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ORIGINAL PAPER

Effect of non-vascularized fibular harvest on the donor limb: radiological evaluation at a mean follow-up of twelve point eight years

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Abstract

Purpose The study is aimed at evaluating the long-term (at a minimum follow-up of 10 years) impact of non-vascularized fibular harvest on the donor limbs.

Methods There were 27 donor limbs ($n=19$ children) available for retrospective radiological review. The graft was obtained bilaterally in eight patients. The following parameters were evaluated in the follow-up radiographs: continuity/non-continuity of fibular regenerate, width of the regenerated fibula, distal fibular station, medial proximal tibial angle, posterior proximal tibial angle, lateral distal tibial angle (LDTA), anterior distal tibial angle, and tibia diaphyseal angulation (interphyseal angles). For analysis and comparisons, the donor limbs were compared to the healthy limbs (controls) of the children with unilateral harvest. Additionally, the impact of continuous and non-continuous fibular regeneration was separately analyzed.

Results The mean child's age at the time of fibular harvest was four years. The mean follow-up was 12.8 years. The fibula was found regenerated in continuity in 22 limbs of 15 children (81.5%). When analyzed as a combined group (both continuous and non-continuous fibular regenerations), all the donor limb radiological parameters matched those of healthy limbs except LDTA ($p=0.04$). In the subgroup analysis between non-continuous and continuous fibulae, significant abnormalities were again obvious in LDTA ($p=0.0001$). The non-continuous fibulae were significantly lesser in width. All limbs with non-continuous fibular regeneration manifested ankle valgus.

Conclusions The non-vascularized fibula emerged as a relatively safe procedure in the long term with minimal affections of the knee, ankle, or tibial anatomy when longitudinal integrity of fibula was restored. The non-regenerations of the fibula may be prone to developing ankle valgus.

Keywords Bone graft · Fibula · Autogenous · Ankle valgus

Introduction

The fibular bone graft is often required in several paediatric orthopaedic conditions to achieve fusions or reconstruct defects. When chosen as the donor bone, it offers multiple advantages. Being palpable subcutaneously at either end, the surgical access is relatively easy. The graft can be obtained from both legs ensuring adequate quantity. Unique triangular profile and mechanical strength are other advantages. Additionally, the properties of an autogenous graft being biocompatible, osteoconductive, and osteoinductive are also fulfilled by the fibular graft. Vascularized fibular grafts are also possible through advanced surgical techniques and are widely practiced.

A look at previous literature reveals that the fibular harvest can be a potentially morbid procedure with reported

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complications of alterations of the superior tibiofibular joint, proximal migration of lateral malleolus, tibiotalar tilt, and valgus tibial deformities [1–4]. Most of the complications were associated with incomplete regeneration of the donor site which usually occurs when either vascularized grafts or osteoarticular grafts are obtained. The procedure is considered safer when the fibula is harvested using the non-vascularized technique, as regeneration of the donor fibula is then theoretically possible because of the preserved periosteum [5, 6]. However, various series report non-continuous regeneration in approximately 25–40% of limbs even with non-vascularized fibular harvests [7, 8].

The long-term donor site outcomes of non-vascularized fibular harvest in the paediatric age group are not well documented especially in limbs with non-continuous regenerations. This retrospective study details the radiological changes occurring in the donor legs following non-vascularized fibular harvest in 19 children. Specifically, the study is aimed at comparing continuous/non-continuous regenerations of the harvested fibula for the regenerated width, ankle valgus, if any, and the alterations of diaphyseal and articular surfaces of the adjacent tibia at long-term follow-up. The comparisons were made to healthy non-donor limbs (controls) of the children where only a unilateral fibular graft was obtained.

Methods

The reported series is a retrospective chart review (2009–2022) of patients' radiological records wherein diaphyseal non-vascularized fibula (unilateral or bilateral) was utilized as the donor bone. The study was part of a larger research evaluating long-term radiological outcomes of the lower limb donor sites following harvest. The series included only those children (under age 12 years at the time of the index procedure) where the whole length of the diaphyseal fibula was obtained after conserving the physeal ends. However, for all harvests, a minimum of 10% of the total length at either fibular end was preserved for ankle stability and safety of the deep peroneal nerve [9, 10]. The fibula was harvested using a periosteum preserving technique to promote its active regeneration. We excluded children where only a section of the diaphyseal fibula was utilized as graft, the graft was an osteoarticular type, or concomitant grafts were obtained from the tibia. Children with neuromuscular or concomitant bony abnormalities of the donor leg at the time of index procedure were also excluded.

