Benha Journal of Applied Sciences (BJAS) **print: ISSN 2356–9751**
Vol. (9) Issue (6) (2024), (109-115) **online: ISSN 2356 –976x**
http://bjas.bu.edu.eg

Short term (at least one year) follow up of free vascularized Fibular graft in the reconstruction of long bone defect

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Abstract :
Bone defect (more than 6 cm) is challenging. The use of free vascularized Fibular graft in reconstruction is an option. The aim of this retrospective study is to assess the clinical outcome as regarding to union, graft hypertrophy and complications in a short term follow up (at least one year follow up) . From: July 2017 to Dec 2023, a series of 14 patients (8 male - 6 female) reconstructed by 16 FVFG was reviewed retrospectively (two of them undergoes revision with ipsilateral Fibula) for at least one year follow up. The right side was involved in 6 cases and the left side in 8 cases with mean age 22 years ranging from (2-42) year. Sites of bone Defect include: Femur in four cases , Humerus in four cases, Tibia in three cases , Radius in two cases & Ulna in one case. The causes of bone defects were nonunion in five cases, tumor in five cases, post traumatic bone loss in 1 cases, psuedoarthrosis one case , osteomyelitis one case & infected modular TKA one case. Results : Bony union at both ends occurred only in five patients (30%).The time for graft union & hypertrophy positively correlated with age. Graft hypertrophy occurred in eight cases (60%). Nonunion (70%) ,implant failure (30%) & stress fracture (25%) were the most common complications .Short term functional outcomes : In the upper limb : only 2 cases (children) have a good result & one patient fair result after wrist arthrodesis. In the Lower limb 2 patient (children) can walk without support even with nonunion after one year.

Keywords: bone defect reconstruction, Free vascularized fibular graft, functional evaluation.

1.Introduction:

Reconstruction of long bones defect caused by (trauma, oncological resection, osteomyelitis or congenital psuedoarthrosis) is a complicated and difficult problem. Historically, amputation often was the only solution after extensive traumatic bone loss or oncologic resection. Traditionally, nonvascularized bone graft were used with some success in noncomplex defects [1].

In 1975, Taylor reported the first use of a microvascular transfer of vascularized Fibula for large defect in long bones. The advantages of this technique is fast healing, ability to hypertrophy, relative resistance to infection, and ability to solve defects in the most unfavorable scenarios (scarred or irradiated beds) [2].

Nonvascularised graft serves as an osteoconductive scaffold. Remodeling of the graft is limited. It is initiated by creeping substitution since no intrinsic osteogenic potential remains. Limited revascularization clarify the high rate of complications **.** Vascularized bone grafts, support all aspects of bone regeneration (osteoinduction, osteoconduction and osteogenesis) [3] . The Fibula is a tubular bone with a suitable length, and mechanical strength. It is considered the best donor bone for large bone defects. The free vascularized Fibular graft also can be used for the reconstruction of long bone combined with soft-tissue defect. The Fibular graft can be transferred, together with subcutaneous tissue and skin as osteocutenous composite graft to provide direct wound coverage [1].

2.Patients and methods:

During the period between July 2017 – December 2023 this retrospective study was carried out using free vascularized Fibula in reconstruction of long bone defect in upper limb or lower limb of any pathology with minimum follow up at least one year. All cases are done in Nasser institute .

This retrospective study reviewed 14 patients (8 male & 6 female) reconstructed by 16 FVFG (two of them undergo revision with ipsilateral Fibula) with mean age 22 years, ranging from (2y – 42y).

The indication for surgery was a bone defect caused by a fracture nonunion (n=5), resection of bone tumor (n=5),osteomyelitis (n=1) , psuedoarthrosis (n=1) & infected TKA (n=1) .The recipient sites for the grafts included : Femur (n=4), Humerus (n=4), Tibia (n=3), Radius (n=2) and Ulna (n=1).

Osteosynthesis involved in this study includes non bridging plate (n = 8), bridging plate (n = 5) ,external fixation (n = 2), screws alone at one end (n = 2), Kirschner wire (n =2). Osteosynthesis was adapted for each case but typically bridging plate if possible is the gold standard.

Inclusion criteria included any patient less than 70 years old (due to atherosclerosis) with massive long bone defect (more than 6 cm) caused by any pathology.

Exclusion criteria included those patients unfit for surgery or with Peripheral neurovascular affection. Bone defect less than 6 cm was also excluded.

Patient demography, medical records, operative procedure, hardware used, time to union, graft hypertrophy & complications all were reviewed.

