Reconstruction of Traumatic, Open Supracondylar Femoral Fractures by Autologous Fibular Strut Grafting and Cortico-Cancellous Bone Grafting - A Single Centre, Observational Study

Short Title: Reconstruction of Bone loss in supracondylar fractures femur

Author list: Raju Iyengar M.S. DNB, Nagesh Cherukuri M.S, Chandrasekar Patnala M.S

Institutional Affiliation of all Authors: Department of Orthopaedics and Traumatology, Nizam’s Institute of Medical Sciences, Hyderabad-82, India

Address for Correspondence:
Raju Iyengar, M.S. Orth. D.N.B. Orth.
Associate Professor
Department of Orthopaedics & Traumatology
Nizam’s Institute of Medical Sciences,
Punjagutta, Hyderabad. 500 082.
Telangana
E-mail: rajuayengar@rediffmail.com
Mobile: +91-99858 11481
Fax: +(91)-40-23310076

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ABSTRACT

Objectives. To study the safety and efficacy of staged reconstruction of distal femoral (supracondylar) bone loss using autologous fibular strut, cortico-cancellous bone grafting.

Design. Single Centre, Observational study, with review of literature.

Setting. Urban Level I Trauma Centre,

Patients/Participants. 18 consecutive patients (mean age: 35± 8.5 years, all males) with open supracondylar fracture and intercondylar extension (Type C3), (AO type) operated between January 2010 and February 2014 with severe bone loss in 11 patients and moderate loss in 7.

Intervention: Single free fibular strut was used in 12 femurs and dual fibula in five femurs with autologous cortico-cancellous bone grafting in all.

Main Outcome Measures. Clinical union, radiological union, and knee function using the Sanders score.

Results: Mean follow-up was 45.5± 17 months. The mean radiological union time was 18 ± 2.6 weeks. Functional assessment after union revealed one patient with excellent knee function, 11 good, five fair, and one, poor function according to Sanders scoring. The mean knee range was 49°(range 5°-110°) in which nine patients achieved a knee range >80°. Mean limb shortening was 2 cms (range 0-7 cms). No limb shortening was observed in five patients. Patients were pain free and had no significant graft or donor site morbidity.

Conclusion: Staged fibular strut grafting, cortico-cancellous bone grafting for traumatic open supracondylar femoral fractures with significant bone loss is a promising technique with a good safety profile and long-term efficacy.

Keywords: Supracondylar fracture femur; bone loss; free fibular reconstruction; fibular struts; cancellous bone grafting.

INTRODUCTION

Distal femoral fractures are rare with a reported incidence of 4% to 7%. They have a bimodal distribution: low energy fractures at old age and high energy fractures in younger individuals. Trauma due to high energy fractures are often complex and challenging to treat, especially when there is severe bone loss.

About one third fractures of femur occur in the supracondylar area of which 10% are open injuries. The femur is the second most common site of bone loss. It amounts to 22% of all traumatic skeletal losses. In two wheeler accidents, the rider is hit in the knee in a flexed position, creating distal femoral comminution and is associated with proximal tibial and patellar fractures. As the distal femur has very few muscular attachments, especially on the anterior surface, it is more prone for expulsion of the fragments leading to bone loss. Frequently, there is associated crushing of the articular cartilage especially in the intercondylar area. The wound of exit at times will be very small but large fragment will be ejected and the wound shrinks because of the elasticity of tissues.
Attempting limb reconstruction in the presence of significant bone loss usually involves multiple surgeries.\(^2,3\) With the advent of modern techniques of fracture stabilization and soft tissue reconstruction, while it is possible to salvage severely injured limbs in the acute phase, subsequent stages of anatomical reconstruction are challenging. Bridging the areas of skeletal loss with viable bone while maintaining limb length, alignment and rotation do not always correspond to a satisfactory functional outcome. Multiple surgeries are psychologically and financially demanding, time consuming and often yield poor results.\(^4\) The relative rarity of these injuries and the considerable variation in their configuration makes it challenging to establish a standard management protocol. Therefore, a flexible and individualized approach to treatment is required in these patients.