As per our institutional protocol, the donor's legs are evaluated at each follow-up using long-leg standing radiographs (anteroposterior) with patella facing forwards as well as leg lateral views. The following parameters were evaluated in the latest follow-up radiological records [11–13]: continuity/non-continuity of fibular regenerate, width of the regenerated fibula, distal fibular station (Malhotra grade), medial proximal tibial angle (MPTA), posterior proximal tibial angle (PPTA), lateral distal tibial angle (LDTA), anterior distal tibial angle (ADTA), and interphyseal angle (tibia diaphyseal angulation) in both anteroposterior (IPA-AP) and lateral views (IPA-LAT) (Fig. 1). The continuity of fibular regenerate was considered indicative of restored lateral column support of the leg. The width of the regenerated fibula was measured as follows: the total tibial diaphyseal length was divided into three equal sections. The fibular/tibial width was measured at these levels, and the average of these ratios was taken for deducing relative width of the regenerated fibula. These measurements were performed on both anteroposterior and lateral views (Fig. 2). The fibular station was quantified as Malhotra grades [11]: Malhotra grade 0: fibular growth plate at the level of the talar plateau, grade 1: fibular growth plate between the top of the talus and the distal tibial growth plate, grade 2: fibular growth plate in line with the distal tibial growth plate, and grade 3: severe migration with fibular growth plate proximal to the distal tibial growth plate.

Statistical calculations: There were 27 donor limbs in 19 children (unilateral 11 and bilateral 8) where desired records were accessible (Fig. 3). Accordingly, control calculations were possible from only 11 healthy limbs. Angle and other measurements were performed by two independent experienced observers, and averages were taken (rounded off to unit place) for statistical calculations.

The recording of Malhotra grades was descriptive. Based on our previous experience, a combination of Malhotra grade >1 and LDTA <84 degrees was better indicative of ankle valgus [7]. For other parameters, donor and non-donor (control) limbs were compared using the Student *t*-test. Comparisons were also made between limbs with continuous, non-continuous fibular regenerates and healthy limbs to distinctly highlight the effect of incomplete regeneration. p value of <0.05 was taken as significant.

Results

The mean age of the children at the time of the index procedure was four years. The indications for fibular graft were spinal fusion (12 children), osteosynthesis of non-union (5 children), and reconstruction of the osseous defect (2 children). The mean follow-up available was 12.8 years (range, 10.6–15.3 years).

