Biological Reconstruction of Large Bone Defects with Vascularized Fibular Autograft

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ABSTRACT

Background: Given its biological and structural qualities, vascular fibular autograft is a good option for the reconstruction of large defects in long bones. **Materials and Methods:** A descriptive and retrospective observational study was conducted. We included all cases of patients who underwent surgery in our hospital between January 1, 2014, and January 1, 2021, and who had a vascular fibula autograft either standalone or in combination with a structural graft (Capanna technique). **Results:** There were 26 documented vascular fibula autograft procedures. Eight of the procedures involved the reconstruction of a long bone defect. The bone defect was an average of 7.7 cm in length. In five of the cases, the origin of the bone defect was post-traumatic, and in the remaining cases, it was tumoral. In all cases, complete consolidation was achieved. Surgical procedures performed on the lower extremities yielded better clinical and functional outcomes. **Conclusions:** Vascular fibula autograft either on its own or in combination with a structural graft, as described in the Capanna technique, is an excellent alternative for the reconstruction of bone defects ≥ 5 cm. Radiological, clinical and functional outcomes are good, with an acceptable rate of complications.

Keywords: Autograft; free tissue flap; reconstruction; bone defect.
Level of Evidence: IV

Reconstrucción biológica de grandes defectos óseos con autoinjerto de peroné vascularizado en huesos largos

RESUMEN

Introducción: El autoinjerto vascular de peroné se presenta como una muy buena opción en la reconstrucción de grandes defectos óseos en huesos largos gracias a sus características estructurales y propiedades biológicas. **Materiales y Métodos:** Se realizó un estudio observacional descriptivo y retrospectivo que incluyó a todos los pacientes operados con un injerto vascular de peroné aislado o asociado a injerto estructural (técnica de Capanna) desde el 1 de enero de 2014 hasta el 1 de enero de 2021 en nuestro hospital. **Resultados:** Se realizaron 26 cirugías mediante un injerto vascular de peroné; en 8 de ellas, se utilizó el colgajo vascularizado de peroné para la reconstrucción del defecto óseo en hueso largo. El tamaño medio del defecto era de 7,7 cm. El origen del defecto era postraumático en 5 casos y tumoral en el resto. Se consiguió la consolidación completa en todos los pacientes. Los resultados clínicos y funcionales en las escalas de valoración fueron mejores en pacientes operados en el miembro inferior. **Conclusiones:** El uso de un colgajo vascularizado de peroné asociado o no a aloinjerto estructural es una estrategia útil en la reconstrucción de grandes defectos óseos (≥5 cm), independientemente de la causa de la lesión; la supervivencia del injerto y la función son buenas, con una tasa de complicaciones aceptable.

Palabras clave: Autoinjerto; colgajo libre; reconstrucción; defecto óseo.
Nivel de Evidencia: IV

INTRODUCTION

The reconstruction of large bone defects is a challenge for the orthopedic surgeon both because of the complexity of the patient and the technical difficulty of the surgery. This requires a high degree of specialization and involvement of the specialist who carries out the entire process, from early diagnosis to the patient's final discharge.

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The reconstruction of large bone defects can be performed by means of: mechanical systems (megaprosthesis), mixed systems (composite) and biological reconstructions (vascularized grafts).

Vascularized bone grafts have been proposed as an alternative in the reconstruction of long bones since Crock's studies in 1967 on vascular support in lower limb bones. In 1975, Taylor performed the first vascularized fibula flap (VFF) with a posterior approach. In 1979, Gilbert improved the technique with the lateral approach used today.[1]

Reconstruction using vascularized versus non-vascularized grafts is proposed because, although they are more technically complex, they are especially indicated for defects >5 cm, have better long-term results and consolidation rates, and cause fewer complications due to their better biological properties.[2] Vascular anastomosis produces a revascularization of the graft that preserves the function of osteoblasts and osteoclasts facilitating remodeling and osseointegration of the graft in a more efficient manner.

