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Treatment of Open Femoral Fracture with Bone Loss: Review Article

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ABSTRACT

Background: Attempting limb reconstruction in the presence of critical bone loss usually involves surgery which had technically difficult, time-consuming, physically, and psychologically demanding for the case, with no guarantee of a satisfactory outcome. The function of the salvaged limb might be disappointing due to residual pain, joint stiffness, and neurovascular deficit. The case might require a secondary amputation due to refractory disease or non-union. Thus, the correct initial decision as to whether to embark upon limb reconstruction or to perform a primary amputation had important but difficult.

Objective: The aim of this essay had to evaluate various treatment options for open femoral fracture with bone loss regarding, different methods to compensate for bone loss, and the complications of each one.

Methods: PubMed, Google Scholar, and Science Direct were searched using the following keywords: Treatment of open femoral fracture, Bone loss, and Bone loss and complications. The authors also screened references from the relevant literature, including all the identified studies and reviews, only the most recent or complete study was included between June 2000 and December 2020. Documents in a language apart from English have been excluded as sources for interpretation were not found. Papers apart from main scientific studies had been excluded: documents unavailable as total written text, conversation, conference abstract papers, and dissertations.

Conclusion: Bone loss had a relatively uncommon problem encountered in the treatment of open fractures, and usually occurs in the femur and tibia. The majority of defects had small and could be managed with standard methods of fixation, and autogenous bone grafting. Larger defects with complex soft-tissue problems could be managed by shortening, fixation with later lengthening.

Keywords: Treatment of open femoral fracture, Bone loss, Bone loss, and complications.

INTRODUCTION

Historically, because of the problems involved in initial limb salvage, and the subsequent difficulty of reconstructing large skeletal defects many fractures with critical bone loss had been treated by primary amputation. Modern techniques of fracture stabilization, and soft-tissue reconstruction made many severely injured limbs with bone defects salvaged in the acute phase of treatment [1].

Loss of bone might occur acutely in high-energy open fractures, or it might result after the debridement of devascularised or contaminated bone**,** the surgeon had faced with deciding how much bone to remove. Aggressive debridement of bone fragments helps in reducing the risk of disease, but it also might create posttraumatic segmental bone defects (PTSBD). Most authors recommend the removal of bone fragments that had contaminated, and devoid of soft-tissue attachment. Inadequate resection of contaminated tissue, specifically bone, increases the risk of chronic disease because this contaminated devitalized tissue had an excellent medium for disease, the injured blood supply limits the body's local resistance to disease[2].

Surgical reconstruction of bone defects presents a critical challenge for orthopedic surgeons. Traditional procedures to bridge segmental bone defects had autogenous or allogenic bone grafting. However, these procedures usually require multiple surgical procedures, no weight-bearing during treatment, had a limited extent of bone defect reconstruction [3].

Various donor sites could be used for vascularized bone grafting, such as the iliac crest, ribs, or the fibula. The accompanying skin paddles (fibula, rib, ilium) or muscle components (latissimus dorsi, serratus anterior in rib flaps) might be harvested at the same time. Thus, reconstruction of combined soft-tissue and bone defects could be provided by this technique. There had also been indications for use in smaller defects, where improved blood supply had needed for healing. The fibula had generally accepted as the most suitable vascularized bone graft for the reconstruction of composite segmental long-bone defects[4].

Internal bone transport or distraction osteogenesis had used successfully for bony reconstruction for bone loss procedures. Techniques include gradual or acute shortening, rapid distraction using auto-distractors, transporting, using orthobiologic, adjuvant techniques to assist in the consolidation of regenerate, docking sites[3].

For several years, circular external fixators had the method of choice for the correction of shortening and deformity in the long bones. Besides bone lengthening, circular external

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fixators also allow post-operative angular, and rotational adjustments [5].

Contemporary methods of limb lengthening include modifications of the technique, combined procedures, or purely intramedullary procedures including lengthening over a nail, also known as the monorail procedure, lengthening by distraction osteogenesis followed by nailing[6]. However, difficulties with the control of the distraction rate had the main drawbacks, which might in turn cause insufficient bone regeneration [3].

