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Role of Non Vascularized Fibula Graft in the Management of Post Osteomyelitic Bone Defects in Children

Anil Agarwal MS Ortho [1], Ankur MS Ortho [1], Ankit Jain D Ortho [1]

Abstract

Osteomyelitis continues to be widely prevalent in low socioeconomic countries. The challenges associated with the disease include weakened pathological bone, cavities, pathological fractures, non-union and gaps. This article discusses uses of non-vascularized fibular graft for management of the sequelae of osteomyelitis. A review of literature reveals this technique to be quite successful with fewer complications. Being technically less demanding and easy, this procedure remains an important tool in the management of bone defects due to osteomyelitis in children.

Keywords: Osteoarticular infection, Reconstruction, Bone graft

Dr. Anil Agarwal

Dr. Ankur

Dr. Ankit Jain

Address of Correspondence
Dr. Anil Agarwal,
Department of Paediatric Orthopaedics, Chacha Nehru Bal Chikitsalaya, Geeta Colony, Delhi, India.
E-mail: anilrachna@gmail.com

[1]Department of Paediatric Orthopaedics, Chacha Nehru Bal Chikitsalaya, Geeta Colony, Delhi, India.

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Introduction

Due to the socioeconomic conditions in low-income countries, there is a significant burden of septic arthritis and osteomyelitis in the pediatric population. Both conditions are associated with significant morbidity, at presentation and in terms of their sequelae. The early phase of osteomyelitis is characterized by pain, swelling, inflammation, discharging sinuses and loss of function besides associated constitutional symptoms. The radiological changes can be varied: osteopenia (certain varieties may present as sclerosis), periosteal reaction, erosions, cavities or sometimes pathological fractures. In established cases, there can be considerable devitalization of skin and soft tissues. Previous operative scars and scarring due to healed or active sinuses may be present in the surrounding area. The extremity may exhibit deformity alongside loss of joint motion. Radiological findings may deteriorate to reveal osteopenia, sequestra, involucrum, cavities, bone gaps/ loss, pathological fractures, nonunion, tapering metaphyseal ends (likened to "rat tails"), concurrent physeal plate involvement and growth disturbance of variable severity.

The management of osteomyelitis is directed at identification of organism and control of infection using appropriate antibiotics. Decompression or debridement may be warranted to reduce the bacterial load and remove necrotic tissues. In the chronic scenario, debridement, sequestrectomy, reconstruction of soft tissue/ osseous defects and deformity correction remain the mainstay of treatment.

The management of osteomyelitis and its sequelae needs to be individualized, incorporating careful consideration of the local and general condition of the child. The treatment option may sometimes be dictated by site of osteomyelitis and experience of the clinician. For example, in case of sequelae involving the forearm bones, the possible options can include single bone formation, producing cross union between forearm bones, osteogenesis using Illizarov/ external fixator application, Masquelet technique, and autogenous/ autologous bone grafting [1-9]. Additionally, some clinicians prefer the surgeries to be staged, with primary surgery aimed at

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control of infection followed by reconstruction [10].

Bone grafts are used extensively in children, either to fill bone defects or achieve osteosynthesis. Among all donor sites in the paediatric age group, the fibula occupies a unique position. It fulfils the fundamental properties of an autogenous graft (osteoconduction, osteoinduction and osteogenesis), and additionally offers ease of access, unique triangular shape characteristics, cortical strength and choice of sides for harvest. The current review article briefs the use of non-vascularized fibular graft for management of osteomyelitis in children. The tool has been variously used for both early stages and reconstruction of post-osteomyelitis defects. The graft usage will be discussed under the following sections: presentation or post debridement defects, impending pathological fractures, nonunion and bone gaps/loss.