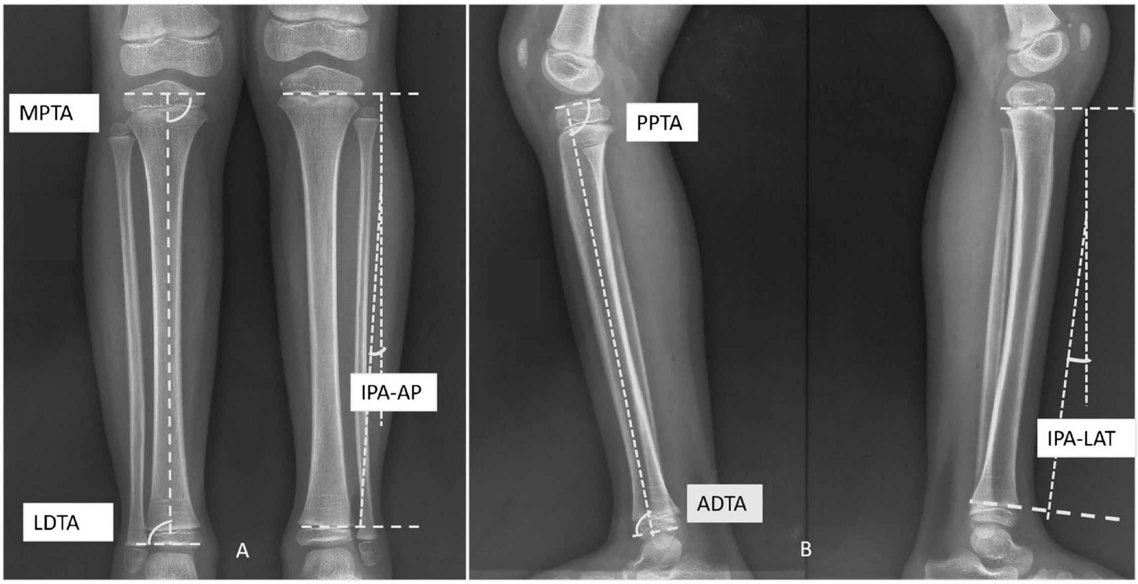

Fig. 1 The various parameters measured (**A** anteroposterior, **B** lateral radiographs): proximal tibial joint orientation angles, i.e., MPTA and PPTA; distal tibial joint orientation angles LDTA and ADTA; and tibia diaphyseal angulations (IPA-AP and IPA-LAT). Additionally, the longitudinal continuity of fibular regenerate and distal fibular station (Malhotra grade) was also noted

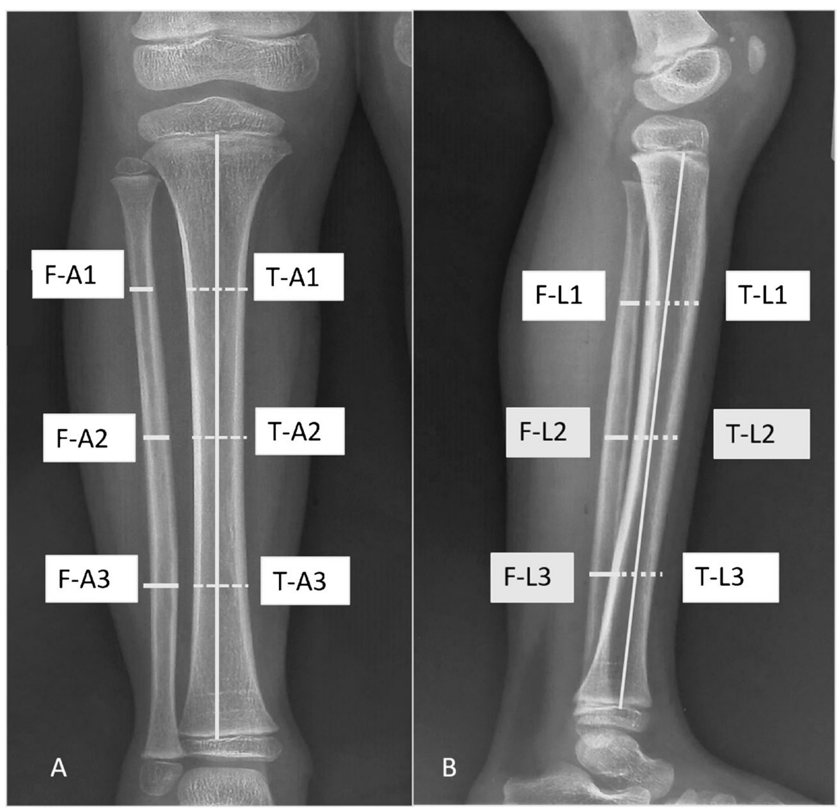

Fig. 2 Width of the regenerated fibula (**A** anteroposterior, **B** lateral radiographs): the total tibial diaphyseal length was divided into three equal sections. The fibular/tibial width was measured at these levels, and the average of these ratios was taken for deducing relative width of the regenerated fibula respective to tibia. The descriptions F-A1, 2, 3 and T- A1, 2, 3 respectively denote fibular and tibia width in the anteroposterior view, whereas F-L1, 2, 3 and T- L1, 2, 3 represent similar measurements in the lateral view