Gene therapy techniques offer the best option for the local or technique upregulation of the body's healing mechanisms, involving the whole sequence of factors. At present, only preliminary animal work had done in this zone[7].

This essay aimed to evaluate various treatment options for open femoral fracture with bone loss regarding, different methods to compensate for bone loss, and the complications of each one.

CLASSIFICATION OF FRACTURES

Two classification techniques had developed for open fractures. In the classification of open fractures developed by Gustilo, Anderson gives an idea about the severity of the injury, recommendations for treatment, and a guide to prognosis[8].

Table (1): Classification of Gustilo, Anderson [9-10].

<table>
<tr><th>Type</th><th>Wound</th><th>Level of contamination</th><th>Soft tissue injury</th><th>Bone injury</th></tr>
<tr><td>Type I</td><td>Less than 1 cm long</td><td>Clean</td><td>Little soft tissue damage
No crushing</td><td>The fracture is usually simple transverse or oblique with little contamination.</td></tr>
<tr><td>Type II</td><td>More than 1 cm long</td><td>Moderate contamination</td><td>Slight to a moderate crushing injury
No extension soft tissue damage</td><td>Moderate comminution</td></tr>
<tr><td>Type III</td><td>More than 10 cm long</td><td>High degree of contamination</td><td>Extensive damage to soft tissues</td><td>Fracture caused by high-velocity trauma</td></tr>
<tr><td colspan="2">Type IIIA</td><td colspan="3">Includes any segmental, or severely comminuted open fractures, soft tissue coverage had adequate</td></tr>
<tr><td colspan="2">Type IIIB</td><td colspan="3">- Massive contamination.
- Severe comminution.
- Extensive injury to or loss of soft tissue, with periosteal stripping, exposure of bone.
- After debridement, a segment of bone had exposed, and a local or free flap had required.</td></tr>
<tr><td colspan="2">Type IIIC</td><td colspan="3">- Any fracture with an arterial injury that requires repair, regardless of the degree of soft tissue injury.</td></tr>
</table>

The Trauma Department at Hannover, Germany (Tscherne), had developed an open fracture score that considers the AO/ASIF fracture classification; bone loss; loss of soft tissue, skin, muscle, neurovascular injury, the presence of compartment syndrome; foreign body contamination; final bacteriologic analysis; time from injury to onset of treatment. This score provides four categories, type I through IV, based on points allocated for each category. This open fracture classification had used in a prospective series of 651 open fractures treated in Hannover, Germany, from 1984 to 1989[11].

Table (2): AO/ASIF soft tissue injury classification[12].

Scale:
1. Normal (except open fractures).
2-4. Increasing severity of the lesion.
5. A special situation.
Skin lesions (closed fractures):
IC 1 No skin lesion.
IC 2 No skin laceration, but contusion.
IC 3 Circumferential degloving.
IC 4 Extensive closed degloving.
IC 5 Necrosis from contusion.
Skin lesions (open fractures):
IO 1 Skin breakage.
IO 2 Skin breakage < 5 cm, edges contused.
IO 3 Skin breakage > 5 cm, devitalized edges.
IO 4 Full-thickness contusion, avulsion, soft-tissue defect, muscle-tendon injury.
Muscle-tendon injury:
MT 1 No muscle injury.
MT 2 Circumferential injury, one compartment only.
MT 3 Considerable injury, two compartments.
MT 4 Muscle defect, tendon laceration, extensive contusion.
MT 5 Compartment syndrome/crush injury.
Neurovascular injury:
NV 1 No neurovascular injury.
NV 2 Isolated nerve injury.
NV 3 Localized vascular injury.
NV 4 Extensive segmental vascular injury.
NV 5 Combined neurovascular injury, including subtotal or complete amputation.

DIAGNOSIS

Open femoral fractures had uncommon, there had few reports which refer specifically to their management. Although they had usually the result of high-energy trauma and had often associated with considerable comminution, the bone loss had infrequent. However, in a minority, it could occur either at the time of the original injury or as part of subsequent debridement[13].

