Original Article

Outcome of application of primary versus secondary Illizarov's fixator in open tibial shaft fractures

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BACKGROUND: The present study aimed to compare outcome of primary and secondary Illizarov's fixator application as a treatment method for type III open tibial fractures in terms of non-union and wound infection.

METHODS: This prospective study was done in a tertiary care center. Forty-eight type III tibial fractures were treated with Illizarov's apparatus between 2008 and 2011. The patients were divided into two groups depending on the treatment protocol, timing of wound closure and Illizarov's application, primary ($n=28$) and secondary ($n=20$).

RESULTS: In the primary group, healing was achieved in all 28 patients. The median time to recovery was 24 weeks, and the median number of operations was 3. There were 6 patients with a bone defect. In the secondary group, complete recovery was achieved in 18 out of 20 patients. The median time to recovery was 30 weeks, and the median number of operations 5. There were 9 patients with a bone defect. The median time to recovery and the number of operations were significantly smaller in patients undergoing primary operation. Union was 100% in the primary group and more than 95% in the secondary group. Chronic osteomyelitis persisted in one patient and below amputation was done in one patient in the secondary group.

CONCLUSION: Primary wound closure and Illizarov's fixation required a smaller number of operations and shorter time to recovery than secondary wound closure and Illizarov's fixation, mostly due to a significantly less number of patients with a bone defect in the primary group.

KEY WORDS: Open fractures; Limb salvage; Debridement; Illizarov's fixator; Tibial fractures

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INTRODUCTION

Fractures of the tibia are very common in patients with trauma. Their treatment, prognosis, and outcome are mainly determined by the mechanism of injury, degree of comminution, soft tissue injury and fracture displacement. Fractures by indirect trauma have a better prognosis than by direct trauma. Minimally displaced

fractures allow more simple treatment than displaced fractures. Therefore, high-energy injuries have added to the number, cost and complexity of fractures of long bones, especially those of the tibia and so have the treatment modalities addressing them.

The tibial shaft is one of the most common sites of an open fracture. The type of treatment selected for open

tibial fractures depends on the individual characteristics of the fracture and the concomitant soft-tissue injury, making experience and clinical judgment an important part of over-all treatment. There are increasing expectations for surgeons to understand and apply the newer techniques in the treatment of open fractures, such as the use of flap coverage and bone transplant techniques, to help patients to obtain an optimum functional outcome. We evaluated and compared the use of primary and secondary Illizarov's application as the mode of fracture stabilization of type III tibial fractures. Although there are many classification systems for open fractures, we have used Gustilo's classification.^[1-3]

METHODS

Forty-eight type III tibial fractures were treated with Illizarov's apparatus between 2008 and 2011 in B.H.U., Varanasi, India, AIIMS New Delhi, India, and V.C.S.G.G.M.S.R.I. Srinagar, Pauri Garhwal, India. The patients were divided into two groups depending on the treatment protocol, timing of wound closure and Illizarov's application primary ($n=28$) and secondary ($n=20$). In the emergency room, all patients were assessed according to the guidelines of Advanced Trauma Life Support.^[4] All patients gave informed consent before being included into the study. The study was authorized by the local ethical committee and was performed in accordance with the ethical standards of the 1964 *Declaration of Helsinki* as revised in 2000. There were 36 men and 12 women. Type III open and/or comminuted tibial fractures were the major inclusion criteria. Exclusion criteria included low energy fractures, type III C open fractures and biomechanical unstable external fixation. All open lacerated wounds were irrigated copiously with around 9–10 liters of normal saline followed by debridement of the devitalized bone and soft tissue.^[5] Early intravenous antibiotics were administered in the emergency room to decrease the rate of infection. Antibiotic prophylaxis for gram-positive organisms was performed routinely with first generation cephalosporin for all open fractures. Antibiotic prophylaxis for gram negative organisms, typically with an aminoglycoside, was used for type III A/B open fractures. Antibiotic prophylaxis for anaerobic organisms, typically with penicillin was used whenever there is the possibility of infection with clostridium perfringens, such as from contamination with soil (particularly with injuries that occur on a farm) or public waters such as rivers or lakes. Antibiotic therapy

