

Original Article

Free fibula flap for lower limb salvage after tumour resection

Vinay Kant Shankhdhar, Prabha S. Yadav¹, Ajay Puri¹, Ashish Kasat¹, Jaiswal Dushyant¹, Ram Badari Narayan Raghu¹, Ashish Gulia¹

ACTREC Tata Memorial Centre, Navi Mumbai, ¹Tata Memorial Centre, Mumbai, Maharashtra, India

Address for correspondence: Dr. Vinay Kant Shankhdhar, Flat No. 101, Mandavi Building, Anushakti Nagar, Trombay, Mumbai - 400 094, Maharashtra, India. E-mail: vinayshankhdhar@gmail.com

ABSTRACT

Context: Post-tumour resection lower limb salvage. **Aim/Introduction:** Resection of tumours of the femur and tibia around the knee and ankle joints results in large bony defects. Often arthrodesis is an alternative; in case, adequate functional motors cannot be preserved or due to economic constraints. Thus, in an immunocompromised patient, the vascularised fibula is the best form of reconstruction. The vascularised fibular flap (pedicled/free) can be used in combination with an allograft. We refer to such a combination reconstruction as 'allocombo'. The vascularised fibular graft hypertrophies in due course of time, and till that period, the allograft provides the required mechanical strength to allow early ambulation. **Subjects and Methods:** A retrospective study of 24 cases of vascularised fibular graft for lower limb reconstruction was conducted from February 2003 to March 2014. The average defect size was 15.5 cm and the average length of fibula harvested was 24.35 cm. A total of 19 free fibular flaps and 5 pedicled fibula were done. Mean age was 26 years. Fibula was nestled in the allograft obtained from the tissue bank. **Results:** The mean follow-up time was 52 months. Free flap success rate was 96%. Successful healing was achieved at 45 ends (97.8%). Radiological evidence of union at osteotomy sites occurred at an average of 6.8 months. Eight patients eventually succumbed to disease. At the final follow-up, the mean Musculoskeletal Tumour Society functional score of the evaluable patients was 26 (range 20–30). **Conclusions:** Pedicled fibula is a good option if the defect is within 14 cm of the knee joint at the femoral end. The vessels have to curve around the fibular head, thus its removal improves the reach of the pedicle. The flap is easy to harvest with predictable vascular anatomy and it can provide a large amount of vascularised bone and skin paddle. It results in early ambulation, rehabilitation and reduced morbidity. We realised that fixation is easier and chances of vascular injury are less in free as compared to pedicled fibula.

KEY WORDS

Allocombo; Capanna procedure; vascularised fibula with allograft

Access this article online	
Quick Response Code: 	Website: www.ijps.org
	DOI: 10.4103/ijps.IJPS_113_17

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Shankhdhar VK, Yadav PS, Puri A, Kasat A, Dushyant J, Narayan Raghu RB, *et al*. Free fibula flap for lower limb salvage after tumour resection. Indian J Plast Surg 2018;51:274-82.

INTRODUCTION

Resection of tumours of the femur and tibia around the knee and ankle joints results in large bony defects.^[1] While prosthesis offers a reconstructive option,^[2] often arthrodesis is an alternative; in case, adequate functional motors cannot be preserved or due to economic constraints (for those patients who cannot afford megaprosthesis). In an immunocompromised patient, the potential for infection and non-union increases if a non-vascularised bone graft is used.^[3,4] Thus, a vascularised fibula is the best form of reconstruction in such cases. The vascularised fibular flap (pedicled or free) can be used in combination with an allograft. We refer to such a combination reconstruction as 'alocombo.' The vascularised fibula provides the potential for biological incorporation and the irradiated allograft offers early mechanical strength. The vascularised fibular graft hypertrophies in due course of time, and till that period, the allograft provides the required mechanical strength to allow early ambulation. The goal of our work was to analyse the results of vascularised fibular graft to bridge the defect resulting after tumour resection.