The vascularized fibula graft, in particular, is the most extensively utilized microvascular bone flap due to its remarkable versatility for reconstructions, as it allows single or double-barreled assemblies or the association of musculocutaneous flaps to correct coverage defects.[2,3] All of these alternatives allow it to be used in defects ranging in size from 5 cm to 25 cm, as long as the last 7 cm distal and 4 cm proximal of the fibula are spared to avoid complications in the donor area (Figure 1).

Figure 1. Anteroposterior radiograph of the donor area of the fibula. Radiographic control after fibula extraction.

For all these reasons, the main objective of our study was to review a series of patients operated on using this technique in our hospital. The secondary objective was to conduct a literature review on the subject to compare our results with those that have been published.

MATERIALS AND METHODS

A descriptive and retrospective observational study was conducted and included all operated patients in whom a vascularized fibula graft was used in isolation or associated with structural grafting (Capanna technique) from January 1, 2014 to January 1, 2021, at our Center. The objective was to evaluate the effectiveness of the vascularized free fibula flap in long bone reconstruction.

The vascular fibula graft is a highly complex surgical technique that two teams perform in the same operation. In the preoperative study, the length of the fibula needed to reconstruct the defect is planned and a computerized angiotomography is performed to visualize the vascular tree of the donor area. During surgery, one team prepares the recipient site (if treating an oncological patient, by en bloc tumor resection and, if treating a nonunion, by debridement and the necessary osteotomies for the subsequent attachment of the microvascular fibula), while the other team extracts the microvascular fibula flap in the donor site. Before proceeding to resection of the fibula, the size of the segment to be resected is verified again. A technical detail of special interest is that, to avoid flap ischemia, the flap must be kept in the donor area until the preparation of the recipient vascular area is completely finished. When the Capanna technique is used, the team working on the recipient bed prepares the structural graft (cadaveric tibia or femur allograft) by tunneling and creating a window for the passage of the fibula vascular pedicle. Once the recipient bed is prepared (and the structural graft if needed), the fibula flap with its vascular pedicle and the microvascular anastomosis in the recipient site is removed. Finally, the graft is fixed with the chosen osteosynthesis system. All flaps are monitored by Doppler ultrasound in the immediate postoperative period, including those requiring a skin island flap to cover the defect; this has been effective in assessing their clinical viability.

Patients having VFF reconstructions in areas other than the extremities, such as the mandible, were excluded, as were those with reconstructions managed with another type of graft or flap and those with insufficient medical records.

Depending on the patient's evolution, clinical and radiological follow-up took place monthly, quarterly, half-yearly, and yearly for a minimum of two years. After surgery, plain radiography was used to assess complete bone healing in both donor and recipient bones.

Demographic variables (sex and age), bone affected (femur, tibia, ulna and humerus), disease, defect size, number of previous operations, type of reconstructive procedure (isolated VFF or associated with structural graft), and complications were recorded, as well as the functional outcome of the donor site (American Orthopaedic Foot and Ankle Society (AOFAS) scale), the functional outcome of the recipient site (Musculoskeletal Tumor Society (MSTS) scale) (Table 1) for the lower limb and the QuickDASH questionnaire (Table 2) for the upper limb, among others.

Table 1. *Musculoskeletal Tumor Society* (MSTS) Lower Limb Function Scale (LLS)

Score	Pain	Function	Emotional component	Support	Walking	Gait	Final score
5	No pain	No restriction	Enthused	None	Unlimited	Normal	
4	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	
3	Modest	Recreational restriction	Satisfied	Brace	Limited	Minor cosmetic	
2	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	
1	Moderate	Partial restriction	Accepts	One cane or crutch	Inside only	Major cosmetic	
0	Severely disabling	Total restriction	Dislikes	Two canes or crutches	Not independent	Major handicap	

Taken from Arnal-Burró J, Calvo-Haro JA, Igualada-Blazquez C, Gil-Martínez P, Cuervo-Dehesa M, Vaquero-Martín J. Hemipelvectomía tras sarcomas de localización pélvica de alto grado: pronóstico en condrosarcomas frente a otros tipos histológicos. *Revista Española de Cirugía Ortopédica y Traumatología* 2016;60(1):67-74. https://doi.org/10.1016/j.recot.2015.04.002