A. Presentation or post debridement defects

The presentation of osteomyelitis may be cystic cavities in the metaphyseal or diaphyseal region [11,12]. There is a distinct risk of collapse or pathological fractures with large cavities, more so when the lesions abut the physis [13,14]. In some cases, debridement of necrotic bone and sequestrum create such defects in the osseous structure. Another scenario is chronic osteomyelitis with sclerosis e.g., Garre's sclerosing osteomyelitis, when resection of hyperostosis lesion creates a significant bone defect [15,16]. Post debridement, these cavities become filled with blood and offer an ideal growth milieu for the residual bacterial population. It is therefore desirable that such cavities are filled with an inert material. We have used non vascularized fibular grafts for filling such cavities. They double up as filling material and promote healing of the osseous defect. The biological activity initiated the region due to bone grafting (i.e., neo-vascularization and neo-osteogenesis) supplements antimicrobial therapy to eradicate infection (Figure 1, 2).

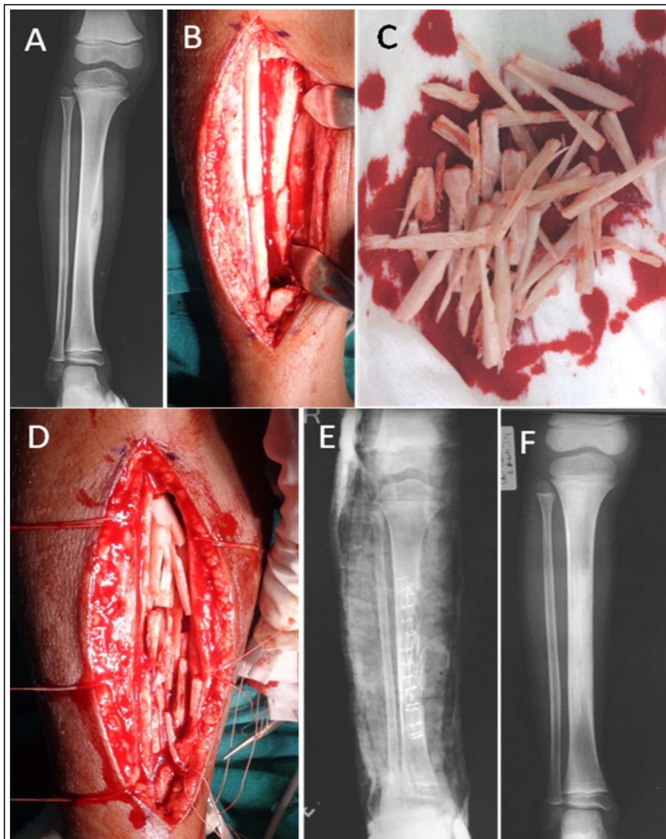

Figure 1: Post saucerisation defect reconstructed with non vascularized fibular graft: A. 7 year child with Garre's sclerosing osteomyelitis of right tibia B. Saucerization procedure left a cavity on the medial aspect of bone C,D,E. Bone grafts obtained from contralateral fibula made as match sticks, used to fill dead space. F. Follow up 6 months: healing and control of infection.

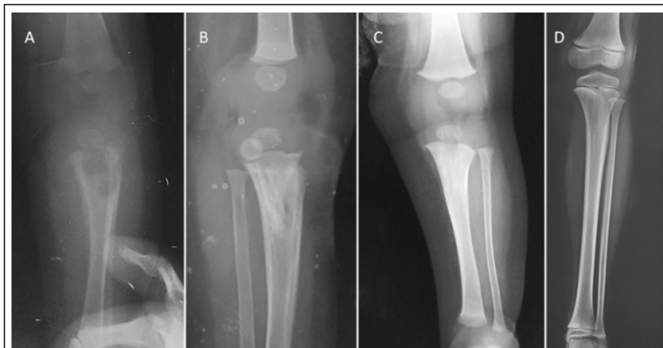

Figure 2: Cystic presentation of osteomyelitis packed with match sticks fibular grafts: A. 1 month old child with cystic presentation of osteomyelitis. Aspiration grew methicillin-resistant staphylococcus aureus B. The cavity was debrided. There was a large bony void post debridement. To obliterate dead space and prevent collapse, the cavity was packed with non vascularized fibular graft. The procedure was covered with sensitive antibiotics for 6 weeks and limb splinted in an above knee slab C. Follow up 3 months: control of infection and incorporation of graft D. Follow up 8 years: Normal osseous structure.