In our Institute, we used a single stage reconstruction with autologous, free, non-vascularized fibular grafting and autologous cortico-cancellous bone grafting followed by lateral plate application for these injuries. The safety and efficacy of this method has not been explored before. We now report our experience.

**PATIENTS AND METHODS**

This is a retrospective study performed in the Department of Orthopaedics and Trauma Care, at a multi-specialty, tertiary care hospital. The study population include all patients who underwent surgery for open, comminuted, supracondylar and inter-condylar femur fractures with bone loss of a moderate to severe grade between January 2010 and February 2014. After initial stabilization and wound debridement, fractures were treated with open reduction and fixation with reconstruction of bony defect by fibular grafting and autogenous cortico-cancellous bone grafting. The clinical presentation, surgical details and post-operative follow-up were retrieved from medical records. The safety outcomes studied included: post-operative surgical site wound infection, donor site morbidity, vascular occlusion, and deep vein thrombosis. The efficacy parameters considered were clinical union time, radiological union time and cumulative functional score as assessed using the Sanders functional scoring system.\(^5\)

Initial management and pre-operative preparation

Patients were medically optimized in the emergency room before surgery. All patients underwent debridement of the wound and a groin to toe slab support except for 3 patients that were treated with an external fixator (2,13,16). The wound was then sutured over a corrugated rubber drain and examined periodically. Vascular insufficiency if any, at the time of presentation was assessed by clinical examination. If posterior tibial/dorsalis pedis pulses were absent or feeble on palpation in the fractured leg compared to the contralateral side, a Doppler study was performed using a hand-held vascular Doppler device. In patients who had Doppler signals less than 2+, further evaluation by contrast spiral computed tomography and color Doppler study were done. Routine antibiotic prophylaxis included institution of a combination of broad spectrum antibiotics at the first hour after obtaining the wound swabs for culture and sensitivity from the open wound. The combination included intravenous Cefotaxime sodium one gram STAT and then three times daily, Amikacin sulfate 500mg and Metronidazole 400 mg STAT. The regimen was modified later (if required) based on the wound swab culture and sensitivity report. During optimization of the patient, the wound was periodically examined every 24 hours. In case of wound infection, further wound debridement was performed or antibiotics modified. The antibiotics were changed from intravenous to oral route on the seventh day and continued for another three more days, or till the definitive surgery. Intravenous antibiotics were continued for five days post definitive surgery and then changed to oral antibiotics.

Definitive surgery

The definitive surgery was performed when the patient was optimized medically and psychologically. All associated injuries below the hip joint were addressed along with the index surgery. Injuries of acetabulum and upper extremity were treated subsequently. The procedures were performed under spinal anaesthesia. The characteristics of injury and recovery of all patients is given in Table 1.
Internal fixation

The surgical approach was the standard, lateral distal third in all cases. Definitive surgery in the form of internal fixation for supracondylar bone loss was performed in four steps: Reconstruction of the articular block, fibular grafting, cortico-cancellous bone grafting, and stabilization using a variety of methods.

Reconstruction of articular block

Reconstruction of the articular block was carried out after studying the relative rotation of both condyles. The limb length was equalized to the contralateral leg with a longitudinal traction. Following this, having the position of the medial condyle as the reference, the lateral condyle was de-rotated, translated and reduced to medial condyle, creating an articular block, and temporarily fixed with K wires.

Fibular grafting along with correction of coronal tilting of the articular block

The fibula (e) was harvested according to standard protocol after assessing the extent of bone loss. Ipsilateral fibula was preferred because of ease of harvest. Use of single or double fibular strut grafting was based on the columnar reconstruction. If both columns needed to be addressed, then dual fibulae were used. At least 2 cms. additional to the required length of fibula was harvested to compensate for the length that would be buried at both the ends. One or two long K wires were passed retrograde into the condyles medially and laterally under fluoroscopic guidance and served as the site for the fibular strut. An 8 mm reamer was used to ream over the K wires into the condyles for about 10 mm and the fibula was threaded over the K wires to bury the distal end of the fibula in the metaphyseal area of respective condyles. Reamer induced aspirate from the proximal femur was obtained manually and stored.

