during 3 hours of ischemia and exhibited a prolonged re-perfusion response relative to muscle. Non-atherosclerotic patients have a collateral circulation which is inadequately developed to address major vessel injuries. On the other hand young patients have higher elasticity and better survival rates in high energy traumas (*18*). Preoperative angiography is associated with an increase in ischemic time (*22-24*) ; on-table angiography may be helpful during the surgery.

Injuries of the popliteal artery have been shown to be associated with higher rates of amputations than injuries of the femoral artery (*25*). This may be related to late diagnosis or surgical difficulties in the popliteal region. It has been shown that grade 3C tibia fractures carry greater risk of amputation than grade 3C femur fractures (*11,26*). The use of vascular shunts in such cases was first described by Eger in 1971 (*27*). Some authors state that the use of vascular shunts add more harm to the intima by necrosis, but a review of lower limb salvage following fractures with vascular injury showed that the use of a shunt prior to skeletal fixation followed by a vascular repair can significantly reduce ischemia time compared with approaches that favor skeletal fixation first (*22,28*). In addition, salvage rates have been found to be higher with the use of a vascular shunt (*22*). Simmons *et al* (*28*) favored to use endovascular stent (EVS) instead of reverse saphenous vein graft as a definitive treatment to restore perfusion without need of a time-consuming temporary shunt in select cases. Shunting permits time to evaluate soft tissue viability and un-stressful time for orthopedic surgeons to do a satisfactory bone fixation. Although the idea is a temporary bone fixation on the first day, sometimes first-day stabilization can become a permanent fixation. In this study,

permanent first day fixation was achieved in 5 patients (17.2%). Venous repair has been shown to be associated with improvements in union time, infection rate and chronic atrophic changes in open tibial fractures (*29*). In our cases we did not need any venous repair due to rich venous collaterals.

Associated crush type injuries and neural injuries were found to be predictors of amputation following vascular compromise (*23*). Poorer functional outcomes in patients with a neural injury, especially sciatic or tibial nerve, have been published (*23,24*), consistent with our findings.

Patients with high energy open extremity fractures and massive soft tissue damage pose a demanding clinical challenge, requiring a complex inter-disciplinary approach and multiple orthopedic, vascular and plastic-reconstructive procedures. Negative-pressure wound therapy, used in the form of the vacuum assisted closure - VAC System (KCI, USA) improves healing of excessive soft tissue damage (*30*). VAC incleases the blood flow increases the soft tissue oedema and supports cleaning the infected wounds (*31,32*). Some surgeons have doubts about using vacuum dressings with these compound fractures because of fears to induce a sudden haemorrhage. Despite its multiple advantages, however, the VAC is only rarely used in the area of vascular anastomosis. VAC dressing was mostly used at fasciotomy areas in this study.

With regard to the concept of "damage control orthopedics", external fixation plays an important role in the management of multi-trauma patients (*33*). Management with an external fixator is more appropriate in cases where the fracture is open, grossly contaminated, unstable and associated with vascular injury. Problems related to the injury, such as infection and bone loss, make the treatment even more difficult (*34*). Current studies show satisfactory results with the application of external fixators for open femur fractures with extensive soft tissue injury (*35,36*). Prophylactic fasciotomy is recommended by multiple surgeons (*37,38*). The requirement for fasciotomy has been significantly reduced in literature reports since shunts have become widely used (*22*). We performed crural fasciotomy in all cases requiring vascular repair. Early application of systemic anticoagulant therapy prevents further thrombosis in the microcirculation and reduces amputation rates (*37,39*).

At 2 and 7 year follow-ups, the LEAP (Lower Extremity Assessment Project) study showed no differences in functional outcomes between patients who underwent either limb salvage surgery or amputation (*4*). They also concluded that spending excessive effort to preserve the knee joint is mandatory in such cases that require amputation.

Although most of our patients reported some degree of restriction in mobility, none of the patients in this study favored first day amputation as a treatment choice.

CONCLUSION

The decision to amputate versus salvage should be left up to the patient and their care team after discussing their options and future possibilities rather than relying solely on a scoring system. Soft tissue injury and neurologic deficits have been found to be highly correlated with disability. Bone fixation with an external fixator allows for adjustments after surgical intervention. Although vascular shunts were associated with a reduction in ischemia time, outcomes were more affected by the patients' socio-economic status than overall treatment. Occupational changes, long hospitalizations and multiple surgeries seemed acceptable for our patients.

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