continued for 48–72 hours after the initial debridement. Antibiotics can be given for as long as 120 hours after debridement depending upon individual cases. Prophylaxis against tetanus was considered with all open fracture in the emergency room.^[6,7] Extensive soft tissue laceration was extended with the use of sharp dissection until healthy tissue was seen at each end. The laceration was then explored systematically to ensure complete debridement of all devitalized tissue and contaminants. After the initial irrigation, debridement and stabilization of the bone, the traumatic laceration was addressed. Operative extensions of the initial lacerated wound were sutured primarily. All attempts were made to remove the devitalized tissue, and primary closure of the lacerated wound was done using tension free interrupted nylon sutures wherever feasible. Early intensive repeated debridement is a fundamental principle of treatment of severe soft-tissue injuries. Patients who had a type-III injury with extensive soft-tissue damage returned to the operating room within 24–48 hours for re-inspection and additional debridement of the soft tissues. The goal of repeated debridement was to remove all necrotic tissue from the lacerated wound so as to remove the substrate for infection. Repeated debridement every 24–48 hours was necessary to achieve this goal. If safe closure could not be accomplished, the size of the lacerated wound was minimized by mobilization of the adjacent tissues over the bone with or without additional split thickness skin grafting. In the primary group, when the soft tissue bed was stable and no necrotic tissue was evident, delayed closure or coverage of the fracture was performed within 72 hours if possible (at most 7–10 days) with application of Illizarov's apparatus.^[8] In the secondary group if the fracture coverage was not possible and the lacerated wound is severely contaminated, a monolateral external fixator was applied with plastic surgery procedures. Polymethylmethacrylate beads impregnated with antibiotics (tobramycin 2 mg/kg body weight) were used in crush injuries (In type III A/B open fractures) to deliver locally high concentrations of antibiotics. An occlusive dressing was placed over the wound to form a bead pouch, which allowed the antibiotics to remain in the local environment. The Illizarov's external fixator in the secondary group was applied after 4–5 weeks. The application of Illizarov's apparatus involved the use of pre-assembled frames to save the operative time. We generally used a four-ring construct except in segmental fractures (2 cases) where a 5 ring and 6 ring constructs were used. Wire insertion site hygiene was meticulously taught to the patient. Immediate postoperative regimen

consisted of range of motion exercises of the ankle and knee. Partial weight bearing was commenced within 48 hours progressing to full weight bearing within the limits of pain. The patients were assessed clinically and radiologically for alignment, bone contact, and later, callus formation, in the outpatient clinic. If no callus response was evident in 3–6 weeks, compression at the fracture site was performed. The frames were removed under analgesia and sedation in the outpatient clinic. The leg was protected in a patella-tendon bearing cast for further 4 weeks. Bone defects larger than 3 cm were treated by bone transport (Figures 1–4). Bone transport was initiated 7 days after corticotomy and was

Figure 1. A radiograph showing loss of bone.

Figure 2. A radiograph showing loss of bone and corticotomy done.

Figure 3. A radiograph showing bone transport and lower end fibular osteotomy at 6 months.

lengthened by 1 mm/day. After docking, the frame was retained until fracture union and consolidation of the regenerate while in intractable pin tract infection docking was performed after the circular external fixator had been replaced with the unilateral external fixator. Once radiological healing was evident, the connecting rods were dynamised and the patient allowed weight bearing on the extremity. External fixator was removed after the formation of callus and the healing of docking place. At 12 months callus formation in the X-rays indicated union which was clinically verified by the absence of pain and motion on full weight bearing with the destabilized frame still attached (Figure 5). If pain or angulations occurred, the frame was re-stabilized and immobilization continued until the above criteria were met. If the patient could tolerate weight bearing, the frame was removed and the limb protected in a functional brace or patella-tendon bearing cast for a further period equal to the time from application of frame to its removal. Union was determined to be the time when fracture healing occurred and all forms of immobilization or support were discontinued. Johner and Wruhs criteria were used to rate the final results.^[9]

Figure 4. A radiograph showing bone transport and second corticotomy at 9 months.

Figure 5. A radiograph showing new bone formation and union at 12 months.

