Original Article

OUTCOME OF LOWER EXTREMITY SALVAGE WITH IPSILATERAL VASCULARIZED FIBULA AFTER TIBIAL BONE TUMOR RESECTION IN PEDIATRIC AGE GROUP

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ABSTRACT

Background: Malignant bone tumors are difficult to diagnose at every level of pubertal growth in children and such defects are challenging to reconstruct. The purpose of this study was to report clinical characteristics and outcomes of limb-sparing surgeries in a series of pediatric patients after resection of tibia sarcoma using the TESS questionnaire.

Material and methods: In this study, we retrospectively reviewed data of patients having tibial sarcoma, who underwent salvage of lower extremity with ipsilateral vascularized fibula after tibia tumor resection from July 2016 to July 2017 with follow up till July 2019, retrieved from hospital database software. We collected demographic, oncological data, reconstructive data, complications, and outcome during a 2-years follow-up. Morbidity was assessed by the number of hospital visits during the follow-up period.

Results: Single staged tribalization of the fibula was done in all 7 pediatric patients who had the age of 12±2.4 years and among them 5(71.4%) were male. Out of 7 patients, 5(71.4%) had Osteosarcoma with the mean ± SD size of the defect after tumor resection being 13±2.6 cm. Weight-bearing in 5(71.4%) patients, was started at 6 months. Mean ± SD TESS at 3 months, 6 months, 1 year, and at 2 years showed gradual improvement in daily routine activities of the patient ($p<0.001$). Mild hypertrophy was observed in 4(57.2%) patients who had no complications after 2 years.

Conclusion: Single-stage pedicled ipsilateral fibula transposition for tibial segmental defect has fewer complications with better outcome making it the procedure of choice for tibia reconstruction.

Key Words: Lower Extremity, Fibula, Morbidity

INTRODUCTION

Marked variation in the incidence of pediatric bone tumors has been observed all over the world. In children, various benign and malignant tumors such as fibrous dysplasia, osteoblastoma, histiocytosis x, lymphoma, adamantinoma, and Ewing's sarcoma involve diaphysis of long bones.[1] Malignant bone tumors account for 3-5 percent of neoplasms among children aged 0-14 years and 57% of those tumors occur in bones of the lower extremities.[2] Also, these tumors are difficult to diagnose at every level of pubertal growth in children and such long bone defect reconstructions affect children physically, socially, and psychologically.

Limb sparing resections of tibial tumors have evolved with advances in reconstructive surgery, orthopedic oncologic surgery, medical oncology, and radiation oncology and it has become the treatment of choice for >80% of children without increase in mortality.[3,4] Various options for reconstruction of such defects are in use including endoprosthetic replacement, non-vascularized bone graft, ipsilateral transposition of the fibula, free fibula bone graft, distraction osteogenesis by Ilizarov ring fixator, and reimplantation of recycled