SUBJECTS AND METHODS

A retrospective study of 24 [Table 1] of vascularised fibular graft for lower limb reconstruction was conducted at our centre from February 2003 to March 2014. In 20 cases, resection and reconstruction were done at the same time. Of the remaining four, one was removal of antibiotic spacer; total knee replacement prosthesis removal was done in two cases and in one, removal of the allograft with the plate was done.

The histopathologic diagnosis was Giant-cell tumour ($n = 8$), Ewing's sarcoma ($n = 3$), osteosarcoma ($n = 8$), periosteal tumour ($n = 3$) chondrosarcoma ($n = 1$) and adamantinoma ($n = 1$). Eight were female and 16 were male with the mean age of 26 years (range: 13–40 years). The average defect size was 15.5 cm (minimum of 8 cm and a maximum of 25 cm) and the average length of the fibula harvested was 24.35 cm (minimum = 20.5 cm and maximum = 28 cm). The length of fibula harvested is always much more than the defect. Harvesting long length of fibula ensures easier dissection of the peroneal pedicle, thus longer pedicle length. Nineteen free fibular flaps (FFFs) and five pedicled fibula were done. Double-barrel fibula was done in three cases. Wherever

double barrel was possible, it was preferred over allograft as it provides more vascularised bone stock. If the defect is small about 8–10 cm and pedicle length required is not much, only then double barrel is possible. For double barrel, distal segment has to flip up. For this, we need to excise at least 2 cm of bone for smooth curving of the pedicle. However, a combination of double barrel and allograft is not possible due to space constraints.

Intercalary reconstruction was done for 5 cases and arthrodesis for 19 cases (3 for ankle and 16 for knee). For ankle arthrodesis, free fibula was always used. Advancement of fibula distally towards the ankle results in traction of the peroneal vessels. Suitable internal fixation using a combination of plates, screws and K-wires was used to stabilise the construct. Suitable strut allografts were obtained from the hospital tissue bank.^[5]

Preoperatively, the site, size and involvement of the soft tissues were assessed in consultation with the orthopaedic colleagues. For defects within 14 cm above the knee joint, we planned pedicled fibula and free for defects beyond this. For segmental defects of the tibia, tibialisation of the fibula was done, but we have not included those cases for the present study.

Pedicled fibula

Harvest of the fibula flap

The reach of pedicled fibula is comfortable for 14 cm defects above the knee joint. Posterior tibial artery division improves the reach in larger defects. The posterior tibial artery was divided only in one case of the total five pedicled cases (20%), as the pedicled fibula was just falling short by 1 cm. The division of posterior tibial artery improved the reach proximally by about 2 cm as now, the pivot point shifted to the origin of the anterior tibial artery. No pre-operative angiography was done in this case; however, vascular clamps were applied for 20 min on the posterior tibial artery before its division to ascertain the limb vascularity. In other pedicled cases, division of posterior tibial artery was not required as the reach was adequate even without its division.

After the excision of the tumour, the fibula flap was harvested using the standard anterior approach. The ipsilateral fibular head increases the pedicle length requirement in the pedicled fibula, as the vessels have to curve around it. Thus, fibular head is also harvested (taking care to preserve the common peroneal nerve) with fibula providing with a longer bone and in all cases