RESULTS

Forty-eight patients with 52 fractures were followed up until union and for a further period of 24 months. The patients were assessed for pain and functional limitations, and examined for angular and rotational malalignment, and range of motion. Their leg lengths were measured clinically. The mean age of the patients was 40.5 years (range, 16–65 years). Road traffic accidents were responsible for the majority of the patients. In the 52 fractures, three fractures were segmental, and one was bilateral. Four of the 48 patients had multiple traumas. In the 52 fractures, 6 were proximal metaphyseal, 36 diaphyseal and 6 distal metaphyseal. Pin tract infection occurred in 23 patients. In 14 patients, infection was resolved by systemic antibiotics for 5 days. In another 7 patients, soft tissue release around the offending wire was done and in 2 patients the wires had to be completely removed and reapplied. Three patients had an angulation of 5° at the fracture site, and 2 patients had shortening of 1–2 cm. Stiffness around the ankle occurred in 6 patients. Range of motion of the knee was satisfactory in almost all patients. Five patients had EHL transfixation, which later recovered after removal of the frame. None of the patients had neurologic or vascular complications. The grade IIIA fractures were closed successfully with no wound complications. Of the grade IIIB fractures, 5 wounds could be successfully approximated and 7 patients required a gastrocnemius flap. Six patients with a grade IIIB comminuted fracture presented late after injury with wound infection and 3 required gastrocnemius flaps at a later stage. Five patients required split thickness skin grafting to cover exposed bone.

In the primary group, healing was achieved in all 28 patients. The median time to recovery was 24 weeks, and the median number of operations was 3. There were 6 patients with a bone defect. In the secondary group, complete recovery was achieved in 18 out of the 20 patients. The median time to recovery was 30 weeks, and the median number of operations was 5. There were 9 patients with a bone defect. Union occurred at an average of 5.3 months (3.5 to 8.5 months). Based on Johner and Wruh's criteria, the final results were rated as 36 excellent, 8 good and 4 fair. No poor results were seen (Table 1). Out of 15 patients, 9 had nonreactive atrophic bone defect. Among 9 patients with nonreactive atrophic bone defect, 4 had partial necrotic fragment, 3 had necrotic fragment and 2 had segmental defect. Bone defects larger than 3 cm were treated by bone transport (Figures 1 and 2). During follow up at 6 and 9

Table 1. Johner and Wruh's criteria for evaluation of final results after tibial shaft fracture^[22]

Criteria	Excellent	Good	Fair	Poor
Non union/infection	None	None	None	Yes
Neurovascular injury	None	Minimal	Moderate	Severe
Deformity (degrees)				
Varus/Valgus	None	2–5	6–10	>10
Pro/Recurvatum	0–5	6–10	11–20	>20
Rotation	0–5	6–10	11–20	>20
Shortening (mm)	0–5	6–10	11–20	>20
Mobility				
Knee	Full	>80%	>75%	<75%
Ankle	Full	>75%	>50%	<50%
Subtalar	>75%	>50%	<50%	
Pain	None	Occasional	Moderate	Severe
Gait	Normal	Normal	Mild limp	Significant
Activities				
Strenuous	Possible	Limited	Severely limited	Impossible
Study results	36	8	4	0

Table 2. Comparison of the primary and secondary groups

Parameters	Primary	Secondary
Number of cases	28	20
Median number of operations	3	5
Median time of recovery (weeks)	24	30
Bone defect	6	9
Tibial shortening	0	2
Chronic osteomyelitis	0	1
Below knee amputation	0	1
Union	28	18

months, the bone transport was evident and osteotomy of lower end fibular was done as fibula was hindering the transport of the tibia by acting as strut (Figures 3 and 4). This bone transport required 6–12 months in the primary and 12–24 months in secondary groups (Figure 5). In our series there were 2 patients with tibial shortening. In the secondary group, one patient underwent below knee amputation on the 17th day due to severe infection and foot drop (Table 2). The sensations were intact in the amputated limb. In the secondary group, one patient had chronic osteomyelitis persisted for 2 years in which sequestrectomy had to be done after union, and one patient had nonunion.

