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Fibular donor site following non vascularized harvest: clinico-radiological outcome at minimal five year follow-up

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Abstract

Purpose The long-term donor site outcome of non vascularized fibular harvest in paediatric age group is not well studied. We evaluated clinical and radiological characteristics of fibular harvest site in children at a minimum five year follow-up.

Methods The patients with donor legs underwent both physical and radiographic examination. Clinical parameters evaluated were pain, neuromuscular weakness, and standing tibiocalcaneal hindfoot valgus in the donor limb. Radiologically, longitudinal non continuity in regeneration, medullary canal reformation, Malhotra grading, and lateral distal tibial angle (LDTA) were documented.

Results Sixteen patients (18 legs) were available for follow-up. The average follow-up was 6.23 ± 1.1 years. None of the patients reported pain or neuromuscular weakness related to the donor leg. Five patients reported cosmesis issues related to exaggerated ankle valgus. Medullary canal restoration was seen in 3/14 regenerated fibulae. Harvested legs had overall higher fibular station than contralateral unintervened ankles. Non continuity in regeneration were seen in 4/18 legs. There was clinical hindfoot valgus, abnormal LDTA, and fibular station in these patients. Clinical valgus matched better with a combination of fibular station and LDTA (83.3%) rather than fibular station or LDTA (75%) alone.

Conclusions Fibular regeneration was complete in more than 75% legs at follow-up of > five years but remodeling and reformation of medullary canal was delayed. Long-term fibular non regeneration was persistently responsible for development of ankle valgus deformity. Middle lower third fibular junction is critical area for non restoration of medullary canal and non continuity.

Keywords Non vascularized graft · Fibula · Children · Ankle valgus · Regeneration

Introduction

Bone grafting is frequently required in paediatric practice to fill bone defects or to achieve osteosynthesis. The limited availability of donor graft sites remains a major problem in children. Fibula because of its accessibility, duality, and structural characteristics, remains an important source of autogenous graft. Both vascular and nonvascular options to harvest fibula are available. In health care settings, where microvascular surgical techniques and bone banks are not available, non vascularized fibula is still commonly used.

Fibular harvest is long related with several donor site complications: pain, ankle valgus, sensory motor weakness, ankle instability, fibular migration, and tibial deformities [1–3]. The morbidities enhance when a vascularized harvest has been obtained as fibular regeneration does not occur or when harvest includes either proximal or distal end or complete bone [1, 4–6]. Non vascularized fibular harvest is associated with distinct regeneration potential so complications are less commonly documented.

The long-term donor site outcome of non vascularized fibular harvest in paediatric age group is not well studied [1, 3, 7, 8]. Therefore, we conducted the present study to identify clinical and radiological characteristics of fibular harvest site in children at a minimum five year follow-up. We specifically focused on ankle valgus, non continuity of fibular regenerate,

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medullary canal reformation, fibular station, and lateral distal tibial angle (LDTA) in the donor leg.

Material and methods

The study is retrospective review (2009–2012) of patient's case records operated utilizing autogenous non vascularized fibular graft (unilateral or bilateral). We follow a periosteum preserving technique for fibular harvest conserving a minimum of 10% of total length at either fibular ends according to our institutional protocol to maintain ankle stability and for safety of proximal deep peroneal nerve [6, 9]. We included those patients who were aged less than 12 years at the time of index procedure and the whole length of diaphyseal bone after conserving fibular physeal ends was used for graft purpose. We excluded patients who required osteoarticular graft or only a portion of diaphyseal fibula was harvested rather than the whole available length or had neuromuscular or bony pathology in donor leg. All patients were recalled for a physical and radiographic examination. Informed written consent from the patients and guardians was obtained for publication of results and photographs.

At final follow-up, clinical parameters evaluated were pain, neuromuscular weakness, and hindfoot valgus in the donor limb, if any. We quantified clinical hindfoot valgus using standing tibiocalcaneal angle as follows [10]: Patients were made to stand with patella facing forwards similar to the position for radiographs. Tibiocalcaneal angle was measured as the angle between the bisectors of the calf and the calcaneus with pivot at ankle joint. Results were classified as valgus for angles $> 5°$ [11]. The radiological measurements were done on standardized anteroposterior standing x-ray. The non continuity in fibular regenerate, if any, was recorded for loss of lateral fibular support. Medullary canal recanalization was documented as a sign of completion of regenerate remodeling. Additionally, the radiological ankle valgus was quantified using fibular station (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, grade 3: severe migration with fibular growth plate proximal to the distal tibial growth plate) and lateral distal tibial angle (LDTA, the angle between the tibial mechanical axis and the distal tibial joint surface; normal range, 84–92°) [12, 13]. The standing tibiocalcaneal angle and LDTA were measured by two independent experienced observers, and averages were taken (rounded off to unit place) for statistical calculations.