Table 1: Overview of cases

Patient	Age (years)	Sex	Intercalary or arthrodesis	Provisional diagnosis	Free or pedicled	Site of tumour	Allograft	Defect	Length of fibula harvested	Type	Advanced/flipped	Surgery done	Primary excision	MSTS score (1 year, last follow-up)
1	13	Male	Intercalary	PNET	Free C/L	Femur	Yes	16.5	20.5			Removal of AB spacer-free fibula arthrodesis + plating	No	No follow-up
2	14	Male	Ankle arthrodesis	PNET	Free	Tibia	No	10.5	22			W/E+live fibular transfer	Yes	24, 26
3	15	Male	Arthrodesis	OGS	Free C/L	Knee	Yes	16.5	21			Live fibula reconstruction	Yes	Expired
4	16	Male	Intercalary	OGS	Free C/L	Femur	Yes	18.5	23			Knee arthrodesis with double fibular autograft struts	Yes	Expired
5	16	Female	Arthrodesis	GCT	Pedicled	Knee-distal femur	No	10	23		Advanced	Wide excision + pedicle fibula arthrodesis	Yes	28, 30
6	16	Male	Intercalary	OGS	Pedicled	Femur	Yes	12	23		Advanced	TKR removal + pedicled fibula knee arthrodesis + DCP	No	Flap loss, expired
7	18	Male	Ankle arthrodesis	PNET	Free	Tibia	No	8	20.5	Double barrel		W/E + knee arthrodesis + live fibula doubled + Ex fix	Yes	Expired
8	19	Male	Arthrodesis	Osteosarcoma	Free	Femur	Yes	21	26.5			W/E with knee arthrodesis + allograft + plate	Yes	26, 27
9	21	Female	Arthrodesis	GCT	Free	Tibia	No	20	26			Live fibula arthrodesis+flap cover	Yes	No follow-up
10	21	Male	Intercalary	Periosteal OGS	Free	Femur	Yes	18	24.5			Live fibula reconstruction after W/E femur	Yes	Distal nonunion
11	22	Male	Ankle arthrodesis	GCT	Free	Knee-Prx Tib	No	13	26			W/E with live fibula alloarthrodesis	Yes	25, 27
12	24	Female	Arthrodesis	Osteosarcoma	Free	Shaft femur	Yes	21.5	25.5			Wide excision + live fibula allograft combo arthrodesis	Yes	Fracture of allograft
13	26	Male	Arthrodesis	GCT	Free	Femur	Yes	25	28			W/E + knee arthrodesis with allo + live fibula combo	Yes	22, 24
14	28	Female	Arthrodesis	Osteosarcoma	Free	Femur	Yes	21	24.5			W/E + live fibula + plating	Yes	Expired
15	29	Female	Arthrodesis	GCT	Free	Femur	Yes	16.5	24.5			W/E U/E tibia + live fibula arthrodesis	Yes	No follow-up

Contd...

Table 1: Contd...

Patient	Age (years)	Sex	Intercalary or arthrodesis	Provisional diagnosis	Free or pedicled	Site of tumour	Allograft	Defect	Length of fibula harvested	Type	Advanced/flipped	Surgery done	Primary excision	MSTS score (1 year, last follow-up)
16	32	Female	Arthrodesis	Chondrosarcoma lt. femur L/E	Free	Femur	No	10	25	Double barrel		Excision + double-barrel live fibular graft + knee arthrodesis	Yes	No follow-up
17	32	Male	Arthrodesis	GCT	Free	Femur	Yes	17.5	26			W/E + live fibula + custom plate	Yes	19, 20
18	33	Female	Arthrodesis	GCT	Pedicled	Femur	No	9.5	25		Flipped	Removal of allograft and plate+live fibula graft and fixation	No	Amputation secondary to disease
19	34	Male	Arthrodesis	OGS	Free	Femur	No	10.5	27	Double barrel		W/E + double-barrel live fibula	Yes	Expired
20	39	Male	Arthrodesis	GCT	Free	Tibia	No	13.5	23			W/E + live fibula arthrodesis	Yes	23, 25
21	39	Male	Arthrodesis	Osteosarcoma	Pedicled	Ankle	No	11.5	26		Flipped	W/E + pedicled fibula + allograft	Yes	27, 30
22	39	Male	Arthrodesis	OGS parosteal D/E femur left	Free	Femur	Yes	18.5	27			Live fibula-allocombo with DCS fixation after removal of implant	No	Expired
23	40	Male	Intercalary	Adamantinoma L/E tibia recurrent	Pedicled	Tibia	No	17.5	26		Flipped	Intercalary excision with live fibula allocombo	Yes	25, 26
24	32	Female	Arthrodesis	OGS parosteal femur	Free	Femur	Yes	15.5	21			Excision + free fibula knee arthrodesis	Yes	Expired