Cortico-cancellous bone grafting

The anterior iliac crest tricortical bone grafts were harvested from ipsilateral side. These were nibbled and mixed with reamer induced aspirate and placed in the supracondylar area at the proximal fibula-femur junction, around the fibular grafts and over the entire length of the autograft. When dual fibulae were used, grafts were placed between the fibulae. Following this, the rent in the quadriceps was identified and repaired. As large volumes of ipsilateral anterior iliac crest are harvested, to prevent herniation at the site, the incision was made meticulously and confined to sub-periosteal region. This provides innate strength to the muscles and prevents herniation. Fibular grafts were then obtained to the desired length.

DEFINITIVE SKELETAL FIXATION

The use of implant DCS, CBP and Ilizarov was purely based on clinical judgment of the strength, the integrity of the articular block and its position. If the articular block was strong enough to hold the DCS lag screw and not rotated much, then DCS was preferred otherwise CBP was used. In cases where the internal milieu was not congenial for internal fixation then Ilizarov fixation was used for definitive skeletal stabilization. All implants were procured from Bombay Ortho® Rajkot India.

Once DCS as an implant is decided, then the articular block was held with a bone clamp. Under fluoroscopic guidance, a 2mm guide wire was passed in the articular block transversely as per the standard principles of DCS fixation, i.e. the guide wire is 2cm above the knee joint and at the junction of posterior two thirds and anterior third in the condyles. Reaming is done by a triple reamer over the guide wire and lag screw is passed in a standard fashion with a care not to keep the lag screw proud, which irritates the lateral structures.
this juncture, the lag screw remains anterior and the fibula is in the posterior part of condyles. An adequate dimension of barrel plate is selected so that minimum of 4 bicortical screw purchase is there in femur bone. The fibula(e) will be placed abutting the femoral proximal femoral cortex and the intramedullary “K” in the fibula will be driven into the femoral medullary canal so that the fibula is stabilized. The barrel plate is fixed in compression mode with few mm of longitudinal compression.

In cases where the articular block was coronally tilted and with significant comminution then condylar buttress plate was chosen as internal fixation device. An appropriate length and side specific condylar buttress plate was selected such that four good bicortical screw purchase is obtained in the proximal fragment of femur. This CBP is placed over the coronally tilted articular block and fixed with two or three fully threaded 6.5 mm non-cannulated cancellous screws. The entire fibula plate construct was then used as a lever to correct the coronal tilt of the flexed articular block, reduced to shaft of femur and clamped to the proximal femur with a Verbrugge clamp. The fibula(e) will be placed abutting the femoral proximal femoral cortex and the intramedullary “K” in the fibula will be driven into the femoral medullary canal so that the fibula is stabilized. A longitudinal compression by a few millimeters was applied to the construct to enhance the stability and proper union. Screws were then driven into the condylar buttress plate and K wires projecting form medial and lateral end of knee joint was bent.