Results

Followed-up clinical and radiological records of 16 patients were available for analysis (Table 1). Bilateral harvest was taken in two patients making a total of 18 harvested fibulae. The average follow-up was 6.23 ± 1.1 years. Average patient age at follow-up was 11.13 ± 2.47 years. The broad indications for fibular harvest were filling bone defects in two and osteosynthesis in 14 patients. None of the patients reported pain or neuromuscular weakness related to donor leg. Five patients reported cosmesis issues related to exaggerated ankle valgus compared to opposite leg (patient 1, 2, 8, 12, 16). Fibular regeneration in continuity occurred in 14/18 legs (77.78%).

On clinical measurements, hindfoot valgus was observed in ten out of 18 (55%) harvested legs. Except for five patients mentioned above, the valgus was asymptomatic and patients did not complain of any foot or ankle deformities. All four non continuity fibulae had clinically obvious hindfoot valgus. The unintervened leg also had valgus angles (9° each) in two patients (patients 1 and 2) but the contralateral donor leg then had more severe valgus (15, 12° respectively).

Non continuity in regeneration were seen in 4/18 fibulae (22.22%) (patients 2, 8, 12, 16). The non continuity was limited to middle lower third junction in all patients. Both fibular station and LDTA were abnormal in all these patients (Fig. 1).

Medullary canal restoration was seen in 3/14 regenerated fibulae (21.42%) (Fig. 2). In other legs with a continuity of fibular regenerate 11/14 (78.57%), middle lower third junction was the critical area where medullary canal integrity was not restored (Fig. 3).

The fibular station in unilateral harvests ($n = 14$) was zero in seven; one in three; two in three and three in one leg. The contralateral unintervened leg had zero in ten; one in four. Thus, fibular station of one existed in several unintervened legs as well (Fig. 3). In bilateral harvests, the fibular station was zero on both sides in one patient (patient 4) (Fig. 2). In other patient (patient 16), it was zero and three on right and left leg respectively (Fig. 1). Harvested legs had overall higher fibular station than contralateral unintervened in 6/14 ankles (42.86%). In legs with non continuity of fibula, the fibular station was ≥ two Although no definite relationship between clinical valgus and fibular station could be made, in general, valgus angles ≥ 10° were associated with stations ≥ two. Thus, several normal ankles had fibular station up to one and only higher stations had manifest ankle valgus.

Unilateral harvested legs ($n = 14$) had abnormal LDTA in 7/14 (50%). LDTA in unilateral unintervened versus harvested legs was (84.64 ± 4.84 and $82.29 \pm 6.39°$degrees respectively; p value = 0.283). Only one patient with bilateral harvest (patient 16) had abnormal LDTA, that too in one ankle only (68°) (Fig. 1). Considering the LDTA criteria of $< 84°$ abnormal, four unintervened legs had out of range LDTA as well (patients 3, 5, 6, 12). Out of total eight abnormal LDTA, six had clinical ankle valgus (75%) (patients 1, 2, 8, 12, 13, 16). Both LDTA and fibular station were abnormal together in six ankles (patients 1, 2, 5, 8, 12, 16), and out of these, five legs (83.3%) had clinical hindfoot valgus as well. Thus, clinical valgus matched

Table 1 Patient data

S.no.	Age At follow-up (years)	Follow-up (years)	Side	Bilateral	Clinical hindfoot valgus* (°)		Non continuity, if any		Medullary canal restoration		Malhotra Grading (0–3)		LDTA* (°)	
					R	L	R	L	R	L	R	L	R	L
1.	5	5	R	–	15	9	No	–	No	–	2	1	82	85
2.	12	5.5	R	–	12	9	Yes	–	No	–	2	0	78	89
3.	13	6	R	–	7	2	No	–	No	–	0	0	84	80
4.	13	7	–	Yes	2	2	No	No	Yes	Yes	0	0	88	90
5.	10	6	R	–	2	2	No	–	No	–	1	0	79	78
6.	13	6.5	R	–	1	3	No	–	No	–	0	1	84	78
7.	15	5	R	–	6	1	No	–	No	–	0	0	87	87
8.	10	6.5	L	–	1	10	–	Yes	–	No	1	3	85	70
9.	12	7	R	–	5	4	No	–	No	–	0	0	95	88
10.	12	6	R	–	1	1	No	–	No	–	1	1	84	86
11.	8	5.5	R	–	3	2	No	–	No	–	0	0	83	84
12.	14	9	L	–	4	9	–	Yes	–	No	0	2	83	72
13.	10	5.75	R	–	7	−2	No	–	Yes	–	0	0	80	78
14.	9	6	L	–	2	6	–	No	–	No	0	1	93	86
15.	11	5	L	–	4	5	–	No	–	No	0	0	91	88
16.	11	8	–	Yes	6	12	No	Yes	No	No	0	3	85	68