Donor and control limb comparison

At follow-up, the donor fibula was regenerated in continuity in 22 limbs of 15 children (22/27 limbs; 81.5%). One child had continuous regeneration in the left limb but non-continuous regeneration in the other (Fig. 4). Overall, the mean width of regenerated fibulae matched those of controls in both anteroposterior and lateral views ($p = 0.83$ and $p = 0.49$

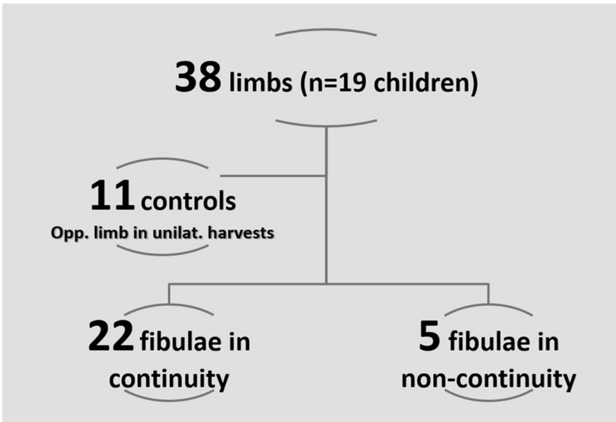

Fig. 3 Patient flow chart. Abbreviations: opp., opposite; unilat., unilateral

respectively) (Table 1). The fibular station was abnormal in 7 limbs (Malhotra grade 2) and LDTA values (< 84 degrees) in ten limbs. Of these, six limbs had combination of abnormal fibular station as well as LDTA indicating the presence of definite ankle valgus (6/27; 22.2%). All five limbs with non-continuity of fibular regenerate had ankle valgus (100%). Overall, the donor limbs had lower LDTA values than controls ($p = 0.04$). The knee alignment (MPTA and PPTA) was similar in the donor and control limbs (Fig. 5). No significant tibial diaphyseal deformations were noted in any plane.

Subgroups and intragroup comparison

When subgroups of fibulae regeneration in continuity and non-continuity were matched with controls, distinct findings emerged. The fibulae in continuity were similar to control limbs in all compared parameters (Table 2). On the other hand, the non-continuous fibulae were thinner and manifested statistically significant alterations of LDTA ($p < 0.001$) (Table 3). As stated above, the distal fibular station was 2 in all non-continuous fibulae along with abnormal LDTA values. Intragroup comparison of fibulae with regeneration in continuity and non-continuity also revealed similar findings (Table 4).

Fig. 4 The impact of restored lateral column support of the leg by continuous fibular regeneration: 15 years follow up (**A** anteroposterior, **B** lateral radiographs). Both fibulae were resected as graft in this child. There was continuous regeneration of fibula in the left limb but non-continuous regeneration on the opposite side. LDTA values of 78.6 degrees and fibular station of two indicated the presence of ankle valgus on the right side. The fibular regenerate was thinner on the right compared to the left. The LDTA values were higher on the left side (83.3 degrees) compared to the right limb. The fibular station was 1 on this side

Table 1 Comparison of parameters in donor versus control limbs

Parameters	Donor limbs ($n=27$)	Controls ($n=11$)	p value*
F/T AP	0.4 ± 0.1	0.4 ± 0.0	0.83
F/T LAT	0.4 ± 0.1	0.4 ± 0.1	0.49
MPTA (in degrees)	88.0 ± 4.3	86.8 ± 2.1	0.24
PPTA (in degrees)	80.2 ± 7.0	81.0 ± 3.7	0.65
LDTA (in degrees)	85.3 ± 5.1	88.8 ± 4.1	*< 0.05*
ADTA (in degrees)	90.2 ± 6.2	88.5 ± 5.0	0.39
IPA-AP (in degrees)	2.8 ± 2.1	2.7 ± 1.6	0.85
IPA-LAT (in degrees)	9.7 ± 7.3	6.9 ± 4.8	0.17

*Unpaired Student *t*-test. Abbreviations: *F/T AP*, fibula/tibia width ratio in anteroposterior view; *F/T LAT*, fibula/tibia width ratio in lateral view; *MPTA*, medial proximal tibial angle; *PPTA*, posterior proximal tibial angle; *LDTA*, lateral distal tibial angle; *ADTA*, anterior distal tibial angle; *IPA-AP*, interphyseal angle anteroposterior view; IPA-LAT, interphyseal angle lateral view