B. Impending pathological fractures

Osteomyelitis may primarily weaken the bone or the resulting bone loss makes the osseous structure prone to pathological fractures. In such cases, the bone grafting coupled with stabilization promotes healing and also helps control infection (Figure 3).

C. Nonunion

The infected bone loses periosteum and the bone ends become necrotic resulting in a gap non-union, which may continue to harbour the original pathogen (infected non-union). Mechanical instability precludes union. The tapering unhealthy bone ends neither permit secure fixation nor do they support healing. Any treatment plan in post-osteomyelitis non-union must aim at control of infection through debridement, achieving mechanical stability of the fragments, and some form of osteogenic stimulus

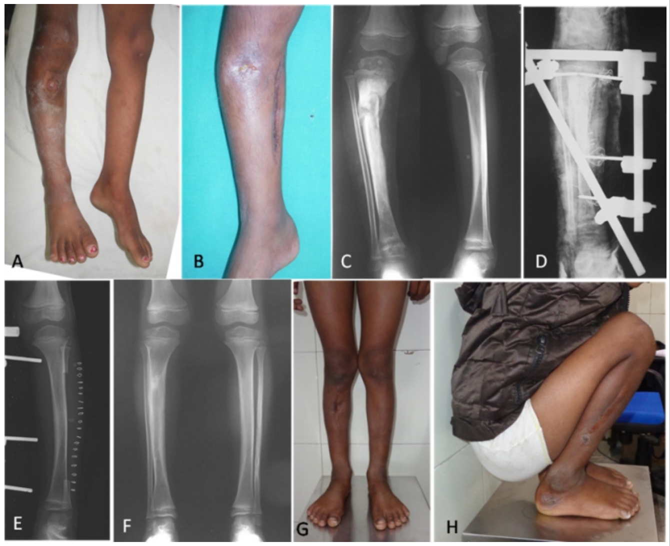

Figure 3: Impending fractures associated with chronic osteomyelitis managed with stabilization and bone grafting: A,B. 5 year child presented with discharging sinus in right proximal tibia. There was a large scar on the posteromedial aspect of limb representing previous operative interventions C. Radiographs revealed a large sequestrum and impending pathological fracture of proximal tibia D. Management using debridement, stabilization with external fixator and bone graft E. Fibular donor site post resection E. Follow up 3 years: Healing of the lesion and incorporation of graft. The fibular donor site has also regenerated F,G. Restoration of normal alignment and knee function.

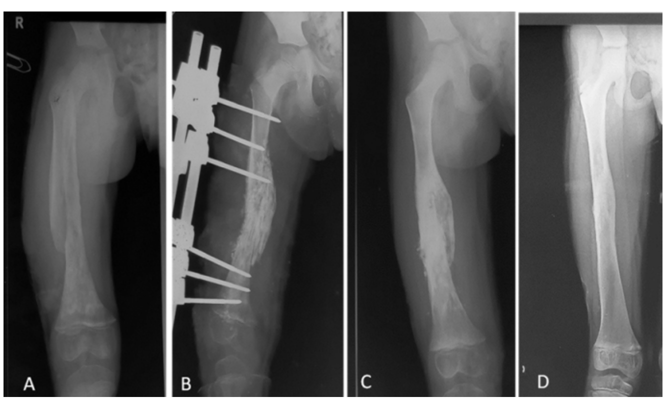

Figure 4: Use of non vascularized fibular bone grafts for infected femoral nonunion: A. Infected femoral nonunion in a 6 year old child B. 'Single stage' protocol with thorough debridement, acute docking, stabilization, copius grafting and coverage with sensitive antibiotics C. Healing obvious by 3 months D. Follow up 4 years: Infection healed and graft incorporated.

to promote union [17].