Table 2. QuickDASH upper limb function scale

Quick DASH

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

Category	No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	Unable
1. Open a tight or new jar.	1	2	3	4	5
2. Do heavy household chores (e.g., wash walls, floors).	1	2	3	4	5
3. Carry a shopping bag or briefcase.	1	2	3	4	5
4. Wash your back.	1	2	3	4	5
5. Use a knife to cut food.	1	2	3	4	5
6. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5

	No at all	Slightly	Moderate	Quite a bit	Extremely
7. During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups?	1	2	3	4	5

	Not limited at all	Slightly limited	Modaretely limited	Very limited	Unable
8. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem?	1	2	3	4	5

Please rate the severity of the following symptoms in the last week.	None	Mild	Moderate	Severe	Extreme
9. Arm, shoulder or hand pain.	1	2	3	4	5
10. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5

	No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	So much difficulty that I can't sleep
11. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand?	1	2	3	4	5

*Taken from Medicine Princeton Health at https://www.princetonhcs.org/

All these variables were analyzed from the patients' medical records and the results obtained were recorded in a data collection sheet in the SPSS 25 program where descriptive statistics were performed.

RESULTS

Between 2014 and 2021, 26 surgeries were performed with a fibula vascular graft and, in eight of them, VFF was used for the reconstruction of the bone defect in the Orthopedic Surgery and Traumatology Service of the Consorcio Hospital General Universitario de Valencia, Spain. Patients had a mean age of 42 ± 20 years, with a lower limit of 16 years and an upper limit of 72 years. The distribution according to sex, recipient bone, diagnosis and follow-up time is detailed in Table 3.

Table 3. Characteristics of study patients

Patient	Age	Sex	Diagnosis	Bone	Follow-up (months)
1	65	M	Atrophic pseudarthrosis	Femur	13
2	72	M	Atrophic pseudarthrosis	Femur	9
3	27	F	Atrophic pseudarthrosis	Ulna	12
4	56	M	Septic pseudarthrosis	Ulna	54
5	40	M	Atrophic pseudarthrosis	Humerus	42
6	37	M	Ewing's sarcoma	Tibia	54
7	25	M	Osteosarcoma	Tibia	42
8	16	M	Osteosarcoma	Tibia	96

M = male sex; F = female sex.

The average size of the defect was 7.7 cm, the smallest was 5 cm (septic pseudarthrosis of the ulna) and the largest was 17 cm (tibial osteosarcomas). Regarding the size of the VFF, on average, a longer fibula was used in the three tumor cases (21.33 ± 2.30 cm) than in the five non-tumor cases (5.30 ± 1.85 cm).

Isolated VFF was used in the upper limb and, for all lower limb cases, the Capanna technique was used, which consists of associating a structural allograft to the VFF (Figure 2).