Discussion

Principal findings

There are limited bone graft sites in the pediatric age group that offer matching characteristics and quantity such as fibula. Mixed series which included free fibular grafts and osteoarticular grafts described a large number of complications related to the donor site and brought much disrepute to this important source of autogenous bone graft [1, 2, 4]. Our series reported a minimum ten year follow-up of diaphyseal non-vascularized fibular harvested using periosteum preserving technique. Among analyzed donor limbs, the donor fibula was regenerated in continuity in 22 out of 27 limbs (81.5%). The non-continuous fibular regeneration was evidenced in five limbs.

The lateral pillar of the leg is responsible for nearly 1/5th weight transmission exerted in the longitudinal limb axis [14]. With non-continuous regeneration of fibula, the relative mobile distal fibular remnant leads to abnormal loading of distal tibia [8]. The eccentric stresses over the lower tibial epiphysis produce secondary changes and alteration of LDTA. We therefore analyzed continuous and non-continuous regeneration of the fibula distinctly as the integrity of the lateral column of the leg is an important determinant of morbidity related to the fibular graft. Six limbs had abnormal LDTA (< 84 degrees) as well as fibular station two indicating the presence of definite ankle valgus (6/27; 22.2%). Among six limbs, five were those that had non-continuity of fibula.

Overall, the donor fibulae regenerated to thickness matching their counterparts in the control limbs. The tibial and knee alignments were again similar in the harvested and control limbs. The donor fibulae showed lower LDTA values compared to controls. A subgroup analysis subsequently

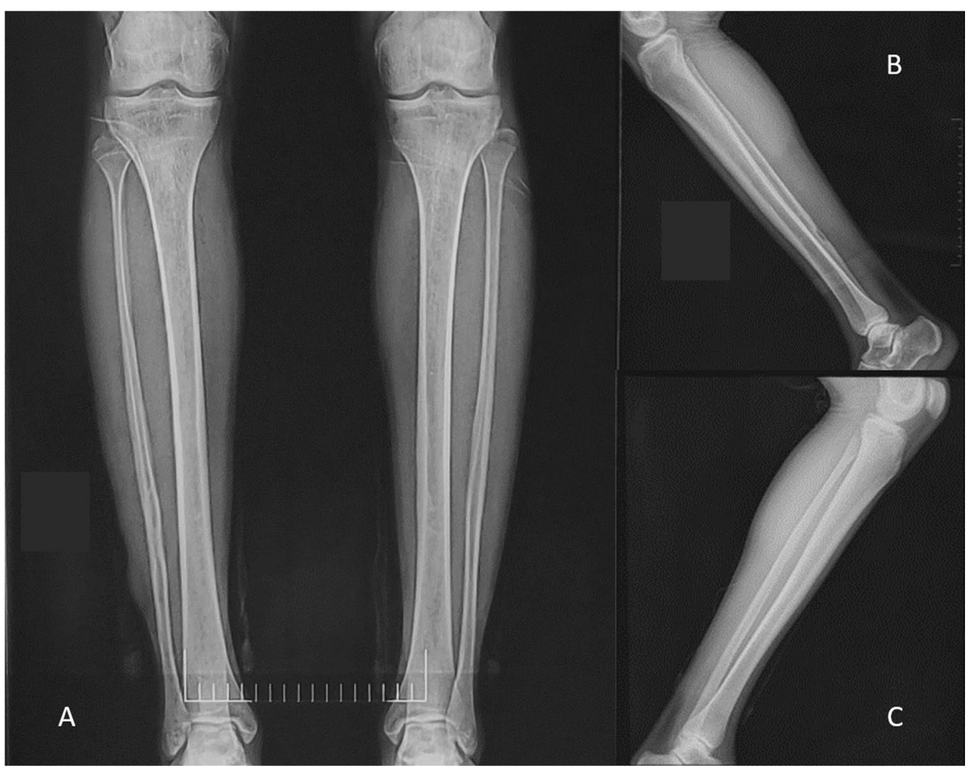

Fig. 5 Follow-up 15.3 years post-harvest (**A** anteroposterior, **B** right lateral radiographs, **C** left lateral radiographs). Absence of ankle valgus on the harvested right side as fibula regenerated longitudinally. The regenerate matched the healthy limb (left side, control) in all measured parameters