PNET: Pancreatic neuroendocrine tumours, GCT: Giant-cell tumour, OGS: Osteogenic sarcoma, TKR: Total knee replacement, DCP: Dynamic compression plate, W/E: Wide Excision, Local Excision, D/E: Distal End U/E: Upper/End

when pedicled fibula is used, it reduces the bulk on the lateral aspect of the knee and improves the reach. The fibular flap was harvested with the head of the fibula along with the maximum length of the fibula available leaving behind 6 cm of the fibula close to the ankle joint. The peroneal vessels are divided at the lower end.

The fibula can be transposed in the defect by either advancing (the upper end of the fibula reaches the upper end of the defect) or by flipping it 180° [Figure 1a-c], so that the lower end of the fibula reaches the upper part of the defect. Flipping improves the reach of the fibula in the upper defects. Pedicled fibula was advanced in two cases (40%) and flipped in three cases (60%). The fibular head was excised in all cases of pedicled fibula as it reduces the arc of rotation of the peroneal vessels carrying the fibula.

Allo-fibula fixation

One side of the allograft cortex is removed to enable fibula to nestle in the allograft [Figure 2]. The length of allograft required is equal to the defect size and the fibula projects out 1 cm on either side so that it can be pegged in the medullary cavity of the femur and/or tibia [Figure 3a and b]. The allograft is fixed using plate and screws, and the fibula is secured using K-wire fixation [Figure 4].

Free fibula with allograft

In cases where the ipsilateral fibula is not available or where the defect is too high up or where the knee joint is not sacrificed, it is usually not possible to use pedicled fibula

and then either ipsilateral fibula or contralateral fibula as a free flap is used. The entire procedure remains the same except that microvascular anastomosis is required. The recipient vessels may be descending branch of the lateral circumflex femoral vessels most of the times. Descending branch of the lateral circumflex femoral vessels are the vessels which supply anterolateral aspect of the thigh and is frequently harvested with the anterolateral thigh flaps, thus a relatively constant, familiar and easy to dissect the vessel. It lies just behind the rectus femoris muscle. Even femoral vessels with end-to-side anastomosis using saphenous vein graft were required in four cases.

In two cases, pedicled fibula was converted into the free vascularised flap. In one case, during fixation of the fibular flap, the peroneal vessel avulsed and anastomosis was then done with the anterolateral thigh flap pedicle. In a second case, the vessel was getting compressed with the femoral condyle and developed a thrombus in the vessels. A venous graft was required and anastomosis was done end-to-side with the femoral vessels.

Statistical methods

Shapiro–Wilk test was used to check the Musculoskeletal Tumour Society (MSTS) Scores. It was normally distributed. The MSTS scores improved over time as checked by the paired *t*-test ($P < 0.0001$). The Statistical Package for the Social Sciences software (Version 25, IBM SPSS Corp., Armonk, NY, USA) was used for statistical analysis.

RESULTS

The mean follow-up time was 52 months (28 months to 109 months). In three cases, skin paddle necrosis was

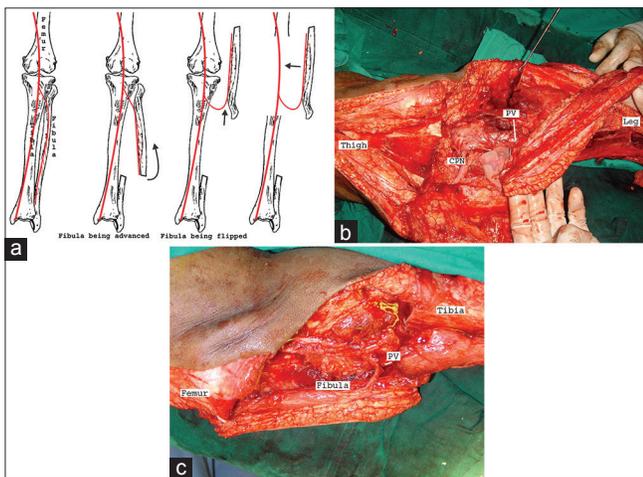


Figure 1: Pedicled fibula being transposed to a defect in the femur. (a) Line diagram to show fibula being advanced and flipped 180°. (b) Pedicled fibula harvested and being flipped 180° to reach defect in the femur. (c) Fibula flipped 180° to reach the defect

