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Chirag V Thakkar
Associate Professor, GMERS, Gotri Medical College, Vadodara, Gujarat, India

Mukesh S Dwivedi
Associate Professor, GMERS, Gotri Medical College, Vadodara, Gujarat, India

Correspondence
Chirag V Thakkar
Associate Professor, GMERS, Gotri Medical College, Vadodara, Gujarat, India

Open distal femur fractures: Treatment principles

Chirag V Thakkar and Mukesh S Dwivedi

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Abstract
Introduction: Open distal femoral fractures are not rare and are difficult to manage. In open grade III injuries, according to Gustilo-Anderson's classification of Open fractures, due to massive trauma to the soft tissue and loss of bone, chaotic mindset of treating doctor compels him to fall prey to petty methods of fixation leading to inferior results.
Method: We studied a group of 24 patients with open distal femur fractures with or without bone loss, classified them and treated according to the steps described in our treatment flow chart. We have tried to formulate a standard, reproducible method of treating such fractures according to priority and need.
Results: We achieved 79.2% good to excellent results according to Knee Society Scoring system on treatment of open distal femoral fractures with author's preferred treatment. This is comparable with many other similar studies pointing towards the fact that our treatment protocol and scoring system for these fractures are worthwhile.
Conclusion: We conclude that immediate management in emergency department, early shifting of patient to the operating room and stabilizing the fracture and carrying out proper debridement of wound and depot antibiotics are important steps in management. Vacuum assisted dressings, sequential debridement, autologous bone grafts, double plate fixation and staged wound management can give good results in the hands of any surgeon.

Keywords: Open distal femur fractures, flowchart, antibiotic career beads or blocks, autologous bone grafts, dual plate fixation

Introduction
Open fractures have posed challenges among the orthopedic fraternity since time immemorial. These fractures, due to their communication with the external environment, predispose to infection [1-3]. Open fractures have also inherent tendency towards non-union (essentially the open grade III fractures), which has led to development and evolution of different methods for treating them [4, 5].
Various treatment options like Ilizarov ring fixator or Temporary/ Permanent AO type external fixator (ex-fix) or Primary Nailing/ Plating with primary or secondary wound closure have been described in literature with advantages and disadvantages when compared to one another [6-8]. Staged treatment in form of provisional ex-fix followed by Nailing or Plating for a diaphyseal/ metaphyseal fracture in addition to the treatment of other soft tissue injuries (venous grafting for arterial damage, split thickness skin grafting, flap coverage, etc.) has also been mentioned by various authors, in which they have achieved good outcomes [7-13].
Due to the dilemma consisting of open wounds, bone loss, comminution, fragile surrounding soft tissues, disputed viability of limb and a series of following reconstructive procedures, which puts the treating doctor as well as the patient in a state of hollow confusion, we have tried to outline a standard, reproducible (in most cases) staged protocol for management of open fractures of distal femur.
In this article we will analyze the results of 24 cases of open fractures of distal femur, which were treated by author's preferred method of management for such cases.

Materials and Methods
Thirty patients from October 2014 to October 2018 were followed up for clinical and radiological evaluation following treatment for open fractures of distal femur.

Inclusion Criteria: All patients with Open Grade I, II and III (OGI/II/III) fractures of distal femur were included in this study. They were classified according to Gustilio and Anderson's classification system for open fractures.
Patients who were a part of this study group were informed about the study and a written consent was obtained prior to the beginning of treatment.

Exclusion Criteria: Out of thirty patients, three were lost to follow up, two had to undergo eventual amputation and one died due to other co-morbidities and systemic injuries, leaving twenty four patients to be reviewed.
In our case series, sixteen were males, four were females (M:F-4:1). Mean age was 45 years with a range from 28 to 56 years. All patients sustained injury due to road traffic accident (RTA) and nine patients had associated injuries. Average time of presentation to the casualty department after injury was 32 hours, least being 3 hours and maximum being 72 hours (3 days). The following table outlines some features of injuries in our study group.