DISCUSSION

Open tibial shaft fracture is the most common open long-bone fracture because of its location and scanty soft tissue coverage.^[10] Generally, open fractures remain open until the patient returns to the operating room for a secondary debridement to ensure that adequate debridement of necrotic tissue from the wound has been done prior to wound closure.^[11] This method recently has been challenged, with authors recommending primary

closure of open wounds in some cases. Shtarker et al^[12] used successfully primary suturing and Illizarov's fixation in the treatment of open tibial fractures. DeLong and associates^[13] reported open fractures with immediate primary closure of the open fracture wound after a thorough debridement. Open wounds were debrided and tension free primary closure using interrupted nylon sutures was attempted wherever appropriate in our series. Early wound closure either by primary suture or other means of wound covers after a thorough debridement was the hallmark of this series. Immediate primary closure of open fracture wounds after a thorough debridement by an experienced fracture surgeon appears to cause no significant increase in infections or delayed union/nonunion. In addition, early closure may decrease the requirement for subsequent debridement and soft-tissue procedures, thereby minimizing surgical morbidity, shortening hospital stays, and reducing costs. The management of the Gustilo type III open fractures starts with the assessment of energy transfer, clinical assessment and radiological examination, fracture classification, and MESS score. The classification of fracture influences the selection of the method of surgical management.^[14,15] Although there are not enough data but a positive influence on bone healing and wound infections can be observed when initial debridement is started within 6 hours from injury.^[16] The early restoration of soft-tissue has dramatically improved the outcome of these fractures. A better understanding of cutaneous blood supply and advances in micro-surgical techniques has improved the outcome of traumatic musculocutaneous defects.^[17] There are numerous treatment protocols for Gustilo type III open tibial fractures.^[18] We used Illizarov's technique with good results especially in cases of bone defect. Bone transport and corticotomy was performed in patients with significant bone loss, and Illizarov's technique was used for bridging bone gaps ≥ 10 cm. In our series, gastrocnemius flaps (10 patients) and split thickness skin grafts (5 patients) were used at different stages of the treatment. In other studies, either split thickness skin grafts or local flaps were used.^[19] The use of different flaps for wound reconstruction in different studies ranged from 65% to 100%.^[20] Illizarov's fixator was chosen to primarily fix those fractures that produced a high rate of complications with conventional methods of fixation. For over half a century, Illizarov's device has been used for the treatment of acute fractures and non-unions.^[21] The structure is stable and the patient can bear weight on the affected limb from the first day, even in much comminuted fractures.^[22] An Illizarov's fixator enables

the surgeon to correct malalignments and in case of bone loss, to perform adequate limb lengthening.^[23] Union was 100% in the primary group and more than 95% in the secondary group comparable to Tukiainen et al^[24] who reported 100% union of 26 tibial fractures in 23 patients treated with the Illizarov's fixator. The Illizarov's device provided early and definitive fixation for high-energy tibial fractures with good results.^[25] Wani et al^[26] and Hosney et al^[27] reported 6 and 5.6 months respectively for union in tibial open fractures treated by Illizarov's fixator and were similar to those in our study. Sen et al^[28] observed a longer duration for union (7.5 months) with Illizarov's fixator and was higher than that we found in the present study. In their study, all patients had Gustilo III fractures with a mean bone loss of 5 cm and 2.5 cm $\times$ 3.5 cm soft tissue loss with extension of fractures to adjacent articular space. Qureshi et al^[29] reported 3.3% nonunion in patients treated with Illizarov's fixator, which was lower than the result of our study. In their study, both open and closed tibial fractures were included in the study and those who needed flap were excluded. In our series in the secondary group one patient underwent below knee amputation on the 17th day due to severe infection and foot drop. Mangled Extremity Severity Score (MESS) is a simple rating scale for lower extremity trauma, based on skeletal/soft-tissue damage, limb ischemia, shock, and age. MESS value greater than or equal to 7 predicted amputation with 100% accuracy. MESS may be useful in selecting trauma victims whose irretrievably injured lower extremities warrant primary amputation.^[30] The decision for amputation or salvage for the more severe injuries is still a controversial issue with legal implications.^[31] Early weight bearing with range of motion exercises of ankle and knee joints were encouraged after the application of Illizarov's fixator. The median time to recovery and number of operations were significantly smaller in patients of the primary group. The Illizarov's device provided early and definitive fixation for high-energy tibial fractures with good results. The treatment we followed is the most recent and aggressive method for reducing the morbidity, number of operations and cost of the treatment. We suggest randomized, prospective studies on this aggressive approach to open fracture care are needed.

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Ethical approval: The study was approved by the local ethics committee and was performed in accordance with the ethical standards of the *Declaration of Helsinki* revised in 2000.

Conflicts of interest: There is no conflict of interest related to this manuscript including personal, commercial, political, academic, or financial aspects.

Contributors: Joshi A proposed the study and wrote the first draft. All authors read and approved the final version of the paper.

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