Clinical evaluation, resuscitation, investigation, and treatment had to be performed techniqueatically to avoid errors leading to an adverse outcome for the case[14].

The standard method of initial assessment, and management had the Advanced Trauma Life Support(ATLS) technique, which had developed to guide clinicians in the early stages of management. The ATLS technique recognizes that the usual model of a detailed history, followed by a techniqueatic head-to-toe physical assessment had ideal for the multiply injured case. The ATLS technique had based on recognizing life-threatening conditions immediately, instituting treatment even if the exact diagnosis had not been established, and limiting the history obtained in the acute setting to collecting facts relevant to the initial task of saving the case's life. There had equivalent techniques for the child, e.g. Paediatric Advanced Life Support(PALS) technique[15].

The history should focus on obtaining information about allergies, medications, past illnesses, pregnancy, the last meal consumed, the events, and the environment of the injury. The primary survey identifies immediate life-threatening injuries; it includes maintaining the airway with cervical spine protection, establishing breathing with ventilation if required, restoring circulation, controlling hemorrhage, assessing disability, and neurological status, determining exposure, and controlling the environment around the injured case[15].

The most useful radiographic investigations initially are lateral cervical spine, chest X-ray, and plain Anteroposterior(AP) view of the pelvis. The hemorrhagic shock was common in multiple trauma; the key early signs were tachycardia, and cutaneous vasoconstriction[14].

There are six causes of life-threatening respiratory compromise: upper airway obstruction, tension pneumothorax, open pneumothorax, flail chest, massive haemothorax, and cardiac tamponade. Abdominal distension, absent bowel sounds, guarding or rebound tenderness suggest an intra-abdominal injury; a rectal(and vaginal examination in females) should be performed, a gastric tube inserted, and an urgent Computed Tomography(CT) scan should be requested[15].

For suspected head injury, a CT scan should be considered in all cases with a Glasgow Coma Scale score of less than 15. A loss of consciousness for more than 5 min or any case with a focal neurological deficit; space-occupying lesions or a midline shift of greater than 5mm had indications for craniotomy[16].

Early skeletal stabilization of major long-bone fractures reduces complications; for cases with severe extra-skeletal injuries or who had hemodynamically unstable, definitive internal fixation might not be feasible, and temporary external fixation had necessary[16].

TREATMENT

Because of difficulty in managing posttraumatic segmental bone defects, and the resultant poor outcomes, amputation historically had the preferred treatment. Massive cancellous bone autograft had the principal alternative to amputation. Primary shortening or use of free vascularized fibular graft also had used to attempt limb salvage[2].

Bone transport with distraction osteogenesis had been suggested as the leading option for defects of 2 to 10 cm, but problems include delayed union at the docking site and prolonged treatment time. The free vascularized bone transfer had been suggested as the leading option for defects of 5 to 12 cm, but hypertrophy of the graft had unreliable, late fracture, common. Bone graft substitutes continue to be developed, but they had not yet reached clinical efficacy for posttraumatic segmental bone defects. Although each of the new techniques had shown some limited success, complications remain common[17].

During the initial presentation of an acute traumatic defect, a simple monolateral four-pin external fixator had applied to the limb. Every effort should be made to remove any devitalized bone, or necrotic soft tissue [17].

The case had returned to the surgery every 48 hours for additional irrigation, and débridement until the zone of injury had declared itself, and the wound had become culture-negative. At this point, the decision to proceed with transport must be resolved[18].

Treatment options:

Management of femoral segmental bone defect includes[2]:

- Amputation.
- Acute limb shortening.
- Autologous non-vascularized cancellous bone graft.
- Free vascularized bone transfer.
- Bone transport distraction osteogenesis.
- Other management techniques.

- **Amputation:**

When an extremity injury had severe enough to be associated with segmental critical of bone, amputation had always been a treatment alternative. The decision to perform either limb salvage or amputation must be made after careful consideration of the characteristics of both injuries in the case[19].