We have been using a 'single stage' protocol utilizing non-vascularized fibular graft to address such problems in children [18, 19]. We perform an aggressive debridement followed by application of an external fixator to ensure mechanical stability and use of copious bone graft spanning the nonunion site. High doses of antibiotics according to culture/sensitivity are administered for 6 weeks postoperatively. The rationale is as follows: When the bacterial load is lowered with debridement and antibiotic coverage, the stability imparted and bone grafting stimulates osteogenesis and healing to proceed without hindrance (Figure 4).

In our post-osteomyelitis infected nonunion femur series of 10 children managed with 'single-stage protocol', union occurred in all patients within an average time of 3.7 months [18]. There was persistence of deep infection despite union in three patients. Average limb shortening was 4.3 cm. The knee motion was severely restricted (≤30°) in three patients. According to Paley's criteria, there were 2 excellent, 4 good, 2 fair and 2 poor results.

D. Bone gaps/ loss

Loss of bone segment(s) in the leg, forearm, metacarpals or metatarsals may lead to angular deformities or shortening of the ray. In these limb sections, the integrity of the adjacent bone(s) generally produces gaps in the infected bone rather than collapse. In the forearm, involvement of the radius leads to acquired radial clubhand deformity [5, 20]. We have described a 'Fibular Intramedullary Bridging Bone and Additional Grafting' (FIBBAG) technique for reconstruction of forearm gaps wherein double augmentation with fibula is undertaken (Figure 5). A strut fibular/ longitudinal split fibular graft is first impacted inside the metaphyseal end of the affected bones. The gap site is then supplemented with copious match stick fibular grafts laid at both ends and over the entire length of the bridging strut. The match stick graft is intentionally spanned over a few extra centimeters on either side to potentially bypass the relatively less vascular bone ends to include adjacent healthy bone as well as increase the host bone-graft surface contact (Figure 6).

The FIBBAG technique utilizes multiple biological principles to help achieve osteosynthesis. The bridging strut provides a biological framework for the formation of callus and promotes endosteal vascular growth from either medullary end. When stabilized with Kirschner wires or external fixator, mechanical stability at the nonunion site is adequately achieved. The additional bone grafts spanning the fibular strut provide the external component of the callus. The technique eliminates the risk of stress fractures described with use of longer non-vascularized grafts [21, 22] thereby permitting use of longer graft sizes and hasten the time to healing. The cortical nature of

Figure 6: Gap reconstruction with fibular graft: A,B. 12 year old child with loss of radial length following osteomyelitis. Typical 'rat tail' appearance can be appreciated in the distal radius. The child presented with an acquired radial club hand. The infection had been quiescent for last 3 years C. Fracture ends engulfed in fibrous and scarred tissues. Post debridement intraoperative gap between radial fragments was 4 cm D,E. The ulna was shortened by 1.5 cm to take care of soft tissue tension, the distal radioulnar anatomy was restored and fixed with K wires and radius reconstructed with FIBBAG technique F. Follow up 4 months. The forearm length was overall shortened, however the radial osteosynthesis was successful G. Clinical alignment at same follow up.