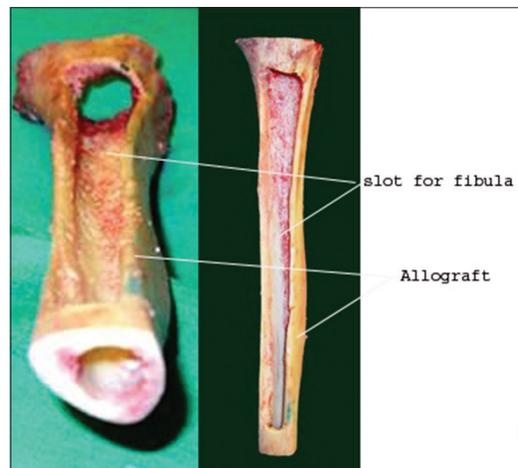


Figure 2: Irradiated and non-antigenic tibial allograft obtained from the bone bank. The allograft is reamed to create a slot for the fibula

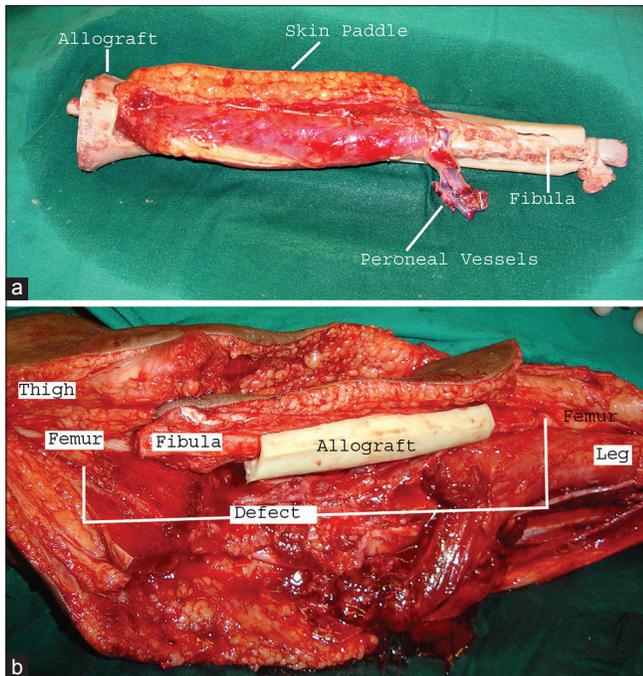


Figure 3: (a) Fibula fixed in the slot of allograft with both fibular ends projecting out to be pegged into the femur on both sides of the defect. (b) The fibula+allograft in the defect

observed but no fibular loss. Of the total 24 vascularised fibula flaps (VFFs), one flap was lost due to vascular compromise secondary to infection, resulting in amputation. This patient later died due to the disease.

Thus, free flap success rate was 96%. One patient required additional bone grafting for distal non-union in a total of $(23 \times 2 = 46)$ bone ends. Successful healing was achieved at 45 ends (97.8%). Guarded partial weight-bearing using walking assists started once evidence of bony union started. It is averaged at about 3-month post-operative. The patient was referred to physiotherapist for proper training of partial weight-bearing. It was progressed to eventual full weight-bearing over the next 6–8-week time. Radiological evidence of union [Figure 5] at osteotomy sites occurred at an average of 6.8 months (5 months to 23 months). In one patient, 2 years after the allocombo surgery, the allograft had not incorporated, but both the superior and inferior osteotomy sites had united, thus the patient was allowed weight-bearing. The vascularised fibular graft had a segmental fracture; this patient required amputation secondary to recurrence.