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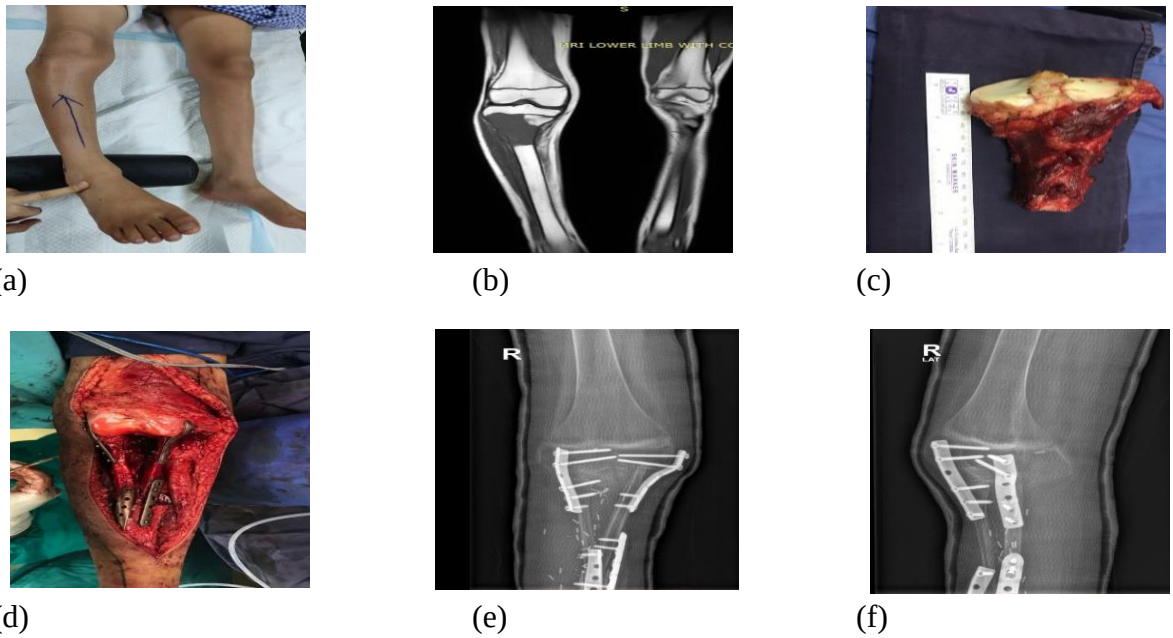
bone after autoclavization, pasteurization, or liquid nitrogen treatment.[5,6] Neoadjuvant or adjuvant chemotherapy and radiotherapy are applied for systemic and local effects to the patient pre-and post-operatively to reduce surgical morbidity.

Transposition of the ipsilateral fibula to the tibia (fibula pro tibia) was suggested by Hahn in 1884 and was first used successfully by Huntington in 1903, to fill a 12.7 cm tibial defect in a 7-year-old boy in a staged manner.[7,8] Various modifications were suggested using ipsilateral fibula with or without allograft to reconstruct segmental tibial defect with good long-term functional results.[9] Functional outcome was most frequently measured by Toronto Extremity Salvage Score (TESS) or Musculoskeletal tumor society (MSTS) 1993 questionnaire.[10] However, there is a scarcity of studies showing outcomes in terms of functional, social, and psychological wellbeing of the patient after such reconstruction by analyzing daily activities using TESS questionnaire in pediatric age group during follow up. The purpose of this study was to report clinical characteristics and outcomes of lower extremity limb-sparing surgeries in a series of pediatric patients after resection of tibia sarcoma using the TESS questionnaire.

MATERIAL AND METHODS

In this retrospective cohort study, data of pediatric patients who underwent salvage of lower extremity with ipsilateral vascularized fibula after tibia tumor resection from July 2016 to July 2017 with follow-up till July 2019, were retrieved from hospital database software. This study was conducted in the Plastic and Reconstructive surgery department of Shaukat Khanum memorial cancer hospital and research center (SKMCH & RC), Lahore, Pakistan. Approval was taken from the Institutional review board (EX-30-09-19-01). Patients with age < 15 years, having biopsy-proven tibial sarcoma on presentation, completed neoadjuvant chemotherapy, showing at least posterior tibial and peroneal vessels not involved by a tumor on MRI and underwent lower limb salvage for tibial defect ≥6 cm with ipsilateral vascularized fibula bone graft were included in the study using non-probability consecutive sampling technique (Data of all the patients fulfilling inclusion criteria at presentation were continuously included in the study). Patients, with age > 15 years and tibial defect <6 cm, requiring only soft tissue coverage for reconstruction, had posterior tibial and peroneal vessels involved in tumor mass, underwent previous flap surgery as a result of initial wound-related complications or pre-existing vascular limb disease were excluded from the study. Patients who had previous tumor excision outside our hospital or presented with distant metastasis or recurrent disease were also excluded.