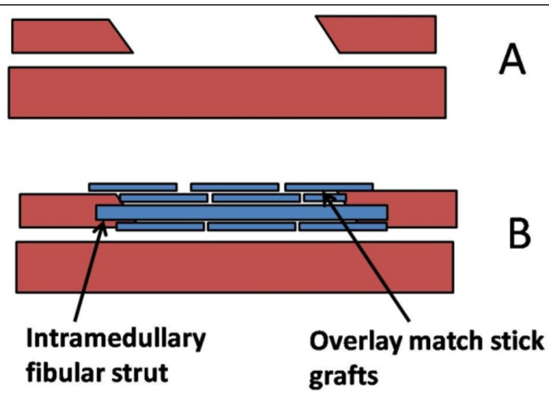

Figure 5: Double augmentation with non vascularized fibular graft (FIBBAG technique): A,B. The gap is bridged with an intramedullary strut followed by matchsticks graft application over the junctional areas and over the strut. Advantages are larger lengths of fibula can be used, stress fractures are reduced, nonunion is prevented at graft host bone junctional areas, healing is faster since both intramedullary and external callus contribute. Additionally, the match sticks graft makes contact with healthy vascular bone and drastically increases surface area.

fibular graft does not appear to hinder bony healing. Stromal cells are higher in cortical grafts and are known for their effectiveness against infection [23, 24].

We reported the usefulness of FIBBAG technique for managing post-osteomyelitis forearm defects in 8 patients [19]. The average patient age was 6 years. The radius was involved in 6 and ulna in 2. Union occurred in all patients. The average intraoperative gap to be spanned was 5.86 cm. The average time for union was 6.63 months. Two patients however required additional bone grafting procedures. No graft fatigues/fractures were noted during follow up. There was no recurrence of infection in any case.

Discussion

Management of chronic osteomyelitis and its complications has always been a challenging task. Depending upon the local and host characteristics, a variety of methods have been used for its management. Even though restoration of original anatomy remains the ultimate goal, it is seldom achieved. In the worst scenario, the salvage procedures have included amputations. Although treatment methods need to be individualized, some of the most commonly used techniques for osteomyelitis reconstruction are distraction osteogenesis, and vascularized/ non-vascularized bone grafting along with some form of stabilization.

Reconstruction using Ilizarov/external fixator is a complex procedure and necessitates advanced surgical expertise. The procedure is time consuming and requires expensive hardware. It is based on adequate patient compliance for success. The procedure additionally runs a risk of skin related and neurovascular complications. The treatment course may be punctuated with secondary interventions needing supervised follow up. The fixator needs to be in place for several months (more, if maturation of regenerate is achieved in frame only) or additional procedures such as stabilization of regenerate and bone grafting may be required.

Bone grafts can be obtained by two means: vascularized and non-vascularized technique. The vascularized graft carries with it the vascular pedicle and is, in theory, better capable of fighting infection and reducing healing times in osteomyelitis reconstructions. However, the microvascular procedures required for this technique require advanced infrastructure, training and experience. The donor site with loss of periosteal cover is complicated with lack of donor site regeneration. In case of vascularized fibular graft, this may lead to valgus deformity of the ankle.

Although known for the past several decades [25-29], there has been a renewed interest in this technique with several series published on the subject in recent years. The non-vascularized fibular graft was believed to work at shorter lengths only (up to 6 cm), considered prone to stress fractures and associated with slower healing times when compared to other methods [8]. None of these previous myths related to non-vascularized fibular graft have been substantiated in the recent evidence. We have safely used it for gaps up to 14 centimeters using the FIBBAG technique [19]. A recent series described its successful use for gaps as large as 25 centimeters [30]. Several other series substantiate the safety and effectiveness of this technique.

Steinlechner and Mkandawire reported outcomes after sequestrectomy in long bones (5 tibia, 1 humerus, 1 radius) in 7 children managed using non-vascularised fibular grafts [31]. The mean time from sequestrectomy to grafting was 5.7 weeks. Fibular lengths varied from 4 to 12 centimeters. Bony union was achieved in all seven patients with a mean union time of 19.3 weeks. In 6 patients, the union time was as low as 12 weeks. No graft related complications were reported. Regrowth of the donor site in 6 and cross union in 1 patient was documented.