Eight patients eventually succumbed to disease. Two were local recurrences. At the final follow-up, the mean of MSTs' functional score of the evaluable patients was 26 (range: 20–30). We had prepared two tables for MSTs

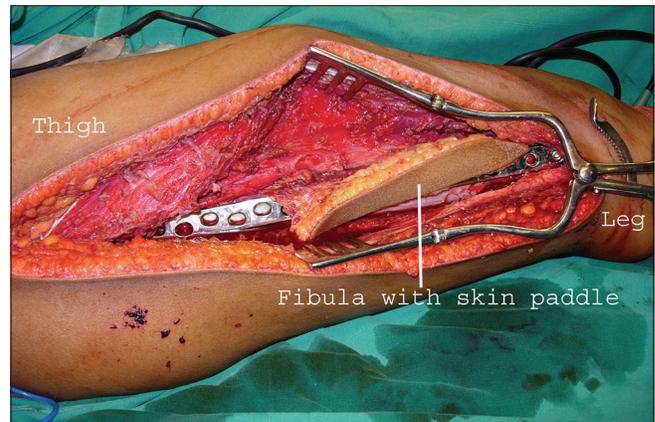


Figure 4: Allocombo fixed with plate and screws and both ends of the fibula pegged in the medullary cavity of the femur and/or tibia

score, one at 12 months and one at the final follow-up. MSTs score had improved [Table 2].

DISCUSSION

The options available after excision of extremity bony tumours are either amputation or limb salvage.

Limb salvage is currently the procedure of choice, as it has been proven that the oncologic outcome is not compromised and the quality of life is much superior as compared to amputation.^[6]

Involvement of major neurovascular bundles, massive soft-tissue resections or severe infections are relative contraindications for limb salvage.^[7]

Knee prosthesis is the ideal reconstructive option,^[8] but often due to the massive resections, endoprosthesis is not possible and arthrodesis is an alternative option to give a stable, durable and pain-free reconstruction.^[3,4]

The Ilizarov technique is another option to deal with such defects, but time required and requirement of chemotherapy in patients restrict the use of this technique. In this subset of patients, pin-tract infections and interference with callus formation are frequent due to aggressive chemotherapy.^[9]

Capanna first reported the use of allograft combined with autologous fibular flap for lower extremity reconstruction after tumour resections. Vascularised fibula alone is too weak to allow early ambulation and intercalary allograft alone leads to delayed

union, non-union or fractures, thus a combination of the two solves the problem. The outer shell of the allograft provides the mechanical strength required for weight-bearing and the inner core of the vascularised fibula provides for the vascularity, thus ensuring good healing.^[9]

Belt P.J. and Dickinson I.C. reported that the complication rates with allograft alone were high and the allograft non-union rate was 50%; they further noted that the FFF hastens time to full weight bearing but does not appear to affect the complication rates of the allograft.^[10] The allograft with VFF union rate in our series was 97.8%. In our series, eight patients succumbed to disease and four were lost to follow-up. A total of three bone complications (one flap loss, one distal non-union and one segmental fracture) occurred of the total 13 patients with long-term follow-up. The complication rate thus came to 23%. Further, in the series by Belt and Dickinson, the mean time to full-weight-bearing in the lower limb cases was 7.5 months and 100% were full-weight-bearing at 18 months. Whereas in our study, guarded partial

weight-bearing using walking assists progressed to eventual full-weight-bearing once evidence of bony union was seen on radiographs. Standard biplanar radiographs were assessed. Bridging across three of four cortices in biplanar radiographs was considered evidence of union at an average of 6.8 months (5 months to 23 months). Please refer Table 3 for Comparison of various factors with other studies and Table 4 for Kaplan–Meier survival chart

CONCLUSIONS

Pedicle fibula is a good option if the defect is within 14 cm of the knee joint at the femoral end. In cases where the tibial condyles are also excised due to oncological reasons, the reach of pedicle fibula is more as compared to cases in which the tibial condyles are spared. This helps in planning for a pedicle or free fibula. Furthermore, the ipsilateral fibular head increases the pedicle length requirement in pedicle fibula as the vessels have to curve around it, so it is important to remove the fibula head taking care to preserve the common peroneal nerve. The flap is easy to harvest with predictable vascular anatomy and it can provide large amount of the vascularised bone and skin paddle. It results in early ambulation, rehabilitation and reduced morbidity. In our experience, we realised that fixation is easier and chances of vascular injury are less in free as compared to the pedicle fibula.