Table 2 Continuous fibular regenerations versus controls

Parameters	Continuous fibular regenerations ($n=22$)	Controls ($n=11$)	p value*
F/T AP	0.4 ± 0.0	0.4 ± 0.0	0.22
F/T LAT	0.5 ± 0.1	0.4 ± 0.1	0.62
MPTA (in degrees)	88.3 ± 4.1	86.8 ± 2.1	0.17
PPTA (in degrees)	78.6 ± 4.7	81.0 ± 3.7	0.14
LDTA (in degrees)	87.1 ± 3.9	88.8 ± 4.1	0.27
ADTA (in degrees)	89.1 ± 6.4	88.5 ± 5.0	0.76
IPA-AP (in degrees)	2.7 ± 2.1	2.7 ± 1.6	0.99
IPA-LAT (in degrees)	9.8 ± 7.8	6.9 ± 4.8	0.20

*Unpaired Student *t*-test. Abbreviations: *F/T AP*, fibula/ tibia width ratio in anteroposterior view; *F/T LAT*, fibula/tibia width ratio in lateral view; *MPTA*, medial proximal tibial angle; *PPTA*, posterior proximal tibial angle; *LDTA*, lateral distal tibial angle; *ADTA*, anterior distal tibial angle; *IPA-AP*, interphyseal angle anteroposterior view; *IPA-LAT*, interphyseal angle lateral view

revealed that fibulae in continuity matched controls for all measured parameters. Thus, lower LDTA could mainly be attributed to fibulae with non-continuous regeneration.

Review of relevant literature

Only a few studies provide long-term donor site descriptions after fibular resection in the pediatric age group. González-Herranz and associates retrospectively studied 23 children (24 limbs) with a mean age of 8.9 years who underwent fibular resections varying 2–24 cm [1]. The available follow-up was a mean of 6.2 years (range, 4–11 years). Evaluations were made radiologically using the contralateral side as control. Overall, the series examined an extremely heterogenous group including resection of different anatomical fibular regions (head, proximal diaphysis, middle diaphysis, distal diaphysis, and lateral malleolus) harvested for variable indications (primary pathology of fibula in seven cases; as bone graft in others) obtained using non-consistent techniques (periosteum preservation done only for some limbs; distal tibiofibular joint stabilization performed in 12 cases).

Table 3 Non-continuous fibular regenerations versus controls

Parameters	Non-continuous fibular regenerations ($n=5$)	Controls ($n=11$)	p value*
F/T AP	0.3 ± 0.1	0.4 ± 0.0	*< 0.05*
F/T LAT	0.3 ± 0.1	0.4 ± 0.1	*< 0.05*
MPTA (in degrees)	86.8 ± 5.5	86.8 ± 2.1	0.99
PPTA (in degrees)	81.6 ± 4.1	81.0 ± 3.7	0.77
LDTA (in degrees)	77.8 ± 2.6	88.8 ± 4.1	*< 0.05*
ADTA (in degrees)	92.9 ± 5.7	88.5 ± 5.0	0.18
IPA-AP (in degrees)	3.5 ± 1.5	2.7 ± 1.6	0.35
IPA-LAT (in degrees)	7.4 ± 3.3	6.9 ± 4.8	0.81

*Unpaired Student *t*-test. Abbreviations: *F/T AP*, fibula/tibia width ratio in anteroposterior view; *F/T LAT*, fibula/tibia width ratio in lateral view; *MPTA*, medial proximal tibial angle; *PPTA*, posterior proximal tibial angle; *LDTA*, lateral distal tibial angle; *ADTA*, anterior distal tibial angle; *IPA-AP*, interphyseal angle anteroposterior view; *IPA-LAT*, interphyseal angle lateral view

Table 4 Intragroup comparisons: continuous versus non-continuous fibular regenerations