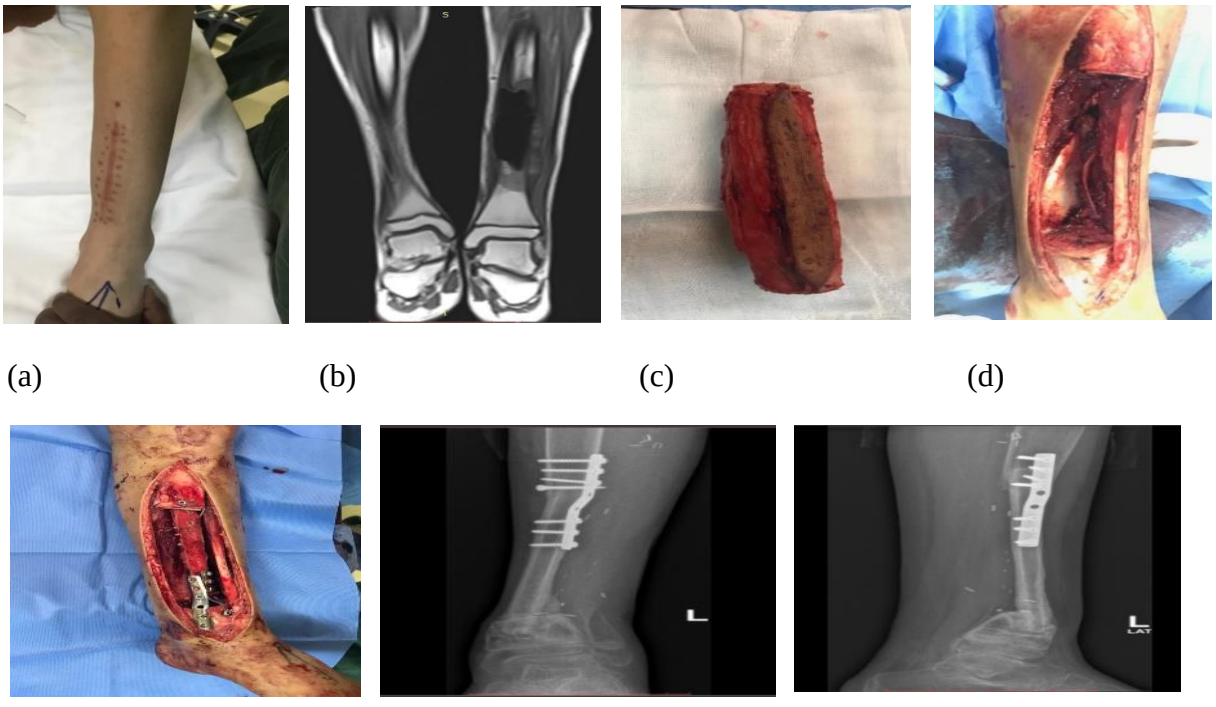
All the study patients were admitted to the hospital one day before surgery. Informed consent was taken by all patient's guardians after explaining the procedure, its complications, and possible future outcomes. The pre-operative assessment was done by routine investigations for surgery, the decision about incisions for tumor resection and fibula flap elevation made, and perforator marking of fibula flap by handheld Doppler done. Prophylactic antibiotics were given before surgery. During surgery, tumor resection was done by the Orthopedic team under pneumatic tourniquet control. After achieving margin clearance by frozen section, the plastic surgery team measured the defect size, harvested fibula bone of the same leg based on peroneal vessels through a separate lateral incision. The fibula was harvested to have at least 2 cm extra length to overlap the tibia proximally and distally. Vascularity of the foot was confirmed by removing a pneumatic tourniquet followed by clamping of peroneal vessels before the division of the pedicle distally. The harvested fibula was transposed to tibia defect after osteotomies as per requirement and fixed in single or double barrel arrangement using K-wire, tension band wire, screws, or plates avoiding kinking, torsion, or tension on the pedicle. The drain was placed for 3-5 days. Final closure in all patients was done without the need for a soft tissue flap.