Acknowledgement

The authors would like to thank Mr. Nilesh Ganthade, Medical Graphics Department, Tata Memorial Hospital, Mumbai

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

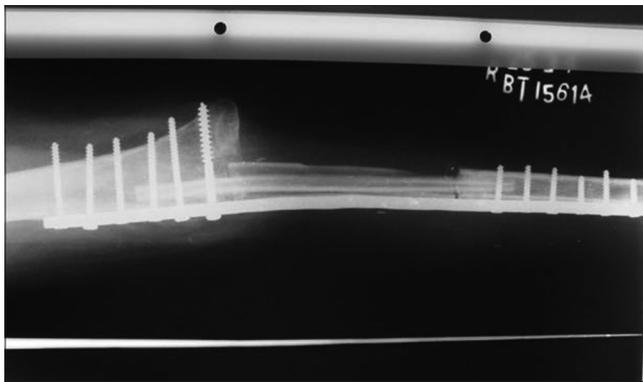


Figure 5: X-ray showing radiological union 1-year post-operative

Table 2: The musculoskeletal tumour society scores over time

12 months	Follow-up	P
24.33±2.74	26.11±3.06	<0.0001

Table 3: Comparison of various factors with other studies

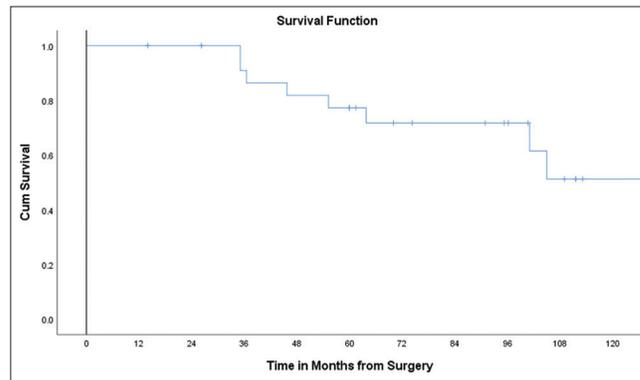
Studies diseasefree survival (years)	Number of patients	Mean followup (years)	Mean defect length (cm)	MSTS score (%)	Complication rate (%)
Zaretski <i>et al.</i> ^[11]	30	2.5	NR	-	37
Krieg <i>et al.</i> ^[12]	16	1.0	16.2	85	-
Eward WC <i>et al.</i> ^[13]	30	4.9	14.8	-	53
Rabitsch <i>et al.</i> ^[14]	12	3.2	18.7	-	50
Parag <i>et al.</i> ^[15]	10	3.1	18.5	86.6	50
Our study	24	4.3	15.5	87	23

MSTS: Musculoskeletal Tumour Society, NR: Normal range

Table 4: Kaplan-Meier survival chart

Case processing summary						
Total n	Number of events		Censored, n (%)			
24	8		16 (66.7)			
Survival Table						
Time	Status	Cumulative proportion surviving at the time		Number of cumulative events	Number of remaining cases	
		Estimate	SE			
1	13.996	1.00		0	23	
2	26.218	1.00		0	22	
3	35.055	2.00		1	21	
4	35.055	2.00	0.909	0.061	2	20
5	36.468	2.00	0.864	0.073	3	19
6	45.700	2.00	0.818	0.082	4	18
7	55.195	2.00	0.773	0.089	5	17
8	59.893	1.00			5	16
9	59.926	1.00			5	15
10	61.405	1.00			5	14
11	63.770	2.00	0.718	0.099	6	13
12	69.947	1.00			6	12
13	74.251	1.00			6	11
14	90.875	1.00			6	10
15	95.211	1.00			6	9
16	96.131	1.00			6	8
17	100.665	1.00			6	7
18	101.027	2.00	0.615	0.127	7	6
19	104.936	2.00	0.513	0.141	8	5
20	108.977	1.00			8	4
21	111.507	1.00			8	3
22	111.540	1.00			8	2
23	113.117	1.00			8	1
24	161.248	1.00			8	0