LDTA lateral distal tibial angle, *R* right, *L* left

*Each measurement taken by two independent experienced observers and averages taken (rounded off to unit place)

slightly better with a combination of fibular station and LDTA (83.3%) rather than fibular station or LDTA (75%) alone.
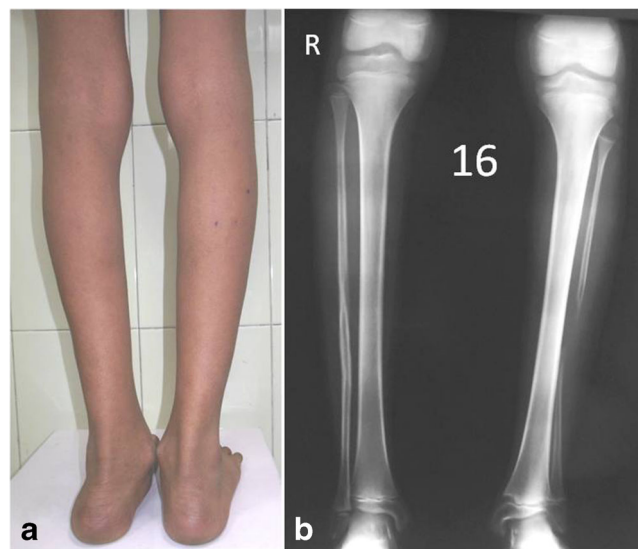

Fig. 1 Patient 16. **a** Bilateral fibular harvest. Clinically obvious hindfoot valgus on left side. **b** Complete longitudinal regeneration on right side. Note that medullary canal reformation is not complete even on regenerated side. Fibular station is 0 and LDTA is 85° on this side. Non continuity of regenerate on left side. Fibular migration, decreased LDTA corresponding to clinically observed hindfoot valgus

Discussion

A general belief prevails that when periosteum is left intact, the harvested non vascularized fibula regenerates with no potential donor site morbidity [14]. So much so, several authors have recommended a reharvest of regenerated fibula [15]. There are only few paediatric series in indexed English literature that
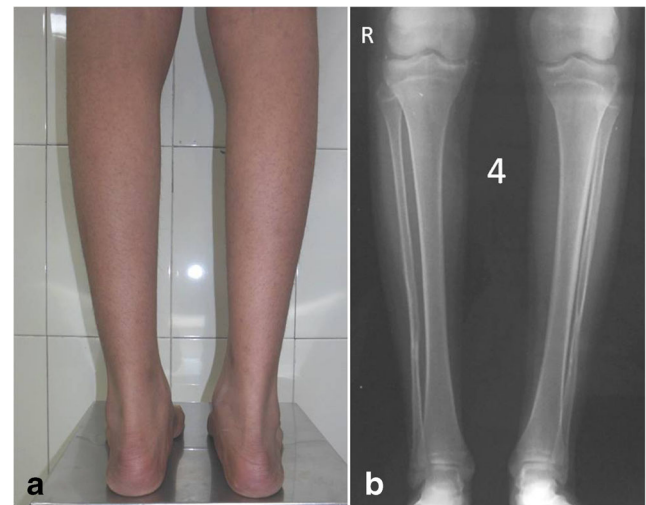

Fig. 2 Patient 4. **a** Bilateral fibular harvest. Normal hindfoot valgus. **b** Skeletally mature child now with fusion of lower tibial and fibular physis. Complete longitudinal regeneration on both sides with reformation of fibular medullary canal on both sides. Fibular stations and LDTA normal on both sides

Fig. 3 Patient 10. **a** Right-sided fibular harvest. Normal hindfoot valgus. **b** Complete longitudinal fibular regeneration. Note the middle lower third junction where medullary canal reformation lags behind. The fibular station is 1 on both harvested and unintervened side in this child