(a) (b) (c)

(d) (e) (f)

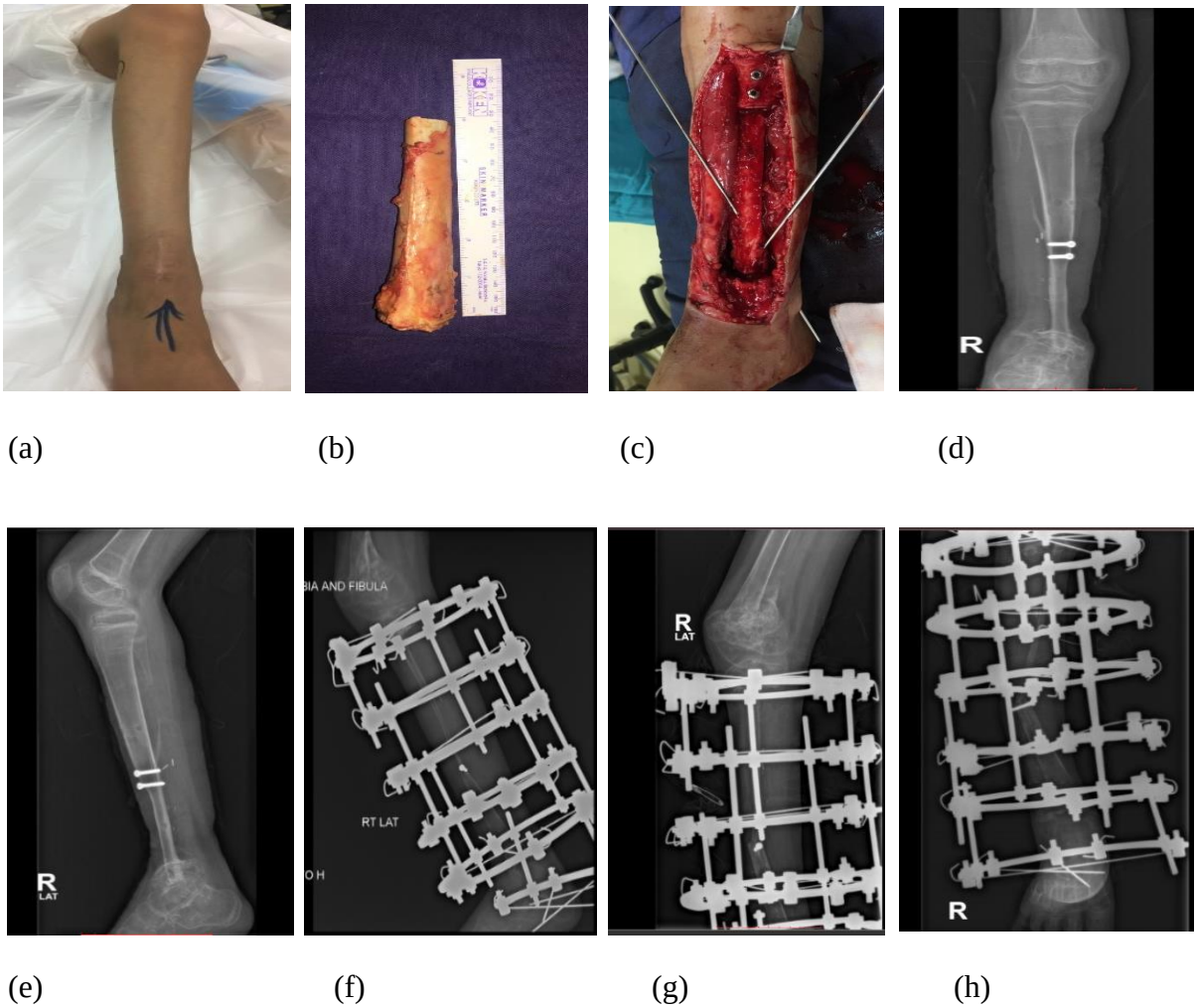
Figure 1: (a) 14 years old male with osteosarcoma of the right proximal tibia (b) MRI image showing tumor of the right proximal tibia (c) Gross picture of 8 cm excised tumor (d) Intraoperative image after fixation of the vascularized fibula as double-barrel with plates and screws (e) & (f) Anterior and Lateral view of X-ray right tibia after 14 months of reconstruction showing the union of bones.