Patwardhan et al reported a larger experience of 26 children with post-osteomyelitis gap non-union treated with non-vascularized fibular graft [10]. The bone involved was femur in 7, tibia in 12, humerus in 3, radius in 3, and the ulna in one patient. They followed a two-stage protocol wherein the initial treatment involved thorough debridement and sequestrectomy. When the infection was controlled, non-vascularized fibular grafting was performed. The mean duration of intermediate 'infection quiescence period' was 6.9 months. The average bone gap spanned was 5.1 centimeters. The mean time to union was 38.8 weeks which occurred in all cases although delayed union was present in 4 patients. One patient exhibited recurrence of infection 6 weeks after the fibular grafting and was treated with distraction osteogenesis. Regrowth of donor fibula was demonstrated in all patients and there were no donor site complications in this series.

In a pediatric study from Thailand, non-vascularized autogenous fibular bone strut (without any additional grafting) was used for 3 humeral, 4 radial and 2 ulnar post infective defects over 7 centimeters [32]. Mean length of bone defect was 9.3 centimeters (range: 8-13 centimeters). The mean follow up was 45.8 months after surgical reconstruction. The average union time was 9 weeks. No fractures were observed in any of the fibular autogenous grafts. No child reported pain or functional disability involving the donor leg at the time of follow up.

Although comparisons between techniques are difficult, the average healing time of non-vascularized fibular graft in most pediatric series ranged from 2.5 – 10 months [31, 32]. The average union time with two-stage procedure using extensive debridement followed by antibiotic spacer and distraction osteogenesis was over a year in one pediatric series [33]. When osteosynthesis was performed with technique involving vascularized grafts, the union time for lower extremity reconstructions averaged 8.4 months [34]. Thus, the reconstruction procedure using non-vascularized fibular grafts fare at par with other techniques when healing times are quantified. Further, the graft incorporates well and subsequently hypertrophies based on functional needs. Further lengthening procedures are possible on the grafted segment. Pinto et al described a case of post infective tibial gap nonunion in a child [34]. Two lengthening at ages 3.5 and 8 years were performed to secure a total length of 9 centimeters.

Although the use of non-vascularized fibular graft is described more commonly for long bones, its use for osteomyelitis affected other body regions is also documented. Gupta et al illustrated one case where the technique was successfully utilized for reconstruction of 1st ray phalangeal loss [35]. With enhanced experience with fibular grafts, general descriptions have given way to region-specific usage of non-vascularized fibular graft for osteomyelitis reconstructions [18-20]. Our series on post-osteomyelitis forearm and femur defects constitute such site-specific descriptions. Pawar et al also described one dedicated series related to reconstruction of radial defects (acquired radial clubhand) using fibular grafts [20].

Summarizing, non-vascularized fibular reconstruction of osteomyelitis defects is a relatively less technically demanding procedure. The surgery can be performed in an average orthopedic setup. Often used alongside mechanical stabilization, it is more economical. A word of caution here: any post-osteomyelitis procedure is prone to reinfection and failures. Fibular reconstructions may suffer from these complications and require careful extended follow up. Appropriate secondary interventions may be required in select cases. Swamy et al reported results of non-vascularized fibular grafting in 20 children with bone defects (19 as a result of chronic osteomyelitis and one as a result of excision of a tumour) [37]. This study reported stress fracture in 1, resorption of graft in 2, nonunion at one end of graft in 2 and superficial infection in 2 patients. There can be additional morbidity related to donor site. Some other fibular series have reported non-regeneration, ankle valgus, compartment syndrome, nerve damage and muscle tethering although these were more commonly reported when harvest was obtained by vascularized means [38]. It therefore, becomes necessary to supervise the donor site as well as primary site post-harvest.

Conclusion

Osteomyelitis poses multiple challenges in form of weakened bone, cavities, pathological fractures, nonunion and gaps. Non-vascularized fibular graft coupled reconstruction is a feasible technique to deal with such pathologies. Our experience reinforces that this technique is less technically demanding and effective.

Declaration of patient consent : The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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