discuss long-term impact of nonvascularized fibular harvesting [1, 3, 7, 8]. Betten et al. determined non vascularized fibular regeneration in 53 patients at a mean follow-up 15 (range, 3–26) years [7]. Thirty two patients were below 15 years of age. Twenty six patients had spontaneous complete bone regeneration within eight to 16 months. Radiographically, the bone density and structure of the regenerate differed from the contralateral fibula. The series did not report any major complications at the ankle region in their series. González- Herranz et al. studied a heterogeneous patient data of 23 children (average age 8.9 years) who underwent 24 fibulae resections and were followed mean 6.2 years (range, 4–11) [1]. The series included patients with variable fibular lengths (2–24 cm), harvest of different anatomical fibular regions (head, proximal diaphysis, middle diaphysis, distal diaphysis, lateral malleolus), dissimilar indications, and surgeries (primary tumour of fibula in 7 cases, distal tibiofibular joint stabilization in 12 cases, non uniform periosteum preservation). Although fibula migrated proximally in 13 cases (55%), authors did not categorically mention that these occurred in cases with incomplete fibular regeneration (14 cases; 58%) [1]. On the contrary, Xin et al. harvested non vascularized fibula using a periosteum-preserving technique in 17 children (mean age 8.4 years), and follow-up of mean 31 months (7–65 months) revealed no incomplete regenerations or donor site complications [8]. The authors in this series however filled graft sites either with cancellous allograft or calcium sulfate. Donor sites were replaced by regenerated newly formed fibula at a mean 12 weeks (range, 4–21 weeks) [8]. In a previous series published from our institution, a total of 30 ankles in 23 patients were evaluated for valgus deformity following non vascularized fibular harvest at a mean follow-up of 39.4 months (range, 24–83 months) [3]. The continuity of fibula in longitudinal dimension was restored in 27/30 legs (90%) by that time. There was presence of radiological

valgus deformity in ten (33%) ankles, yet non continuity of fibular regenerate concomitantly occurred in just two cases.

The current series examined donor legs at mean of 6.23 years. We observed that more than 50% (10/18) donor legs had clinical hindfoot valgus beyond accepted range. The clinical impact of these out of range ankle valgus measurements was largely insignificant, and only in five patients (i.e., with clinical hindfoot angles $\geq 9°$, fibular non continuity, abnormal fibular station, and LDTA both together), the deformity was cosmetically unpleasing to patients. There seem to be many other postulated factors such as anatomical obliquity of the ankle mortise in a normal child before the age of ten years, generalized ligament laxity in childhood, and weakness of the tibialis posterior muscle responsible for ankle valgus rather than fibular harvest alone [4, 5]. Therefore, caution need to be exercised while interpreting ankle valgus in children.

All cases with non continuity of fibular regenerate in our study had ankle valgus supporting the fact that fibula is important lateral buttress to ankle joint [2]. When this support is lost, the weight bearing dynamics of lower tibial plafond and ankle region gets altered leading to changes in lower tibial epiphysis. The fibular recession also leaves a mobile distal remnant which is unable to resist pressure from the talus during weight-bearing. All four fibular non continuities occurred in the middle lower third junction. The medullary canal remodeling was abnormal in same region only. Studies have shown that nutrient foramen to fibula are largely located in proximal third (65%) [16]. Middle (15%) and lower (13%) fibula have limited number of foramen indicating a probable vascular watershed zone in this region. Looking to the fibular non continuity in this particular region as most persistent factor for ankle valgus in long term, we strongly recommend that maximum surgical precision be exercised in this area to keep periosteum violations to minimum. Non continuity in fibular regeneration need to be monitored serially and intervened early to prevent ankle valgus. Being a retrospective analysis, we could not predict at what time the non continuity became established or ankle valgus developed. Many studies have found that predominant fibular regeneration takes place within the first two postoperative years with no further reparative progress after that [7, 14].

Our study had certain limitations. Being a retrospective study, pre or serial radiographs of the donor site were not available. The inclusion of non consecutive cases did not permit calculation of rate of fibular non regeneration among them. Also, data for contralateral unintervened legs emerged from unilateral harvests only. There were limitations of range limits of clinical and radiological indexes used for quantification of ankle valgus as discussed above. The study is probably the first dedicated paediatric series comprising of long-term follow-up of non vascularized fibular donor site. The series was largely homogenous with near total harvests of healthy fibulae preserving proximal and distal epiphysis and reasonable distal fibular support. Our study established the long-term safety of the

technique with regeneration in 77.78% (14/18) legs. Except for definite ankle valgus in fibular non regenerates, the patients had no major symptomatology related to the donor site. The presence of medullary canal although delayed by several years was seen in three legs indicating completion of remodeling and formation of mature bone. There were many children in our series with still a growing skeleton. It is therefore required to keep these children under regular follow-up.

Conclusions

Fibular regeneration was complete in more than 75% legs at follow-up of > five years but remodeling and reformation of medullary canal was delayed. Long-term fibular non regeneration was persistently responsible for the development of ankle valgus deformity. Middle lower third fibular junction is critical area for non restoration of medullary canal and non continuity.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals Retrospective study.

Informed consent Yes.

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