(a) (b) (c) (d)

(e) (f) (g)

Figure 2: (a) 13 years old male with osteosarcoma of the left distal tibia (b) MRI image showing tumor of the left distal tibia (c) Gross picture of 14 cm excised tumor (d) Intraoperative image of the defect (e)Intraoperative image after fixation of the vascularized fibula as a single barrel with plates and screws (f) & (g) Anterior and lateral view of X-ray left tibia after 8 months of reconstruction showing the union of bones.



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 3: (a) 11 years old female with Ewing sarcoma of the right distal tibia (b) Gross picture of 12 cm excised tumor (c) Intraoperative image after fixation of the vascularized fibula as a single barrel with plates and screws (d) & (e) Anterior and Lateral view of X-ray left tibia after 2 months of reconstruction showing the union of bones (f), (g) & (h) Different X-ray views showing Ilizarov fixation after the fracturing of the fibula at 8 months postoperatively.

Assessment during follow up period was done by clinical examination of wounds, functional outcome by Toronto extremity severity score (at 3 months, 6 months, 1 year and 2 years), and radiological analysis by two views X-ray (at 2 weeks, 6 weeks, and as per the requirement of Orthopedic team) of the reconstructed site of the leg. Partial weight-bearing was started with a splint once bone healing was confirmed by radiograph.

We collected demographic, oncological data (primary disease, neoadjuvant, and adjuvant treatment), reconstructive data (location of defect in tibia, length of graft and osteosynthesis type), complications, and outcome data (limb growth and TESS at months, 6 months, 1 year and 2 years) during 2-years follow-up. Morbidity was assessed by the number of hospital visits during the follow-up period.

Descriptive variables were presented by proportions, mean or median values, and percentage as appropriate by data distribution. Data of categorical variables like age, gender, defect size, length of the graft, and outcome measures like TESS were analyzed using the chi-square test. Data of variables like tumor type, tumor size, type of bone arrangement, complications, and the number of days of hospital stay during the

follow-up period were analyzed by Student's T-test. Statistical analysis was performed using SPSS 21.0 statistical software. Statistical significance was defined as p value <0.05.

RESULTS

Single staged tribalization of the fibula was done in all 7 pediatric patients from July 2016 to July 2017 with follow-up till July 2019. The patients had mean ± SD age of 12 ± 2.4 years and among them 5 (71.4%) were male. All patients presented with biopsy-proven bone tumor and completed chemotherapy for the down staging of the tumor before surgery. Out of 7 patients, 5 (71.4%) had Osteosarcoma and 2 (28.6%) had Ewing sarcoma of tibia. The most common site of the tumor was proximal tibia in 3 (42.8%), distal tibia in 3 (42.8%), and Midshaft of the tibia in 1 (14.4%). The mean ± SD size of the defect after tumor resection was 13 ± 2.6 cm. One patient had a defect involving the knee joint due to removal of the proximal end of the tibia while another patient had medial malleolus removal as the tumor involved the distal end of the tibia. Margin clearance was achieved in all patients by frozen section with at least > 1 cm soft tissue and 1 cm bone margin clearance.