Table 1: Characteristic features (and number of subjects) of injuries with distal femur open fractures in our study group

1	**Type of Open Fracture**	**OGI- 3**	**OGII- 5**	**OGIIIA- 8 OGIIIB- 5 OGIIIC- 3**
2	Size of Wound	<10cm- 8	10-20cm- 12	>20cm- 4
3	Extent of soft tissue injury and contamination	Mild- 8	Moderate- 8	Severe- 8
4	Bone loss	None- 12	Comminution +/- Bone loss- 8	Segmental Bone loss- 4
5	Intra-articular fracture extension with Hoffa's fracture	None- 4	Without Hoffa's fracture- 8	With Hoffa's fracture- 12

All the patients with open fractures of distal femur brought to the casualty were carefully evaluated for mode of trauma, time of injury, size of wound, contamination of wound, active bleeding, exposed bone or bone fragments, systemic shock, co-existing injuries, etc. Patients in hypovolemic shock with chest/abdominal/head injuries were treated with multidisciplinary approach and stabilized following ATLS principles. Resuscitation, wherever found necessary, was invaluable and vital.
Primary treatment of all open fractures in casualty started with administration of tetanus toxoid (for prophylaxis), intravenous antibiotics, analgesics, fluid replacement, cleaning of the affected limb with Savlon (GlaxoSmithKline-Cetrimide and Chlorhexidine gluconate) and saline. A soap water formulation can also be used in place of Savlon. Following this, proper preparation of the limb under maximum possible aseptic environment with Povidone Iodine and assessment of wound by visual and palpatory methods was undertaken. Exposed bone was reduced and accommodated in the wound after thorough cleaning and irrigation of wound. Devitalized bony fragments devoid of attached soft tissue and exposed to the external environment and loose bony particles flowing out of the wound during irrigation were all removed from the wound at the first site. A sterile, well padded dressing with a posterior slab support was applied after this.
All patients with OGI and OGII injuries were taken to the operating room (OR) in the next sitting and after cleaning and debriding the wounds, appropriate soft tissue repair was carried out. Definitive fixation with Antegrade/ Retrograde nailing or Minimally invasive/ Open plating was planned for each of such fractures.
All OGIII fractures and OGII fractures with severe contamination and/or soft tissue damage were taken for debridement and stabilized provisionally with ex-fix which spanned the knee joint. The frame of ex-fix was applied keeping in mind the wound site and further plan for soft tissue procedures. Some reducible intra-articular fracture fragments were reduced with clamps and fixed with 6.5mm/4.5mm Cannulated Cancellous screws.
Antibiotics mixed with Stimulan^{R} (Bicomposites, UK), PMMA Beads or a PMMA spacer, were released in the wounds, to be removed at the time of definitive fixation. In cases with segmental bone loss or severe comminution, the PMMA spacer mixed with Vancomycin 1gm and/or Gentamicin 80mg helps prevent infection and maintain the bed of the wound. It prevents surrounding soft tissues to contract and eventual shortening of limb during final fixation. The bed thus created by a PMMA spacer, as described by Masquelet, has the ability to generate osteocytes and to help further in union of grafts with host bone.
Dual or Single plate fixation for all fractures was decided on basis of amount of medial comminution, bone loss, quality of bones, age of patient and condition of the wound(s).
One of the authors, CVT, operated all the cases during the study period following the protocol shown in the algorithm. The flow chart (algorithm) standardizes the line of management for most open fractures of the distal femur. Surgical steps described hereby are easily reproducible by consultants and resident doctors attending government hospitals and trauma centers, which primarily cater to this kind of patients on a regular basis in a country like India.
Ten patients in our series did not require bone grafting and did well with fixation and timely wound management. Nine patients were subjected to cancellous bone grafting (CBG) with free non-vascularised single/ double fibula strut cortical grafts and dual plate fixation (one long, sturdy locking anatomical distal femur plate on lateral side and a less rigid low profile T-Plate on medial side).
CBG and Allogran-R^{R} (Biocomposites, UK), a bone graft substitute made of granular calcium phosphate, were added to fixation in two cases.
Three patients with segmental bone loss were treated with two fibular struts each and CBG added to Stimulan^{R} beads mixed with antibiotics because one of them was diabetic and with severe contamination of wound at presentation and the other two had vascular injury, compromised soft tissue condition and predisposed to infection.