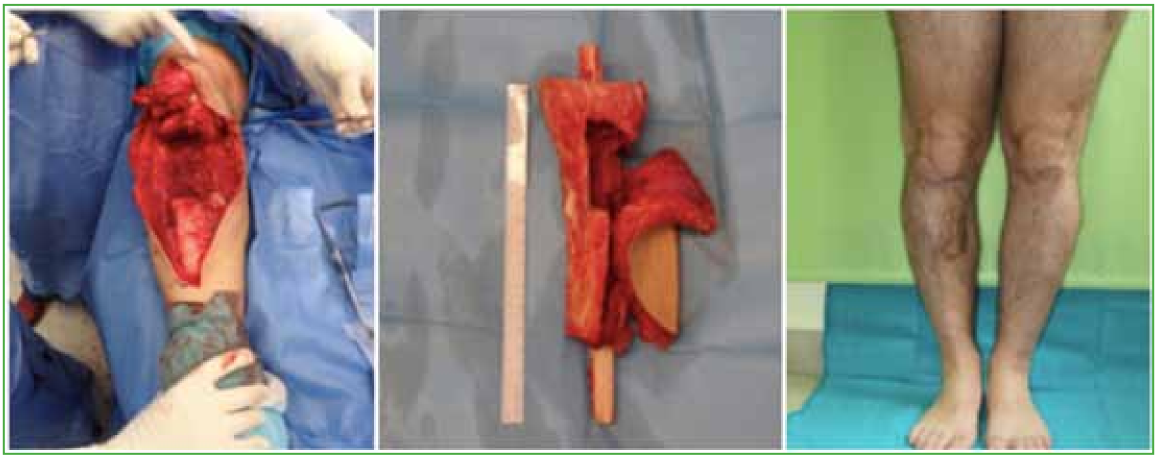

Figure 2. Resection of an osteosarcoma and preparation of the structural allograft to use the Capanna technique.

The mean time to complete radiographic consolidation was 7.16 months (standard deviation [SD] ± 0.75) (Figure 3). The mean time to consolidation was longer in the upper limb (8 months, SD ± 3) than in the lower limb (7 months, SD ± 0.70). In patients who had lower limb surgery, the average time to begin weight-bearing was 4.1 ± 1.47 months.

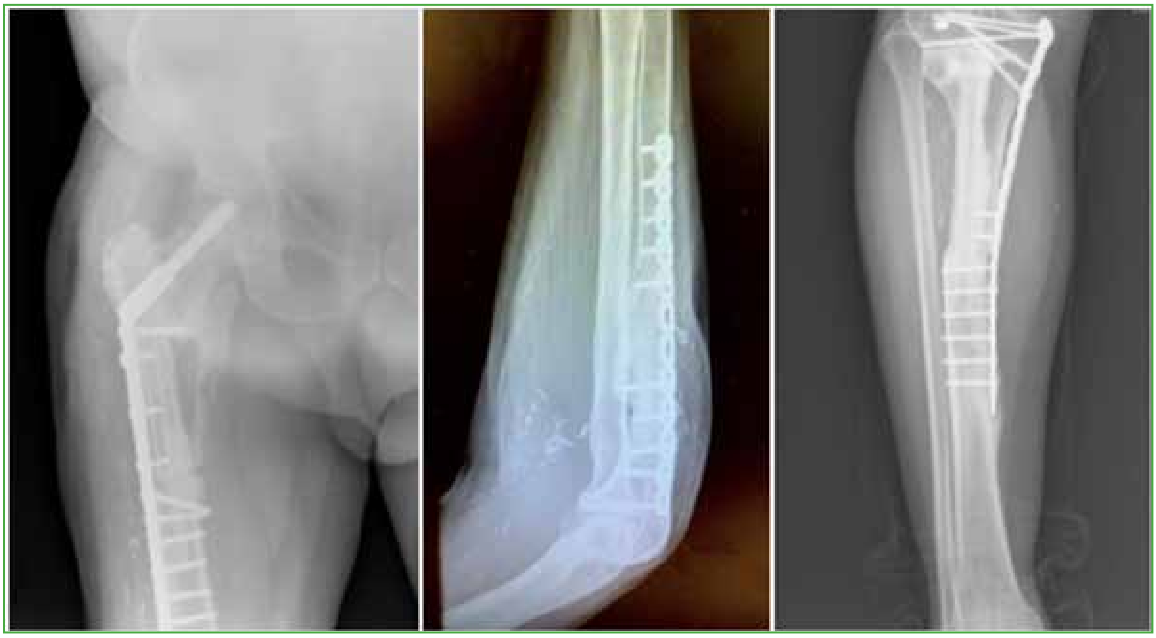

Figure 3. Anteroposterior radiographs of femur and tibia, and lateral radiographs of ulna after complete bone consolidation in radiographic controls.

The mean hospital stay was 7.12 ± 2.99 days. All remained at least one day in the intensive care unit. The mean estimated surgery time was 8 h and 40 min (SD ± 1 h and 32 min).

As for complications, given the diverse etiology for which surgery is indicated, complications were divided into three groups: medical, oncologic and surgical in both the donor and recipient sites. No medical cause of complication was recorded, understanding as such those derived indirectly from the surgery, such as respiratory failure, pulmonary thromboembolism or deep vein thrombosis, arrhythmias, heart failure, etcetera. There were also no oncologic complications in the patients operated on for this cause. None have metastasized and all are currently disease free.