Preoperative angiography was not done routinely except in patients who had pervious trauma or surgery involving the limb (donor site) or peripheral vascular disease. Technetium 99 bone scan was used to assess viability of the fibular graft if viability is questionable. Maximum increased uptake of the graft was seen after seven weeks.

Surgical technique

Harvesting of the Fibula:

Through standard lateral approach, the Fibula was obtained by subperiosteal dissection .The middle third of the Fibula is the most important as the nutrient artery enters the Fibula at this level. The distal osteotomy was always not less than 6 cm from distal tip to ensure the stability of the ankle [4].

The length of Fibular graft depends on the bone defects, which was usually as the length of bone defects plus 4 cm in mismatched bone (Femur, Tibia & Humerus). Aim is to insert Fibular ends into the medullary canal as a single strut [5].

At the recipient site:

Resection and reconstruction was performed as a single-stage procedure or two stages in cases of infected nonunion. Two teams were operated ,one harvesting the Fibular graft, and the other preparing the recipient [5].

The vessels of the recipient site were carefully dissected and exposed. Impacting both ends of the graft into the medullary cavity of the recipient bone was required. Bone fixation was carried by different methods (screws, plate, kirschner wires or external fixator) & was adapted for each case . However bridging plate if possible is the gold standard .The Peroneal vessel was anastomosed to the recipient vessel with (8.0-9.0) interrupted nylon sutures using the microsurgical techniques [6].

Methods of follow-up and statistical analysis:

Clinical examination : Viability is assessed **early** postoperative by monitoring the skin paddle flap (if present) for color, capillary refill and bleeding.

After two weeks postoperatively suture is removed and then the patient follow-up every 3 months in the first year until full bone union, determined by clinical examination and radiographs.

Bone healing, hypertrophic changes and surgical complications (such as stress fracture and nonunion) were confirmed by plain radiographs) .

Bony union of the graft was evaluated by the presence of uninterrupted external bridging callus at least at three cortices. **The hypertrophy** of the graft was evaluated by the difference in diameter of the graft immediately post-surgery and at the final follow-up. Significant **hypertrophy is** defined as (**30% increase** of the original fibular width) **.**

The allowance of weight-bearing was individualized based on weight of the patient, method of fixation, and degree of hypertrophy.

The patients were evaluated **functionally** using the Musculoskeletal Tumor Society (MSTS) score. The system of MSTS is international rating system assigns numerical values (0–5) ranging from (**excellent, good, fair, or poor)** allows comparison of results after limb salvage surgery .

Functional recovery in the lower extremities is assessed by limitations of walking caused by this procedure (maximal walking distance) (inside, outside & stairs) **(Table 1)** & by lifting ability in the upper extremity compared with the opposite one **(Table 2)**. The results were collected on a **data collection sheet** then analysed**. (Table 3)**.

Table (1) walking ability **(MSTS) score**

	Description	Result
5-	Unlimited walking as preoperative **.**	Excellent
4-	Can climb stair	Good
3-	Limited walking (with some difficulty).	Fair
2-	Can walk outside but (with significant limitations)**.**	Poor with limited disability
1-	Can walk inside only	Major disability
0-	Not walking independently only with assistance or wheelchair	Complete disability

Table (2) Lifting ability **(MSTS) score**

	Description	Result
5-	Can carry normal load matching as normal limb	Excellent
4-	Less than normal	Good
3-	Limited (Can carry minor load only)	Fair
2-	Can overcome gravity only	Poor (with limited disability)
1-	Helping: Cannot overcome gravity only assisting the contralateral extremity.	Major disability
0-	Cannot move	Cannot help with Complete disability