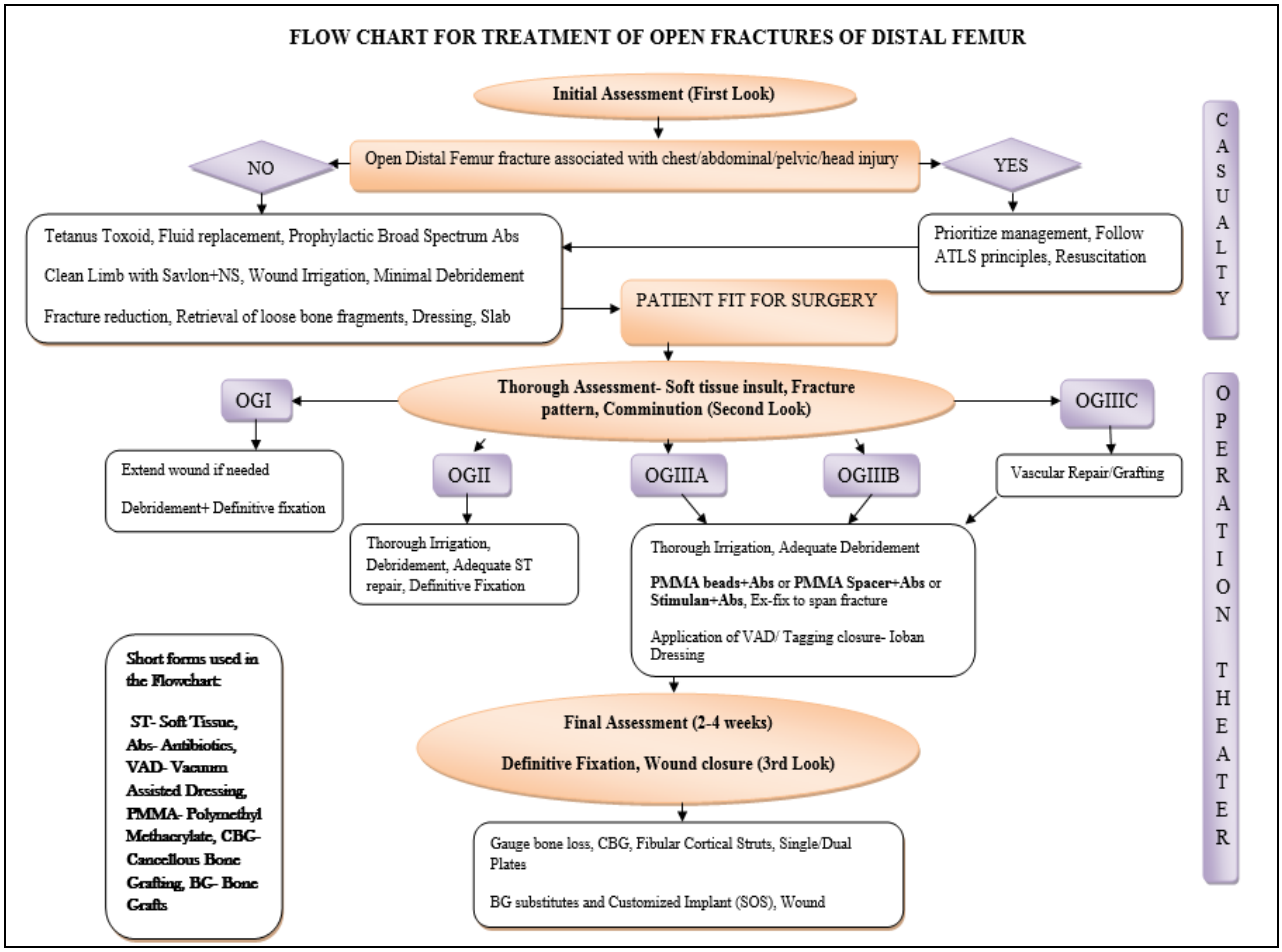

Fig 1: Flow chart for treatment of open fractures of distal femur

Results

All the patients were followed up for an average period of 1.5 years, minimum being 6 months and maximum being 3.5 years. Patients were assessed clinically and radiologically at each visit and their progress was filed.