In some injuries, immediate or early amputation might be the treatment of choice. Immediate amputation had usually indicated in the following situations [19]:

- Severe open fractures with associated vascular injuries requiring repair(type IIIC) when the injury cannot be repaired or the warm ischemia time had over 8hours.
- The limb had been so severely crushed that minimal viable tissue remains for revascularization
- There had irreversible associated soft tissue injury and neurologic damage that would result in final function worse than that provided by the prosthesis.
- In the presence of multiple injuries where immediate amputation to control hemorrhage or to reduce the adverse technique effects of retaining low-viability or diseased tissue might be lifesaving.
- When limb salvage might be life-threatening in the presence of severe chronic diseases such as diabetes mellitus with severe vascular disease or neuropathy.
- A mass causality situation where salvage of life, transportation of the victim, or the need to direct scarce resources to more severely injured causalities had been indicated. Particularly in severe open fractures of the femur, salvage might require repeated operations and prolonged disability for 2years or more. The personal, emotional, sociologic, and economic consequences of expensive, prolonged treatment might cause the case to select amputation early during treatment.

- **Acute limb shortening:**

Limb shortening had a reasonable option for the management of PTF-BDs in certain situations. Of the available options, it had the shortest treatment times and results in the least complications. Acute limb shortening allows fracture healing to begin immediately, improves stability(compared with leaving a gap), and relaxes tension on the soft tissues. This technique also might improve vascularity, reduce neurogenic pain, and allow primary closure or coverage. However, excessive soft-tissue swelling and redundancy might be undesired consequences [20].

Shortening had better tolerated in the humerus than in other bones because, in the upper extremity, equality of limb length had less important functionally. Also, shortening had better tolerated in one-bone segments(ie, the upper arm, thigh) than in two-bone segments(ie, the forearm, lower leg) [20].

Femoral shortening often could be managed effectively by compensatory shortening of the contralateral femur, especially in cases of above-average height[20].

- **Autologous non-vascularized bone graft:**

Autologous nonvascularized cancellous bone graft remains a common method of managing posttraumatic femoral bone defects. Skeletal stabilization with external fixation, intramedullary rods, or plates might be done at normal length or with some shortening. The timing of the bone graft procedure had important[21].

Delaying it 6 weeks after a free-tissue transfer allows complete epithelialization of the flap, therefore decreasing bacterial contamination of the surgical site with skin flora. Healing of the flap to the surrounding native soft tissues also had ensured. Even when tissue transfer had not required, the autologous bone graft should be delayed for 6 weeks to allow wound healing and revascularization of marginally viable tissues[20].

The incorporation of a bone graft had improved by a host bed with stable vascularity. To improve the local blood supply around a diaphyseal defect at the time of graft implantation, all avascular scar tissue had débrided from the surrounding soft tissues. Another method had to recanalize the medullary canal that typically had sealed by the callus on both ends of the recipient's bone; doing so reestablishes the medullary blood supply. Vascular in-growth from surrounding tissue might be stimulated by making multiple small drill holes in local avascular cortical bone or abrading the local cortex with a fine burr[19].

The bone graft mass then had packed firmly, and contoured into the defect, overlapping the cortical ends by at least 1 cm. In general, the case had kept partial weight-bearing until radiographic consolidation of the graft occurs[21].

Autologous bone grafting is generally applicable to manage posttraumatic femoral bone defects, does not require special instrumentation or expertise, and ultimately allows reasonable restoration of function. However, graft incorporation typically had slow, sometimes unreliable, contributing to nonunion, re-fracture, or poor limb function. The technique might not be appropriate for large bone defects[21].

- **Free vascularized bone transfer:**

Vascularized bone transplantation could be done with the rib, fibula, or iliac crest. Free vascularized bone grafting had developed as an extension of microsurgical methods in the 1970s. The technique involves the isolation of a segment of the fibula with attached nutrient artery and veins. This segment had transferred to the femoral defect, and skeletal fixation had followed by vascular anastamoses[22].

The length of the graft had 4 cm more than the femoral defect to allow 2 cm of overlap at the proximal, distal ends. Five centimeters of distal fibula must be left at the donor site to avoid ankle problems, 7 cm of the proximal fibula is usually left to avoid knee and peroneal nerve problems. The average time to the union had from 3 to 6months. In posttraumatic reconstruction, this technique had a union rate of up to 90%[22].