In cases where the internal milieu was not good for internal fixation, then Ilizarov method was used for definitive skeletal fixation. The Ilizarov set was procured from Bombay Ortho® Rajkot, India. The limb was held in mild traction and in anatomical position and transarticular fixation, including the knee was done with standard Ilizarov principles. The proximal tibia was included in the fixation as only distal femur fixation was inadequate. The first K wire 1.8mmX 400 mm was passed in tibia, transversely along the transcondylar axis above the fibula1.5 cm below the tibial plateau. Another wire is passed parallel to medial surface of tibia starting 10 mm lateral to anterior border and with an angle of minimum 30° to first wire. Third wire is passed from fibular head to tibia at an angle of 45° to the first wire. These wires are tensioned on an appropriate sized ring and foundation established. Now ilizarov wires were inserted into the articular block, first wire is always the transcondylar wire at the level of center of patella, at the level of epicondyles, lateral to medial, parallel to the transcondylar wire of tibia. An appropriate size half rings are then attached and connected to tibial ring. Another wire is passed skirting the ring, at an angle of 45° to the transcondylar wire in femur anterolateral to posteromedial in the articular block. Third wire is passed posterolateral to anteromedial in the articular block. Care is taken while passing these wires the knee is flexed to more than 30° so fascia lata and the iliotibial band and the lateral structures are in physiologic tension otherwise knee range is restricted. The tensioning of wires is done sequentially, first the transcondylar femoral wire is tensioned, the distal articular block was extended manually and by applying tension to the distal wires to appropriate upper holes of the Ilizarov ring so that the wires appear like a hammock before tensioning and the tensioning itself will realign the articular block. The is A 6mm tapered schanz pin is applied in proximal fragment and connected to an Italian arch. The distal ring and the proximal Italian arch is connected with 3 connecting rods, while connecting the alignment of fibula(e), articular block and proximal fragment is manually maintained and compressed to increase the stability of the bone grafts. While applying schanz pins care is taken to approximate the surgical incision and then apply the pins. Two more bicortical tapered schanz pins are applied to proximal fragment and connected to Italian arch in different plane to increase the stability.
Thirteen patients were treated with internal fixation with a lateral condylar buttress plate and dynamic condylar screw was used in two patients. In five patients where, the internal milieu was not congenial for internal fixation, the Ilizarov method was used for stabilization of the construct. These patients had physiological degloving of skin, persistent sterile discharge from the exit wound and extensive muscle contusion. So, we avoided internal fixation in these patients and applied Ilizarov frame. In total, 23 struts of fibula were used with a mean length 8.6 ± 1.1cms. All surgeries were done by a single, experienced surgeon. The mean time interval between injury and definitive surgery was 13.7± 6.6 days.

An appropriate length dynamic condylar plate procured from Bombay Ortho® Rajkot, India, was placed over the coronally tilted articular block and fixed with two or three fully threaded, 6.5 mm non-cannulated cancellous screws. The entire fibula construct was then used as a lever to correct the coronal tilt of the flexed articular block, reduced to shaft of femur and clamped to the proximal femur with a Verbrugge clamp. The fibular grafts were then placed intramedullary into the shaft of femur about 10 mm to increase the stability (Figure 1). The K wires were driven intramedullary into the shaft of femur for better stability. A longitudinal compression by a few millimetres was applied to the construct to enhance the stability and proper union. Screws were then driven into the plate and K wires bent.

In patients where Ilizarov fixation was used, transarticular fixation was done with standard Ilizarov principles. The distal articular block was extended by applying tension to the distal wires to appropriate upper holes of the Ilizarov ring so that the wires appear like a hammock before tensioning. Proximally, three tapered 6 mm Schanz pins were used for stabilization in three planes.

Post-surgical management and follow-up

After the surgery, static quadriceps exercises were started on the first post-operative day along with manual patellar mobilization. The patients were discharged on the 5th post operative day and called for suture removal on 12th day. The patients with Ilizarov frame were made to walk on 3rd day itself except two patients. The range of motion was started gradually over three weeks. Knee mobilization was started on the third week after the surgery, initially gently active, then assisted and then on continuous passive motion machine. Continuous Passive Motion device (CPM) was used in the 3rd week in 10 patients and continued for two weeks. Knee range was started at six weeks for fractures associated with patellar fractures treated conservatively. Weight bearing was started after radiological union. The patients were then followed at six month intervals for any symptoms.

Definitions

Clinical union: Painless weight bearing and lack of local tenderness over the site on physical examination. Radiological union: Bridging of the bone on a minimum of three cortices on conventional antero-posterior and lateral radiographs.

Statistical Analysis

All data following normal distribution are reported as mean ± standard deviation (SD) and categorical variables as frequencies and percentages.

RESULTS

Eighteen patients underwent surgery during the study period. all 18 had a Grade IIIA open fracture, as per the Gustilo & Andersen classification. All patients were males with mean age of 35± 8.5 years (range: 18 to 56 years). High velocity road traffic accident was the cause of injury in all patients. Fifteen patients had associated
injuries. In all but one, the injuries were limited to the right side. Two patients were given external fixation elsewhere and referred for further management. One patient underwent spanning external fixation in our institute.