Table (3) Data are presented in

Case No	Pathology	Fixation	Complication
1-	Non united **Lt** Humerus **25** years old	**First operation** Non bridging plate	**United proximal end** Stress fracture &
2-	Ewing sarcoma **Rht** Humerus **20** years old	Non bridging plate distally & Screw proximally	Stress fracture
3-	Chronic osteomyelitis **Rht** Humerus 2 years old	K wire and tension band	United without complication
4-	Infected non united **Rht** Humerus **20** years old	Non bridging plate	One end united **(proxima**l) & other End implant failiure
5-	Infected non united **Rht** Femur **40** years old	**First operation** Screw at distal end **Second operation** Bridging plate	**United** Stress fracture Infection
6-	Osteosarcoma **Rht** Femur **20** years old	**First operation** Bridging plate **Second operation** Bridging plate	Vascular failure – nonunion implant failure **United proximal end**
7-	Fibrosarcoma **Lt** Femur **60** years old	Bridging plate	Vascular failure **–** implant failure **United proximal end**
8-	Ewing sarcoma **Rht** Femur **12** years old	Bridging plate	**United proximal end** – Implant failure
9-	Psuedoarthrosis **Lt** Tibia **4** years old	K wire & External fixator	Nonunion **- hypertrophy**
10-	Open fracture **Lt** Tibia with bone loss **12** years old.	Non bridging proximal plate & K wire	united **&** stress fracture Stress fracture
11-	Infected **Lt** TKA **19** years old	bridging plate **External fixation after infection**	Infected nonunion **proximal end** **United distal end**
12-	Giant cell tumor **Lt** distal radius 24 years old	Non bridging double plate	**united**
13-	Nonunited **Lt** Radius **30** years old	Non bridging double plate	Implant failiure & nonunin
14-	Nonunited **Lt** Ulna **12** years old	Non bridging double plate	**united**

3.Results

Analysis of different parameters of the procedure:

Union:

Patients achieved complete primary union (both junctional sites united) were 5 **(30%)** & 6 patients achieved only union at one end . Mean time of bony **consolidation** after primary operation vary according to age .In adult (more than 20 years old) radiological evidence of union starts to appear at 3-4 months postoperative and by 6th month postoperative the union is complete. In children mean time of union (range from 6 weeks –3 months).

Hypertrophy:

Hypertrophy is the second most important finding after union that indicates success of the procedure as hypertrophy is the character of a living bone. Hypertrophy less than 30% was considered to be magnification of the x-rays and not a true hypertrophy**. Hypertrophy** occurred in eight cases of mismatched bone **(60%).**

Time needed for significant graft hypertrophy depends mainly on age .**Rapid hypertrophy** was observed in all younger patients (all under 12 years) even with nonunion. No significant differences between patients as regards to graft length, reconstruction site, fixation method, or pathology. Gradual weight bearing was allowed after union and progress of hypertrophy especially if the transferred bone is protected by bridging plate .

Type of fixation

Achieving stability after Fibular graft transposition is the key that protect the graft & facilitating union. It was achieved with rigid fixation (bridging plate) if possible or non-rigid fixation as external fixator, K wire, non-bridging plate or screw .Bridging plate decrease stresses on graft and decrease complications .Bridging plate is better than minimal osteosynthesis but may be not favorable in infected bed or long defect not suitable for ordinary size . The main disadvantage of screw fixation is stress fracture which occur in all (3) cases .

Viability evaluation

Eleven cases are **viable** .Viability is assessed **early** postoperative by monitoring the skin flap paddle (if present) for color, capillary refill, and bleeding on pinprick. **Later on** rapid Healing and hypertrophy was evaluated by plain X-rays . **Lack of vitality** evidenced by bone scan occurs in **two** cases. Inadequate perfusion can be **suspected** in **three** cases with bone resorption & poor healing.

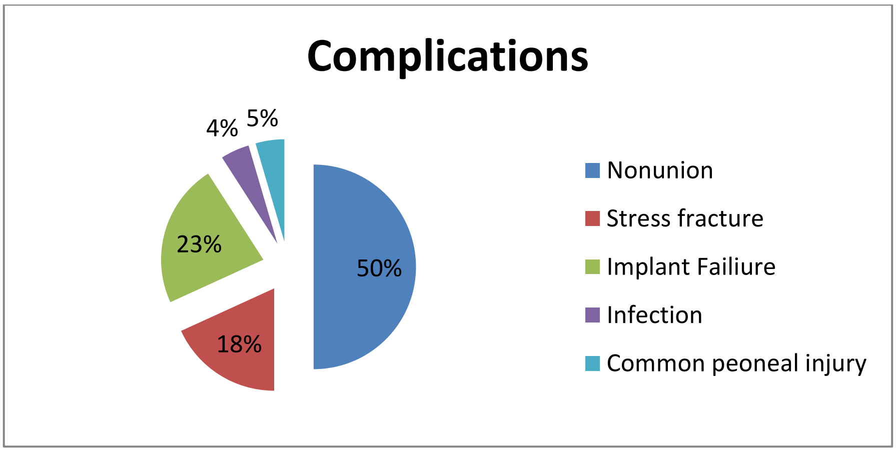
Complications:

No significant complications occurred intraoperative , but one case (osteosarcoma Femur) developed heamatoma immediate in the postoperative period treated by evacuation and heamostasis.