Wound healing: Eight out of twenty four wounds were closed primarily after debridement and tissue repair. These were OGI and OGII injuries. VAD (Vacuum Assisted Dressing) and closure thereafter was performed secondarily in ten patients. These were patients with large wounds, where primary closure was refrained from due to major soft tissue insult (periosteal stripping with crushed muscles) and/or contamination. The remaining six patients were subjected to either STSG or Rotational local flaps or Free flaps according to the need.

In our series eight wounds healed within three weeks, ten wounds healed between three and five weeks and six wounds took more than six weeks to heal.

Fracture healing: All fractures united well in our series. Fracture healing was assessed in all twenty four cases by anterioposterior, lateral, internal oblique and external oblique radiographs of the affected limb (knee with femur). Axial mal-alignment and rotational mal-alignment were evaluated after the fracture union at final follow up. The minimum time for fracture union in our case series was twelve weeks and maximum was ten months.

Note: Fracture union in cases with cortical strut grafting was considered when the cortices of cortical bone grafts and host bone could not be differentiated on radiograph i.e. time when fibular strut grafts incorporated with the cortex of host bone completely.

Malunion: We had varus malunion in two cases and rotational malunion in one. None of the malunions were more than 7˚.

Infection: Three superficial soft tissue infections were encountered during the course of treatment of these patients. All of them were treated with intravenous antibiotics, frequent sterile dressings and a close watch was kept on them until they healed well. One deep infection was noted which was resilient to routine antibiotics. The patient was a known tobacco chewer and a diabetic for 14 years. He was obese with a high BMI. We treated him with higher antibiotics, stimulant beads mixed with antibiotics and sequential debridement. This was a case of OGIII fracture with segmental bone loss of 7cm. Another case of deep infection, which eventually turned to osteomyelitis of femur, was treated with extraction of implants, excision of necrotic and infected bone, multiple debridement and re-fixation at a later date.

Functional outcome: Function at final follow up was evaluated on basis of flexion possible at the knee joint or Knee Range of Motion (KROM), pain in the knee or fracture area, comfort observed during activities of daily living (ADLs) and limb length discrepancy. The author used following scoring system to rate functional outcome following treatment of open distal femoral fractures by the method described in the flowchart.

Functional Outcome Scoring System (Foss) For Open Fractures of Distal Femur

Result	Score	Rating
KROM (range through flexion)		
Stiff knee (Can't walk)	0	Poor
70˚- 100˚	1	Fair
100˚- 130˚	2	Good
>130˚	3	Excellent
Pain		
At rest	0	Poor
During ADL	1	Fair
During Stressful activities only	2	Good
No pain	3	Excellent
Comfort observed during ADLs		
Unable to rise from chair/Walk	0	Poor
Able to walk and climb with support/cane	1	Fair
Able to walk and climb without support/cane	2	Good
Able to walk>1km, swim, cycle	3	Excellent
Limb Length Discrepancy (Shortening)		
>6cm	0	Poor
3-6cm	1	Fair
1-3cm	2	Good
<1cm	3	Excellent

Interpretation of Scoring system FOSS (Functional Outcomes): 0-3 points= Poor, 4-7= Fair, 8-11= Good, 12= Excellent.

In our case series, using this functional scoring system we had these results categorically:

Poor Outcome in no patient, Fair Outcome in 8 patients (33.3%), Good Outcome in 12 patients (50%) and Excellent Outcome in 4 (16.7%) patients.

We also used the KSS (Knee Society Score) to analyze the functional outcome and knee score in our patients. Using KSS we had 5 fair (20.8%), 15 good (62.5%), and 4 excellent (16.7%) results.

Discussion

Open fractures have always been challenging to manage. It amounts to real hard work and multiple operative interventions to reach to a sound end result where both the patient and the surgeon are at mental peace.

According to Rasotgi *et al.* [14], in an Indian trauma set-up, patients comprise mainly of open and closed fractures of the limbs and blunt trauma to the head, neck, abdomen, chest and spine.

An objective method of treatment, adhered to the principles of management of open fractures [6-8] can lead to good results as observed by many physicians outside India.

Outlining an affording treatment plan for poor patients of India (especially farmers), which consists of minimum intervention with maximum outcome and which sticks to the principles of fracture management offering good results with less complications is the need of hour.