Surgical complications in the recipient site were: one wound dehiscence, one breakage of the osteosynthesis material, one patient with malunion and subsequently a pathological fracture and two cases of pseudarthrosis.

Both the patient with septic pseudarthrosis of the ulna and the one with atrophic pseudarthrosis of the humerus were re-operated: the former after one year and the latter after nine months. In both cases, the focus of pseudarthrosis was in the distal pole of the graft and it was necessary to remove the original osteosynthesis material, refresh the focus, place an iliac crest graft with bone morphogenetic protein and use osteosynthesis material again.

The patient with varus malunion underwent, one year later, a corrective proximal tibial valgus osteotomy and screw plate fixation (Figure 4). The pathologic fracture occurred three years after the initial VFF operation and was treated with open reduction, bone autograft and a carbon plate.

Figure 4. Anteroposterior radiographs of the case of varus malunion.

In the donor site, there were only two cases of hallux flexus and one patient suffered a neurological sequela with allodynia and hyperesthesia that evolved favorably.

Finally, the functional score was 27 out of 30 (n = 5) on the MSTS scale for the lower limb, 43.93% mean (n = 3) on the QuickDASH questionnaire for the upper limb and 90% mean (n = 8) on the AOFAS scale for the donor site.

DISCUSSION

The reconstruction of large bone defects is a challenge for the orthopedic surgeon, in this field, the VFF is presented as a good technique for reconstruction in both the upper and lower limb, regardless of the etiology of the bone defect. Although few studies use standardized functional validation systems for reconstructive surgery of this type, we consider it appropriate to use specific validated scales that assess global function in the upper and lower limb, such as the QuickDASH questionnaire for the upper limb, the MSTS scale for the lower limb, and the AOFAS scale to assess the function of the foot and ankle in the donor site. In this context, it should be noted that the use of the MSTS scale for lower limb is limited because two of the five cases are not oncologic.

The results of the functional evaluations were very good, with a mean of 27 out of 30 points on the MSTS scale, similar to the score obtained by Houben et al. (26,3) in their systematic review.[4] In the upper limb, the QuickDASH score was 43.93, considered an acceptable functional outcome. The average AOFAS score was 90 out of a potential 100 points. Therefore, VFF is shown to be a reconstructive method that achieves optimal functional outcomes, especially for treating large defects in the lower extremities. The difference between the results obtained in the upper limb and the lower limb could be due to the lower weight-bearing, which results in less graft hypertrophy, and the fact that the reconstruction of the radioulnar joint in particular is more complex due to its function (Figure 5).[3,5-7]