Arai *et al.* reported frequent failure of free vascularized fibula bone transfer in the management of bone loss in femoral shaft fractures and abandoned the technique in favor of bone transport or bone graft. They noted that good results had been reported in cases with long-standing segmental nonunions, and suggested the technique might be more efficacious in that setting. Free vascularized fibula requires a recipient artery that had not essential to the survival of the limb, although this might not be available in some cases with posttraumatic femoral bone defects[23].

The vascularized fibula bone transfer technique had applicable to large defects, bone could be transferred to the radius, ulna, humerus, femur, or tibia. Living autograft tissue with good strength, immediate stability, disease resistance had transferred, and healing generally had rapid. Despite the improved reliability of microvascular techniques, the procedure still had technically difficult and requires specialty services. In addition, donor site morbidity particularly had problematic in cases with posttraumatic femoral bone defects whose contralateral leg had been placed under high functional demand. The technique perhaps had best indicated in very large defects in which the advantages of immediate restoration of skeletal continuity outweigh the disadvantages[22].

- **Bone transport:**

Distraction osteogenesis:

It had become the preferred technique in most cases with large lower extremity bone defects. This might be related to the increasing number of surgeons who had become familiar with this technique as well as to recent modifications such as distraction, bone transfer over the intramedullary nail to bridge a defect, and achieve function earlier[24].

The technique of distraction osteogenesis had used to effectively treat posttraumatic femoral bone defects. Originally, Ilizarov and others stabilized the limb with a circular external fixator, the bone transport segment produced by osteotomy of the metaphysis. After a 5-day latent period, this segment could be transported approximately 1mm per day to eliminate the diaphyseal segmental bone defect and create a new defect at the osteotomy site. This defect fills with new bone by the process of distraction osteogenesis. The docking site heals in compression by fracture callus. Two to three days of consolidation had required for each day of distraction. Bone graft typically had applied to the docking site, and the ends of the bone might be freshened to stimulate healing[24].

Other refinements of bone transport had been reported. Unilateral rail external fixator techniques had been reported to decrease the soft-tissue problems of transfixion wires. These rail fixators had multiple pin-holding clamps that slide along rails to achieve bone transport or lengthening. They had particularly useful when angular correction had not required. Distraction over a nail had been reported to reduce time in a fixator, allow the earlier return of function, and minimize the incidence of malalignment. The potential disadvantages include disruption of the regeneration by the nail and the risk of medullary disease from contamination of the nail by pin tracts[25].

Successful treatment of PTF-BDs with the Ilizarov technique had reported by many authors. Very large defects (up to 30 cm) could be treated in both adult cases, while concomitant deformity and soft-tissue problems could be addressed in all portions of the extremity. This technique requires specialized training, and equipment as well as a long treatment duration, it had associated with frequent complications. Despite these problems, some form of distraction osteogenesis had probably the most commonly used method of managing intermediate, large PTF-BDs[25].

- **Other management techniques:**

Other techniques for managing PTF-BDs might be applicable, but they had not been accepted routinely [2].

A- *Allogeneic bone:*

Structural allograft had been used to restore bone stock in cases with revision arthroplasty or tumor resection, but it had failed in most PTSBDs because of disease, slow, incomplete remodeling, and high rate of fracture [26].

The use of allograft bone accounts for approximately one-third of bone grafts performed in the United States. It had an attractive alternative to the autogenous bone as it avoids donor site morbidity, and its relative abundance permits it to be tailored to fit the defect size. Despite its use in other zones of orthopedics such as in spinal surgery or joint arthroplasty, considerably less had known about its use in the repair of fresh fractures or nonunions. This might be in part related to the risk of blood-borne disease transmission, and suboptimal clinical results compared to autografts [26].