The mean ± SD length of vascularized fibula harvested was 19 ± 2.7 cm. It was used as a single barrel in 5 (71.2%) patients and as a double-barrel in 2 (28.8%). The proximal end of the fibula was fixed with tibia by plates and screws in 5 (71.2%), screws in 1 (14.4%), and tension band wiring in 1 (14.4%) while the distal end of the fibula was fixed with plates and screws in 4 (57.2%), cortical screws in 2 (28.6%), and K-wire in 1 (14.4%). Knee joint arthrodesis was done in 1 (14.4%) and ankle arthrodesis in 1 (14.4%) patient while joint movements in the rest of the patients 5 (71.2) was normal along with the axial alignment of fibula graft. Adjuvant chemotherapy was given in 4 (57.2%) patients and 3 (42.8%) patients who had margin clearance of > 2cm did not receive adjuvant chemotherapy (Table 1)**.** None of our patients received radiotherapy pre- or post-operatively. The mean follow-up period was 28.6 (Range: 25-39) months with mean ± SD hospital visits 13±(4.2) during the follow-up period. All the patients were assessed by clinical examination and radiologically (when needed) during the follow-up period. Weight-bearing in all patients was started at 6 months in 5 (71.2%) except for the first operated patient 1 (14.4%) who started weight bearing at 5 months. That patient developed a fracture of the proximal end of the fibula after an accidental fall followed by fibula graft resorption and was managed by applying an Ilizarov ring fixator. Another patient had a mal-union at the distal end of the graft and was managed by revision surgery by refreshing bone margins and adding bone graft with an additional 3-month period of non-weight bearing. The rest of the 4 (57.2%) patients had no complications. None of our patients developed recurrence or metastasis during 28.6 months follow-up period. Out of 7 patients, 6 (85.6%) are alive and disease-free to date while 1 (14.4%) patient died due to complications of postoperative chemotherapy.

Table 2 shows the Toronto extremity salvage score (TESS) in all patients measured at 3 months, 6 months, 1 year, and 2 years. Mean ± SD TESS at 3 months was 55.1 ± 4.9 for 7 patients, at 6 months 72.3 ± 7.2 for 6 patients (One patient died after 5 months), at 1 year 81 ± 8.7, and at 2 years it was 82.3 ± 7.4 showing gradual improvement in daily routine activities, socializing and psychological wellbeing of the patient (Statistically significant $p<0.001$). Mild hypertrophy was also observed in 4 (57.2%) patients who had no complications after 2 years.

Table-1: Showing demographic, oncological, reconstructive, and outcome data of study patients.

Sr. No.	Age/ Gen-der	Tumor type and site	Defect size	Graft length	Fixation type	Chemo-therapy	Follow Up		Complications	Outcome status
							Total period (Months)	Number of hospital visits in follow up period		
1.	9 y/ F	Ewing Sarcoma Right distal tibia near ankle joint	12 cm	16cm	Single barrel, Prox--2 screws, Distal--K-wire	Both Neo-adjuvant and Adjuvant	39	18	Fracture of the proximal end, resorption of the graft	Alive and disease-free
2.	14 y/ M	Osteosarcoma Right proximal tibia	17cm	21cm	Single barrel, Prox--TBW, Distal--Cortical screws	Both Neo-adjuvant and Adjuvant	38	20	Malunion at the distal end	Alive and disease-free
3.	14 y/ M	Osteosarcoma, Right proximal tibia near knee joint	9 cm	20cm	Double barrel, Plates with screws	Only Neo-adjuvant	26	12	Nil	Alive and disease-free
4.	14 y/ M	Osteosarcoma, Left proximal tibia	11 cm	24cm	Double barrel, Prox--DCP plate, Distal--Cortical screws	Both Neo-adjuvant and Adjuvant	5	7	---	Dead
5.	13 y/ M	Osteosarcoma, Left distal tibia	12 cm	16cm	Single barrel, Prox--Interfragmentary screws + tubular plate, Dostal--T shaped plate + 6 screws	Only Neo-adjuvant	25	11	Nil	Alive and disease-free
6.	11 y/ F	Osteosarcoma, Right tibial midshaft	14 cm	18 cm	Single barrel, Plates with screws	Only Neo-adjuvant	36	10	Nil	Alive and disease-free
7.	8 y/ M	Ewing Sarcoma, Left distal tibia	16 cm	20 cm	Single barrel, Prox--Interfragmentary screws + tubular plate, Dostal--T shaped plate + 6 screws	Both Neo-adjuvant and Adjuvant	31	12	Nil	Alive and disease-free