Follow up

The mean follow-up was 45.5±17 months (Range: 17 months to 66 months). The mean radiological union time was 18±2.6 weeks. Functional outcomes were assessed at the final follow up using the Sanders scoring system. The scoring takes into consideration the following: knee flexion, extension, angulation, shortening, pain, walking ability, staircase climbing and return to work, for a total score of 40 points (exc. 36-40, good 26-35, fair 16-25, poor <16). Based on these activities, one patient had an excellent outcome, eleven good, five fair, and one poor function. The mean Sanders score on final follow up was 29.4±3.9/40. The maximum possible score is 40. All patients were pain free at the final follow up. The individual scores are given in table 1.

The post-procedure limb shortening was calculated from anterior superior iliac spine to medial malleolus using a tape. It was 2 cms (range: 0-7cms). Five patients had no limb shortening. No patient had an extensor lag. However, due to the need for delayed ROM, 6 knees only had 5 degrees of flexion, one had only 10 degrees of flexion while 2 had less than 40 degrees of flexion.

Regarding radiological union, all the fractures went onto union, since there was significant bony discontinuity between the condyles and the shaft there was quite a degree of malunion in this cohort. Radiological malunion was considered when the angular deformity exceeded 10° and the condyles failed to unite in normal rotation. Two patients had valgus angulation at the fracture site (32° &22°) respectively. Two patients had varus deformity of 11° and 16° respectively. Three patients had recurvatum deformity. There was malunion with condyles in extension in 7 patients. Among the seven patients who had malunited and extended condyles, the knee range was uniformly poor in 5 patients except case no.10 and 11. This shows the relation between anatomical restoration of articular block and knee function.

The gait pattern was bipedal, unassisted normal gait without any shortening in eight patients. Six patients had normal unassisted gait pattern requiring a shoe lift. Two patients had a Trendelenburg gait pattern. One patient used a walking stick prior to injury and continues to use it even after the definitive treatment. One patient uses a standard walking frame for ambulation.

The mean knee range was 49°(range 5°-110°). Nine patients achieved a knee range >80°. One patient (5.5%) developed a sinus, which was a deep infection which drained consistently and healed after implant removal. The mean duration of hospital stay was 17.7±3.5 days. The patients became symptom free and had unassisted gait at the end of 18 weeks. None of the patients developed vascular occlusion, deep vein thrombosis or had donor site morbidity at either fibular or iliac crest sites. The major surgical steps and post-operative knee range of a representative patient are shown in Figures 2a-2d.

DISCUSSION

Our study shows that single stage reconstruction of large bone defects in the distal femur with autologous fibular struts and cortico-cancellous bone grafts is feasible and offers favourable outcomes. We believe this is due to stable fibular fixation to the columnar bone loss along with adequate addition of bone volume to the entire length of the fibular graft. Many studies have described the treatment protocols for bone defects in limbs due to various tumors \(^9,10,11\) and defect non-unions \(^12,13,14,15\). To the best of our knowledge, this is the only series that discusses voluminous bone loss due to acute, high energy trauma of the supracondylar region of femur.
The fibula is the strongest and longest autogenous bone graft available. It can be harvested with minimal donor site morbidity as seen in our series of patients.\textsuperscript{13} It is technically less demanding, quick and inexpensive.\textsuperscript{9,10,11} Anchoring the fibula in the defect with intramedullary wires helps to replace the lost supracondylar ridges.\textsuperscript{9} Sinking the fibula (e) into the soft cancellous bone of distal metaphysis of the femur aids in maintaining the length. This arrangement also provides good nutrition and promotes early revascularization of the fibular graft and enhances union. When a lateral plate is used compression can be used to further enhance union. Because isolated free fibular grafts are prone to stress fractures, the addition of adequate volume of autologous cortico-cancellous bone graft to the entire length of the graft avoids this complication.\textsuperscript{11} Regarding stability of the construct, alignment and knee range, we concur with other authors that internal fixation in the form of locked lateral plate gives better stability over external fixation.\textsuperscript{2,15,21,22} Studies have shown that knee motion can be achieved early with primary internal fixation.\textsuperscript{16,22} The lateral buttress plate helps in effective extension of the articular block and in correcting the coronal tilt of the articular block more than an external fixation device.\textsuperscript{15,22}