Twenty four patients with open fractures of distal end of femur, treated by the author's preferred method, gave us 17% excellent, 50% good and 33% fair results. We compared our results with similar studies having larger number of subjects.

Nicoll [15] in 1964 published an article of 705 cases of tibial shaft fractures. He documented infection rate of 14.3% in that study.

Clifford *et al.* [11] in 1988 treated 97 open tibial shaft fractures with primary immediate plate fixation and recorded infection rate of 10.3% which was quite low.

Guerra *et al.* [2] in 2017 studied 133 open fractures and found 18.80% infection rate in his series.

O'Brien [10] in 1991 recorded 5% infection in a series of 60 cases of open femur shaft fractures.

Our series recorded 8.33% infection rate, where 24 patients out of 30 were under the study group.

Decreased rate of deep infection in our study can attributed to immediate attention offered to the open wound, administration of antibiotics locally in depot form mixing them with either PMMA or Stimulan beads (also called antibiotic careers), whenever found necessary. A thorough second look debridement cannot be overlooked. Stable ex-fix+ depot antibiotics+ thorough wound care, copious irrigation of wound before and after debridement and fixation, timely use of higher broad spectrum antibiotics along with VAD (vacuum assisted dressings) followed by a strong definitive fixation for the fracture (preferably dual plate fixation) with added CBG and/or Cortical strut grafts under strict aseptic and antiseptic precautions are considered as the supporting pillars of our management fortress.

Westgeest *et al.* [4] [2016], in their study conducted at three centers of Canada took into account 791 open fractures of tibia, femur and upper limb long bones and found 17% non-union.

Rosenthal [5] in 1997 studied 104 open fractures of tibial shaft and recorded 27% non-union rate. Syed *et al.* [16] in his series of 29 closed fractures of distal femur had 3 patients with non-union i.e. 10.34% in 2004. This was a small study group with longest follow up until 24 months only.

In our series of 24 cases of open fractures of distal femur, there was 0% non-union rate. This can be attributed to the stable double pillar fixation, liberal use of CBG, BG substitutes, autologous fibular cortical strut grafts and proper staged wound management. It is evident from the literature and personal experience, that decrease in the rate of infection reduces the chances of non-union (infected non-union).

We had 66.7% good to excellent results according to our functional scoring system devised only for the functional outcome analysis of treated open distal femur fractures. Similarly, using KSS we found 79.2% good to excellent results in our case series. Agunda *et al.* [17] presented 89% good to excellent results based on Hospital for Specialized Surgery Knee Score (HSS Knee Score) in their series of 46 patients of closed femur fractures treated with three different types of methods. The longest follow up in this series was 12 weeks. Patil *et al.* [18], in their study of 30% patients of closed fractures of distal femur, documented 96% good to excellent results based on Neer's scoring system. Both these series had patients with closed fractures as their subjects. So there are many scoring systems used to assess functional outcomes following different types of surgeries in and around the knee joint. The scoring systems are best evaluated and described in detail by Collins *et al.* [19].

Our scoring system is simple and limited with two objective (LLD, KROM) and two subjective (Pain, Comfort in ADL) considerations. This scoring is purely based on clinical outcome of the patient and stringent enough to assess results following treatment of open distal femur fractures.

Conclusion

Cases with open distal femoral fractures with or without bone loss should be considered as orthopedic emergencies and treated timely under the guidelines provided in the literature by various authors. The steps in flow chart described by the author in this article are standard outline of management and

are reproducible by every orthopedic surgeon at various trauma centers. In a third world country like India, where cost restraint forces the poor to avail treatment at basic expense in government institutes, minor changes in usage of antibiotic careers, bone grafting methods and implants can benefit the patients to a great extent providing them with a better life.

Extreme close watch on the fracture pattern and wound and its management, primary treatment of patient's general condition and fracture are vital, and top the list of management protocol. Use of substantial amount of autologous cancellous bone grafts (CBG), cortical strut grafts, antibiotic careers (PMMA, Stimulan), bone graft substitutes (Allogran) which act as defect fillers and help in osteoconduction, liberal use of intravenous antibiotics and sturdy definitive fixation along with proper wound closure or reconstructive procedures lead to good results.

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