B- *Demineralized bone matrix:*

The human demineralized bone matrix had a form of allogeneic graft material. Although widely available, known to contain Bone Morphogenetic Protein(BMP). **DeCoster *et al.* had** used demineralized bone matrix as a delivery vehicle for bone graft substitutes while others had suggested its use in conjunction with the autologous cancellous bone to increase the volume of graft material[2].

C- *Titanium cages:*

Titanium cages containing bone graft material recently had reported for the management of PTF-BDs, with reasonable success. The data had preliminary, but the risk of disease and difficulty with the removal of the cage had concerns [27].

D- *Bone graft substitutes:*

An ideal bone graft substitute should provide three elements: scaffolding for osteoconduction, growth factors for osteoinduction, and progenitor cells for osteogenesis. The currently available materials include calcium phosphate ceramics, calcium sulfate, bioactive glass, biodegradable polymers, recombinant human BMPs(OP-1, BMP-2), and autologous bone marrow cells, each fulfills only one of these criteria. However, there had a great interest in improving these materials as the availability of an effective bone graft substitute would solve some of the current limitations associated with the use of autologous bone [28].

E- *Gene therapy:*

Gene therapy initially had evaluated, but zones of concern remain, such as the production of safe vectors for gene therapy, and the assurance that the altered cells would be subject to normal control mechanisms, and not create undesired consequences[27].

All methods for the treatment of PTSBDs require a long time. For most techniques, time in the treatment had related directly to the length of the defect, with approximately 1.5 months needed for every centimeter of defect, in addition to the usual time for the fracture to heal. A femoral shaft fracture(basic healing time, 4 months) with a 5-cm defect(5 x 1.5 = 7.5months) would require approximately 1 year (4+7.5=11.5 months) of treatment[17].

Most cases had not aware of the likely time of treatment at the initial injury, so this should be discussed early. Prolonged time in treatment prevents the case from engaging in normal activities and causes disuse atrophy, loss of income, and psychological stress [17].

Watson *et al.* reported equivalent treatment times(total treatment time, time to osseous union) in cases with femoral shaft fractures with bone loss who had been treated with either un-reamed nails(average, 43 weeks) or external fixators(average, 45 weeks) [29].

Cierny and Zom found no difference in treatment time when bone graft and bone transport had compared in cases with the disease that caused segmental bone defects[30]. **Marsh *et al.*** reported the same treatment time for bone transport, and bone graft in cases with chronic diseased femoral nonunions with the bone loss [31].

Future directions:

Advances in pin technologies had decreased the rates of pin sepsis as well as pin-related pain. Hydroxyapatite-coated pins provide a critical increase in direct bone apposition with a decrease in the fibrous tissue interposition at the pin-bone interface [32].

Because of the improved biocompatibility, and lower pin-bone interface stresses afforded with titanium, titanium alloys, many investigators think that there had a lower rate of pin sepsis with these types of pins[33].

The emergence of orthobiologics holds great promise for large-scale skeletal transports. The ability to augment large regenerate segments with percutaneously applied growth factor adjuvants to reduce prolonged consolidation times had an attractive alternative to spending 1.5 to 2 years on a transport device. Similarly, some of these same materials had currently being used to augment docking site union, and distraction gap consolidation, with early good results. Advances in intramedullary designs might eventually decrease the need for external transport devices[34].

Ideally, the ultimate goal could rapidly distract a transport segment with a simple fixator construct or intramedullary device, followed by percutaneous application of docking, and regenerate site enhancements to achieve rapid consolidation [35].

CONCLUSION

Bone loss had a relatively uncommon problem encountered in the treatment of open fractures, which usually occur in the femur and tibia. The majority of defects had small and could be managed with standard methods of fixation, and autogenous bone grafting. Larger defects with complex soft-tissue problems could be managed by shortening, fixation with later lengthening. New intramedullary lengthening nails might have a role to play. If there had no major problems with soft tissues, fixation, and later bone transport could be considered. Circular frames had particularly useful for more complex problems. Free fibular grafts now had a more limited role. In the future bone morphogenetic proteins in an appropriate carrier might prove useful. Restoration of satisfactory limb function had the main aim, if there had extensive soft-tissue damage, amputation might be preferable.

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