Acute docking and lengthening by the Ilizarov method produces a peculiar deformity, lateralizing the proximal fragment and change in mechanical axis. Moreover, shortening more than 6 cms should not be attempted as it may cause neurovascular compromise\textsuperscript{4}. Ilizarov method requires a substantial learning curve and also effective patient cooperation.\textsuperscript{4,17,13} The procedure spans over nearly two years for the establishment of effective bone growth.\textsuperscript{12} The small distal articular fragment makes the surgeon opt for transarticular fixation, which in turn decreases and tethers the knee.\textsuperscript{18,19} The long-term immobilization results in knee-joint stiffness, pin tract infection, cartilage destruction and muscle fibrosis.\textsuperscript{4}

As observed in a series reported by Coulet et al,\textsuperscript{15} achievement of adequate knee range is a problem with metaphyseal bone losses of distal femur fractures. As most of the cases have articular comminution with articular bone loss, even the best articular reconstruction leaves some void because of the crushing of articular cartilage. This is compounded by injuries to patella which adds to the problem of the damaged extensor apparatus. Reconstruction using strut grafts ad a lateral plate minimizes this problem to a certain extent as the knee can be put to mobilization by early weight bearing. Though a good range of knee motion was not attained in nearly one third of our patients, adequate replacement of bone loss was provided, good limb alignment achieved and patients were pain free. More importantly, stability of the knee was achieved which made activities of daily living possible.

The study sample is small and only historical comparisons made to other methods. The assessment of bone loss was solely based on the length lost and not by bone mass. Replacement of bone volume is extremely important in the prevention of stress fractures. Use of advance fixators like Taylor’s spatial frame instead of Ilizarov, along with continuous regional analgesia would have possibly given better outcomes\textsuperscript{20}. The other limitation is all surgeries were done by a single, experienced surgeon. It is unsure if the results could be affected by variability of the experience of the operators.

CONCLUSION

The use of autologous, free, non-vascularized fibular grafts with autologous cortico-cancellous bone grafts is a useful method in the treatment of significant bone loss due to acute, massive traumatic metaphyseal bone loss of the femur. It has an acceptable short and long term outcome and can be a good alternative to the staged procedures and expensive prosthetic grafts which also have inherent drawbacks. This method is
especially useful in countries where cost is one of the main determining factor in the choice of treatment. The incorporation of bone grafts at the end of 18 weeks makes this a viable alternative to multiple procedures.

REFERENCES


<table>
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<tr>
<th>S No</th>
<th>Age in years</th>
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<td>10</td>
<td>CBP femur</td>
<td>00-110°</td>
<td>41, Excellent</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>Moderate</td>
<td>Closed # both bone Right Leg, # 5th metacarpal Rt, # 2nd digit middle phalanx, # ring finger proximal phalanx</td>
<td>10</td>
<td>CBP femur</td>
<td>00-30°</td>
<td>24, Fair</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

Foot Notes. CBP Condylar buttress plate. DCS Dynamic Condylar Screw # Fracture. Lt. Left, Rt. Right...SSG Split Skin Grafting.
Graph No. 1

INDIVIDUAL SANDERS SCORING AT FINAL FOLLOW-UP

1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18

- Flexion
- Extension
- Abduction
- Adduction
- Shortening
- Lengthening
- Mallet finger
- Swelling
- Infraclavicular weakness
- Intraclavicular weakness

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Fig 1. Showing the bone gap reconstructed with dual fibular graft and Fracture fixed with condylar buttress plate.
Fig 2 a. Pre Op radiograph showing the Supracondylar bone loss.

Fig 2 b. Showing Immediate Post op reconstruction of the bone loss

Fig 2 c. Showing complete remodeling of the gap

Fig 2 d. Showing the knee range of the same patient.