Table-2: Toronto extremity salvage score (Range 0-100)

Serial No.	At 3 months	At 6 months	At 1 year	At 2 years
1.	45	58	71	80
2.	54	76	68	70
3.	65	75	90	92
4.	56	0	0	0
5.	52	78	90	94
6.	63	75	86	90
7.	58	70	88	90

DISCUSSION

Autologous reconstruction is considered to be the gold standard for bony defect especially in the setting of lower limb salvage after tumor extirpation in children. It has replaced amputations in most of the primary bone tumors of the lower extremity in the pediatric age group. Various studies have shown the better outcome of limb-sparing surgeries compared to amputation in terms of functional, social, and psychological wellbeing.[11] Also, some review studies showed that there was no significant difference in recurrence rate, the disease-free period after surgery, and overall survival of patient after limb salvage and amputation.[12]

Among many approaches described for autologous reconstruction of tibial defect, we used single-stage tribalization of the ipsilateral fibula in our pediatric patients.[13] Pedicle ipsilateral vascularized fibula with preserved endosteal and periosteal circulation, is considered to be superior for tibial defects as compared to free vascularized fibula graft which has the risk of flap loss owing to microvascular anastomosis failure and donor site complications.[14] The advantages of using vascularized bone are their osteo-inductive, osteo-conductive, and osteo-progenitor properties along with its minimal donor site morbidity.[15] Limitations of non-vascularized bone graft include large bone defect size, presence of infection, resorption of bone graft, and potential need of soft tissue for closure.

In our study, we used fibula graft in a single barrel manner in most of our cases (71.2%) as the defect size was large (Range 12-17 cm) and one (14.4%) of these patients had a stress fracture and subsequent resorption of graft and later on developed major limb length discrepancy (>2cm). This was consistent with the findings of some studies showing a low rate of stress fracture (10-20%) when the graft was used in a double-barrel manner.[16]

Studies have shown good long-term results and an overall low complication rate after single-stage transposition of the ipsilateral vascularized fibula for tibia defect reconstruction.[17] It was also seen that functional outcome like routine activities, socializing and psychological wellbeing of patients undergoing such reconstructions, is reliably measured by TESS questionnaire as compared to MSTS.[18] The TESS is superior to MSTS as this questionnaire is filled by the patient himself giving details of the patient's activity level, does not require a hospital visit, can be administered by email or electronically, and therefore is used for the long term follow up studies. In our patients, we found that the score improved significantly from 6 to 12-month duration. It was most likely associated with completion of chemotherapy, the start of weight-bearing, and overall improvement in activity of patient owing to painlessness. After 1 year follow-up, the score showed slight improvement which was consistent with many retrospective studies.[19]

The fibula is known to hypertrophy in response to functional loading when it is transferred to a weight-bearing location. Initially, hypertrophy can be appreciated after 4-6 months of bone healing and in 2-3 years its size becomes comparable to the size of the tibia.[20] Variable hypertrophy of fibula was observed in our patients with the achievement of diameter comparable to the tibia in two patients while the rest of the patients are still on follow-up.

Although, our study patient number was relatively small, yet their outcome measures showed that single-stage tribalization of the fibula can replace lower extremity

amputations especially in pediatric patients. Also, even a shortened lower limb with limited movement at the knee or ankle and extensive scarring can have acceptable function for many patients.

CONCLUSION

Single-stage pedicled ipsilateral fibula transposition to fill tibial segmental defect after sarcoma excision is a reliable option in children. Good bone union, fewer complications, hypertrophy comparable to the tibial diameter, and resuming to early weight bearing along with daily activities make it the procedure of choice for tibia reconstruction.

AUTHOR'S CONTRIBUTION

SM: Conception of idea
AFB: Article writing
SU: Data Collection
IR: Review critically
ST: Data Analysis
EAK: Editing

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