Parameters	Continuous fibular regenerations ($n=22$)	Non-continuous fibular regenerations ($n=5$)	p value*
F/T AP	0.4 ± 0.0	0.3 ± 0.1	*< 0.05*
F/T LAT	0.5 ± 0.1	0.3 ± 0.1	*< 0.05*
MPTA (in degrees)	88.3 ± 4.1	86.8 ± 5.5	0.58
PPTA (in degrees)	78.6 ± 4.7	81.6 ± 4.1	0.20
LDTA (in degrees)	87.1 ± 3.9	77.8 ± 2.6	*< 0.05*
ADTA (in degrees)	89.1 ± 6.4	92.9 ± 5.7	0.23
IPA-AP (in degrees)	2.7 ± 2.1	3.5 ± 1.5	0.34
IPA-LAT (in degrees)	9.8 ± 7.8	7.4 ± 3.3	0.30

*Unpaired Student *t*-test. Abbreviations: *F/T AP*, fibula/tibia width ratio in anteroposterior view; *F/T LAT*, fibula/tibia width ratio in lateral view; *MPTA*, medial proximal tibial angle; *PPTA*, posterior proximal tibial angle; *LDTA*, lateral distal tibial angle; *ADTA*, anterior distal tibial angle; *IPA-AP*, interphyseal angle anteroposterior view; *IPA-LAT*, interphyseal angle lateral view

Among the morbid findings presented, significant were incomplete regeneration of fibula in 14 cases (58%), talar tilt in 45%, proximal migration of the lateral malleolus in 55%, and diaphyseal valgus of the tibia in 20% of the cases. The authors recommended the reconstruction of fibular defects whenever feasible.

A German study evaluated 53 patients who underwent mid-diaphyseal non-vascularized fibular harvest at a mean age of 16 (2–51) years [5]. Thirty-two patients were below 15 years of age. The main indication of the harvest was tumour reconstruction. The follow-up ranged from 3 to 26 years, a mean of 15 years. Twenty-five of the 26 patients who had spontaneous complete bone regeneration were less than 15 years of age, and therefore, the study marked younger patient age at harvest as a predictor for regeneration. The study reported no major complications after fibular resection. The instability of the lateral collateral ligament of the knee noted in three patients was restricted to those with incomplete regenerations.

A previous series from our institution reported on mid-term (mean 6.23 years) outcomes following non-vascularized fibular harvests in 16 children (18 limbs) [7]. Five children from that study were also part of this series. Non-continuity in regeneration was seen in four legs (22%), and all these limbs had abnormal LDTA and fibular station.

Another publication from our institute, prospective evaluated fibula donor limbs at a very early follow-up of six months [8]. Although the series did compare continuous and non-continuous fibular regeneration similar to the current study, in that follow-up period, neither the mean width of regenerated fibulae could be evaluated nor the secondary changes related to tibial diaphysis and joint orientation angles were expected. Being a prospective evaluation, the authors were able to record the intraoperative periosteum condition and the approximate proportion of regenerated fibulae at six months (15/25 limbs; 60%). Both studies (Agarwal (2023) and the current study) however highlighted the heightened risk of developing ankle valgus if fibulae non-regeneration was present.

Our current study also substantiated the findings noted in literature that overall, non-vascularized fibular donor site behaves in a favourable manner in the long term. Incomplete/non-continuous regenerations destabilize the leg anatomy and are major causes of complications.

Clinical implications

As was obvious from the results, the anatomy of the donor leg was largely restored once the lateral column of the leg was restored. Thus, non-vascularized fibular harvests should be distinguished from vascularized harvests or osteoarticular grafts which have significant morbidity data attached to them because of fibular non-regeneration [1–4]. The non-continuity of the fibular regenerate, however, resulted in ankle valgus in all limbs in current series too. Many studies have found that predominant fibular regeneration takes place within the first two postoperative years with no further reparative progress after that [5, 15]. It is therefore advised to keep these children under follow-up and intervene appropriately if there is impending non-continuity. Options include reconstruction of the fibular gap or synostosis surgeries of the ankle region [1].