SE: Standard error



REFERENCES

- Simon MA, Aschliman MA, Thomas N, Mankin HJ. Limb-salvage treatment versus amputation for osteosarcoma of the distal end of the femur 1986. *J Bone Joint Surg Am* 2005;87:2822.
- Nouri H, Meherzi MH, Jenzeri M, Daghfous M, Hdidane R, Zehi K, *et al.* Knee arthrodesis using a vascularized fibular rotatory graft after tumor resection. *Orthop Traumatol Surg Res* 2010;96:57-63.
- Donati D, Di Liddo M, Zavatta M, Manfrini M, Bacci G, Picci P, *et al.* Massive bone allograft reconstruction in high-grade osteosarcoma. *Clin Orthop Relat Res* 2000;377:186-94.
- Mankin HJ, Hornicek FJ. Treatment of giant cell tumors with allograft transplants: A 30-year study. *Clin Orthop Relat Res* 2005;439:144-50.
- Lobo Gajiwala A, Agarwal M, Puri A, D'Lima C, Duggal A. Reconstructing tumour defects: Lyophilised, irradiated bone allografts. *Cell Tissue Bank* 2003;4:109-18.
- Rougraff BT, Simon MA, Kneisl JS, Greenberg DB, Mankin HJ. Limb salvage compared with amputation for osteosarcoma of the distal end of the femur. A long-term oncological, functional, and quality-of-life study. *J Bone Joint Surg Am* 1994;76:649-56.
- DiCaprio MR, Friedlaender GE. Malignant bone tumors: Limb sparing versus amputation. *J Am Acad Orthop Surg* 2003;11:25-37.
- Pan KL, Chan WH, Ong GB, Premeenthil S, Zulkarnaen M,

- Norlida D, *et al.* Limb salvage in osteosarcoma using autoclaved tumor-bearing bone. *World J Surg Oncol* 2012;10:105.
9. Capanna R. A new technique for reconstruction of large metadiaphyseal bone defects. A combined graft (allograft shell plus vascularised fibula) orthop. *Traumat* 1993;2:159-77.
 10. Belt PJ, Dickinson IC, Theile DR. Vascularised free fibular flap in bone resection and reconstruction. *Br J Plast Surg* 2005;58:425-30.
 11. Zaretski A, Amir A, Meller I, Leshem D, Kollender Y, Barnea Y, *et al.* Free fibula long bone reconstruction in orthopedic oncology: A surgical algorithm for reconstructive options. *Plast Reconstr Surg* 2004;113:1989-2000.
 12. Krieg AH, Davidson AW, Stalley PD. Intercalary femoral reconstruction with extracorporeal irradiated autogenous bone graft in limb-salvage surgery. *J Bone Joint Surg Br* 2007;89:366-71.
 13. Eward WC, Kontogeorgakos V, Levin LS, Brigman BE. Free vascularized fibular graft reconstruction of large skeletal defects after tumor resection. *Clin Orthop Relat Res* 2010;468:590-8.
 14. Rabitsch K, Maurer-Ertl W, Pirker-Frühauf U, Wibmer C, Leithner A. Intercalary reconstructions with vascularised fibula and allograft after tumour resection in the lower limb. *Sarcoma* 2013;2013:160295.
 15. Parag S, Yogesh P, Rathod J, Nikhil P, Amit J. Limb salvage with microvascular free fibula following primary bone sarcoma resection. *Indian J Plast Surg* 2016;49:370-7.