Non-union of at least one end of the Fibula is the most common complication. It was reported in (70%) of patient .Higher rate of nonunion, may be biological due to vascular failure , mechanical factors or infection.

Stress fracture (4 cases) 25 % and implant failure (5 cases) 30 % is the second common complication. Use of bridging plate, adequate limb protection with (brace or crutch) & gradual weight bearing should be considered, until union & sufficient hypertrophy of the graft.

Deep infection occur in one case ended by infected nonunion. Mild clawing of the big toe due to contracture of the flexor halluces longus muscle & weak foot dorsiflexion with Parasthesia on the dorsum of the foot occurred in one case.



Graph of complications

4.Discussion:

Reconstruction of bone defects caused by trauma, osteomyelitis, or after tumor resection has always been a problem for orthopedic surgeons. Until now there is no golden technique for treatment of a large defect in long bones. Vascularized Fibula can provide adequate length, mechanical strength and hypertrophy potential. In addition, the Fibular graft has the ability to be combined with a skin island, to solve complex problems in bone and soft-tissue defects.[7]

In our study, **bony union** was achieved only in 30 % at both proximal and distal ends of the graft. The second important finding after union that indicates success of the procedure is graft hypertrophy as it is a character of a living bone. Increase diameter of Fibular graft in mismatched bone (Femur - Tibia -Humerus) occur in 60% of the grafts. Children & young adult shows rapid healing & hypertrophy potential that allows rapid rehabilitation.

Enneking et al found a primary union rate range from 86% to 95% of cases within the first 12 months & only **43%** of vascularized fibular grafts achieved **hypertrophy** after **12 months**. Maximum hypertrophy occurred between 2 and 3 years after that no further increase in graft diameter.**(8)**

Achieving **stability** after fibular transposition facilitates union. Fixation with a long bridging plate if possible is better than minimal osteosynthesis. It provides adequate support with equal stress until union & hypertrophy has occurred to allow safe weight bearing.

After intramedullary seating of the fibula into the recipient bone , minimal internal fixation by screws only was used in in three cases . Screw fixing the fibula to the host bone play a role of interlocking screws but has the worst results. All cases had stress fracture.

Stress fracture occur in 4 cases. According **to previous studies** DeBoer et al. found a 40% incidence of stress fracture in the leg in the first year . Stress fracture is due to Repetitive mechanical loading upon the Fibular graft with inappropriate fixation. Rehabilitation process with delayed weight-bearing must be tailored according to degree of postoperative hypertrophy.[9]

Nonunion 70% (at one or both ends) & **fixation failure 30%** were the most common delayed postoperative complications. Such complications delay rehabilitation process. The cause of high rate of nonunion in our study may be biological (vascular failure) , mechanical (Non rigid fixation) or infection.[9],[10].

Younger patients have tendency for earlier and faster graft hypertrophy even with nonunion (as in psuedoarthrosis Tibia, 4 years old). It is probably related to their higher remodeling power.

At the end of this study , all patients were assessed functionally.

In the upper limb group: only 2 cases (children) have a **good** result & one patient **fair** result in wrist arthrodesis after relapsed Giant cell tumor **distal Radius.**

Wrist arthrodesis after relapsed Giant cell tumor distal Radius.

In the Lower limb ,2 patient (children) have a **good** functional result . They can walk outside & climb stair without support even with nonunion after one year.

FVFG in a case of bone defect

Implant failure after failed revascularization

It was obvious that function is influenced by age as children have better functional result .Younger patients have a tendency for earlier and faster graft hypertrophy that is probably related to their higher remodeling power.

The current study has several Limitations including, small number of cases, short time of follow-up, heterogenicity of bone affected & cause of bone defect . Future study may be more relevant as we increase the number of cases & long term follow up. Comparative results & complications of different fixation techniques will evaluate clinical outcome and disadvantages of this technique.

5.Conclusions

The success of the free vascularized fibula is related to its unique vascularity and morphology of the graft. The application of the free vascularized fibular graft is technically demanding, requiring meticulous microsurgical technique. It can provide a useful solution for the reconstruction of skeletal defects of more than 6 cm, especially in cases with combined bone and soft tissue defects. Good functional result can be achieved in children more than adult .

Like all methods of reconstruction of large skeletal defects, FVFG has a high complication rate. Long-term outcomes is required to determine the long term success of this procedure.

Acknowledgments

Author certifies that he has no funding or commercial associations that might pose a conflict of interest in connection with the submitted paper . All investigations were done with ethical principles of research & consent for this study was obtained. The authors would like also to express gratitude to Benha university for supporting this paper.

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