Limitations

The study was a retrospective review of the latest follow-up radiographs. As such, initial or serial radiographs were not assessed. It was therefore not possible to estimate the time when the non-continuity became established or ankle valgus developed. Since the series included non-consecutive patients, there were chances of selection bias, and it was difficult to determine the precise proportion of fibulae going into non-continuous regenerations. Being a long-term study, the records fulfilling desired criteria (> 10 years follow-up) were accessible for limited number of children ($n = 19$). As such, subgroup analysis was based on small limb numbers and therefore should be interpreted accordingly. Further healing and growth alterations could potentially happen as there were many children in our series with a growing skeleton. It is therefore required to keep these children under regular follow-up till skeletal maturity.

Strengths

Our series is one of the first to report > ten years outcome of donor site outcomes following non-vascularized fibular harvest in children. The series represented a near homogenous cohort since the technique to obtain graft was standardized. Appropriate reference values for the measured parameters were feasible since the children with controls age matched those with donor limbs (mean age of children—donor limbs 15.7 years, controls 16.5 years, $p = 0.5$).

Conclusions

The non-vascularized fibula emerged as a relatively safe procedure in the long term with minimal affections of the knee, ankle, or tibial anatomy when longitudinal integrity of fibula was restored. The non-regenerations of the fibula may be prone to developing ankle valgus. It is prudent to keep children with fibular harvest under serial follow-up and intervene appropriately if there is non-continuity of the donor bone.

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Data availability Enclosed within manuscript.

Code availability Not applicable.

Declarations

Ethics approval Retrospective chart review.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

1. González-Herranz P, del Río A, Burgos J, López-Mondejar JA, Rapariz JM (2003) Valgus deformity after fibular resection in children. J Pediatr Orthop 23:55–59
2. Nathan SS, Athanasian E, Boland PJ, Healey JH (2009) Valgus ankle deformity after vascularized fibular reconstruction for oncologic disease. Ann Surg Oncol 16:1938–1945
3. Kang SH, Rhee SK, Song SW, Chung JW, Kim YC, Suhl KH (2010) Ankle deformity secondary to acquired fibular segmental defect in children. Clin Orthop Surg 2:179–185
4. Sulaiman AR, Wan Z, Awang S, Che Ahmad A, Halim AS, Ahmad Mohd Zain R (2015) Long-term effect on foot and ankle donor site following vascularized fibular graft resection in children. J Pediatr Orthop B 24:450–455
5. Bettin D, Böhm H, Clatworthy M, Zurakowski D, Link TM (2003) Regeneration of the donor side after autogenous fibula transplantation in 53 patients: evaluation by dual x-ray absorptiometry. Acta Orthop Scand 74:332–336
6. Xin Z, Kim K, Jung S (2009) Regeneration of the fibula using a periosteum-preserving technique in children. Orthopedics 32:820
7. Agarwal A (2019) Fibular donor site following non vascularized harvest: clinico-radiological outcome at minimal five year follow-up. Int Orthop 43:1927–1931
8. Agarwal A (2023) Nonvascularized fibular harvest in children: impact on donor limbs. J Pediatr Orthop B 32:197–205
9. Soejima O, Ogata K, Ishinishi T, Fukahori Y, Miyauchi R (1994) Anatomic considerations of the peroneal nerve for division of the fibula during high tibial osteotomy. Orthop Rev 23:244–247
10. Pacelli LL, Gillard J, McLoughlin SW, Buehler MJ (2003) A biomechanical analysis of donor-site ankle instability following free fibular graft harvest. J Bone Joint Surg Am 85:597–603
11. Malhotra D, Puri R, Owen R (1984) Valgus deformity of the ankle in children with spina bifida aperta. J Bone Joint Surg Br 66:381–385
12. Paley D (2002) Principles of deformity correction. Springer pp. 1–17
13. Shah HH, Doddabasappa SN, Joseph B (2009) Congenital posteromedial bowing of the tibia: a retrospective analysis of growth abnormalities in the leg. J Pediatr Orthop B 18:120–128
14. Takebe K, Nakagawa A, Minami H, Kanazawa H, Hirohata K (1984) Role of the fibula in weight-bearing. Clin Orthop Relat Res 184:289–292
15. Burchardt H (1983) The biology of bone graft repair. Clin Orthop Relat Res 174:28–42