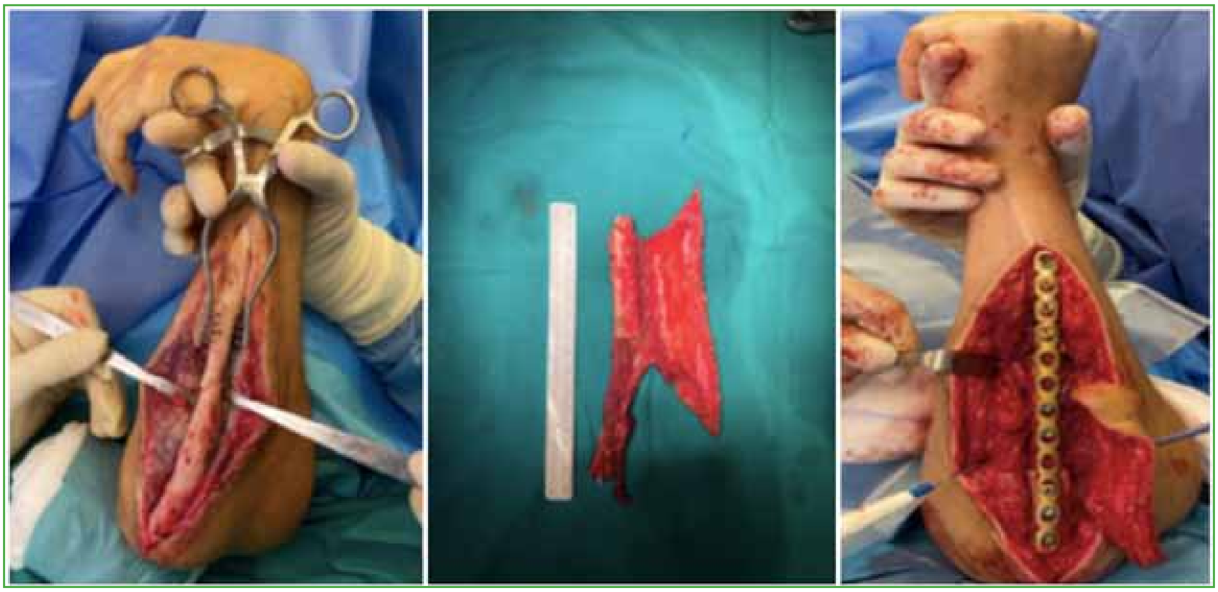

Figure 5. Fibula with its vascular pedicle fixed to the bony defect in the ulna by means of a screwed plate.

Other long bone reconstruction techniques, such as the Masquelet technique or intercalary grafts, have high complication rates, whereas FFF has a low complication rate and good long-term outcomes, though more comparative studies are needed to evaluate all of these techniques and confirm the superiority of any of them.[8-11] It should be noted that, with the advance of oncology, the survival of oncology patients has increased and, consequently, limb preservation treatments have had to evolve to allow limb function to be preserved. Local flaps and bone grafts often lead to insufficient reconstruction with high complication rates.[9,10,12,13] In our study, the three patients with tibial tumors, one with Ewing's sarcoma and the other two with osteosarcomas, had a favorable evolution with great function and no recurrence up to the time of the study.

In contrast to bone allografts, the potential of rejection with VFF is negligible, and multiple studies show that the rate of consolidation in the recipient site is nearly 100% in timeframes ranging from 4 to 6 months.[9,14,15] However, in our series, there were two cases of pseudarthrosis (25%) and the mean consolidation time was 7.17 months, slightly higher than those published. Both cases of pseudarthrosis (one of the humerus and one of the ulna) had proximal consolidation at 5 and 11 months, respectively, but not of the distal focus. After their respective reoperations, consolidation was achieved in both. The difference in our mean consolidation times compared to those of other series may be due to an interobserver discrepancy or to the diagnostic technique used to define this variable.[15,16]

The most common complications described in the donor site are usually edema and leg weakness; however, in our study, the most frequent complication was hallux flexus. We can affirm that complications in the donor site are practically nonexistent or, at least, very easily approachable with outpatient surgery.

There were no cases of vascular permeability, all anastomoses were functional, and the rate of complications was comparable to previous studies. In our experience, reconstruction with the patient's own biological materials, such as the fibula bone flap, is a very effective procedure that provides the patient with very good long-term function of the operated limb, despite the fact that it is a highly complex technical surgery.[2,3,6,16]

This research has several limitations and possible biases as it is a retrospective, non-randomized study with a small sample size. Potential confounding factors, such as the surgeon's surgical expertise, the various rehabilitation therapies completed or not completed by the patients, and the subjective assessment provided by function scales, such as the MSTS, should be considered, as they may result in an overestimation of the results.

CONCLUSIONS

The use of a VFF associated or not with structural allograft is a useful strategy in the reconstruction of large bone defects (≥5 cm), regardless of the cause of the lesion. Graft survival and function are good, and the complication rate is acceptable.

As has been published, good outcomes are achieved with this technique, although, according to our experience, they are more satisfactory in the lower limb, this may be due to the fact that the association of VFF with structural allograft facilitates osseointegration in weight-bearing bones, such as the femur and tibia. It would be advisable to carry out more studies with larger samples, divided into subgroups, to corroborate this hypothesis.

Conflict of interest: The authors declare no conflicts of interest.

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