



# Comparative Study of Degree of Great Toe Movement after Complete and Partial Flexor Hallucis Longus Harvest in Free Fibula Flap

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## Abstract

**Background** The flexor hallucis longus (FHL) muscle is crucial in fine motor control of the great toe but the muscle is often sacrificed in free fibula flap (FFF) reconstruction. The aim of this study was to compare great toe movement between complete and partial FHL resection during FFF harvest to see if FHL can be left behind (without undergoing fibrosis) in situ when bulk is not required at the recipient site.

**Methods** A prospective, cross-sectional, observational study was performed including patients undergoing FFF harvest over a 2-year period. Movement of great toe interphalangeal joint was recorded of operated and unoperated legs in patients undergoing partial and complete FHL harvest and data analyzed.

**Results** There was a statistically significant ( $p < 0.05$ ) difference between the two groups of patients.

**Conclusion** FHL can be safely left in situ in patients not requiring bulk at the recipient site as blood supply, nerve supply, and muscle function are not compromised in partial FHL harvest. Further image-based and dye-based studies are warranted.

## Keywords

- ▶ partial flexor hallucis longus harvest
- ▶ complete flexor hallucis longus harvest
- ▶ free fibula flap

## Introduction

The great toe, or the hallux, plays a significant role in the function of the foot, not only in static and dynamic standing balance, but also in walking, running, and jogging. The flexor hallucis longus (FHL) and flexor digitorum longus (FDL) function during jogging and running as posterior calf muscles to restrain dorsiflexion during late swing and first 50% of the stance phase.<sup>1</sup> The FHL muscle helps in fine motor control and has less impact on gross motor control.<sup>2</sup> It plantarflexes the hallux at the interphalangeal (IP) joint, plantarflexes the foot, and is innervated by the tibial nerve.<sup>3</sup>

The FHL is one of the six muscles in the lower leg encountered during harvesting the free fibula flap (FFF). Prior to the concept of a perforator flap, surgeons did not dissect the perforator and often used the FHL for the FFF to protect the vascular pedicle and increase the survival rate.<sup>4-6</sup> This also helped in increasing flap volume and repairing soft tissue defects.<sup>6</sup> However, the FHL harvest was done irrespective of whether or not muscle bulk was required at the implant site; the rationales being that it increased flap survival and that leaving it behind would result in muscle fibrosis, and thus not offer any added advantage at the donor site. After the concept of the perforator flap was introduced,

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flap harvesting became more complex. The use of a perforator flap ensured survival and eliminated the need for a complete FHL harvest. A thin muscle sleeve along with the FFF was sufficient.<sup>6</sup>

Donor site morbidity, although not severely disabling, is common. There are two large series<sup>7,8</sup> and several smaller series<sup>9-12</sup> in which this problem is discussed. Common *motor* problems include inability to both flex (impaired FHL)<sup>13</sup> and extend<sup>14</sup> the hallux, and ankle stiffness and instability, while *sensory* problems range from numbness of the lateral side of the leg and dorsum of the foot to edema and mild pain at the donor site.<sup>11,15</sup>

The complete harvest of FHL in FFF continues to be a widespread practice to date. However, there remains a lack of research on the effect of resecting FHL in patients. One school of thought advocates complete resection of the FHL stating no added advantage of leaving the muscle in situ as it will eventually undergo fibrosis. The other states that FHL should be preserved to minimize donor site morbidity. This study aims at understanding the effect of FHL harvest (partial as well as complete) on the movement of great toe and thus the function of the foot, in patients undergoing FFF reconstruction.

## Methods

The present study received approval from the Institutional Ethics Committee and was performed over a period of 2 years after obtaining written, verified, and informed consent from the patients. The 40 patients included in the study were divided into two groups of 20 each depending upon the requirement of muscle bulk at the recipient site. Patients requiring muscle bulk underwent complete FHL resection and were thus placed in the “Complete FHL harvest group” while the rest in which only a thin cuff of FHL muscle was harvested were placed in the “Partial FHL harvest group.”

### Surgical Steps

There are a few differences in the surgical technique employed between the two groups.

#### Complete FHL Harvest

Patients in whom the *FHL* was harvested *completely*, transection of the FHL was done proximally from the origin and distally at the level of the distal fibular osteotomy. The motor nerve was cut with the muscle, all the perforators from the posterior tibial artery were observed and carefully cauterized, and the muscle was harvested with the flap (► **Fig. 1**).

#### Partial FHL Harvest

When the *FHL* muscle was *preserved*, the flap including the fibula with the peroneal artery were carefully dissected away from the FHL muscle, with only a thin cuff of muscle around the bone and pedicle (► **Fig. 2**). Rest of the muscle was left intact. The motor nerve to the muscle (► **Fig. 3**), all the perforators from the posterior tibial artery (► **Fig. 4**), and origin of the muscle from the interosseous membrane and tendon going distally were observed and carefully preserved and the muscle was not harvested with the flap.

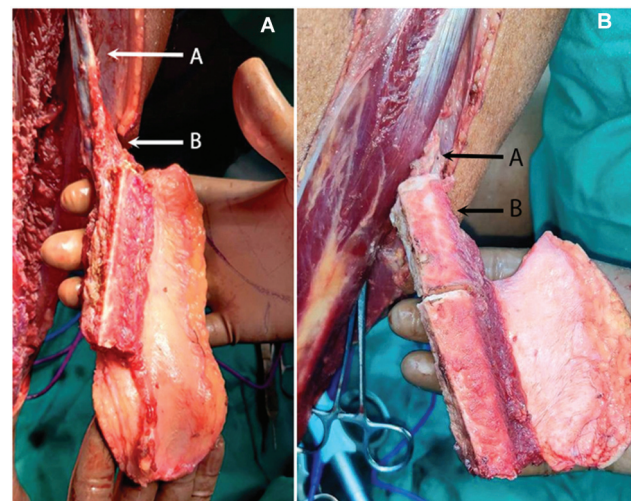


**Fig. 1** Complete flexor hallucis longus (FHL) harvest; (A) Proximal leg; (B) pedicle of flap; (C) FHL muscle harvested with flap.

Each patient was followed up at 6 months after surgery to record the degree of great toe movement (of flexion) at the IP joint of both the legs. The leg from which FHL was harvested was called the “Donor leg” and the unoperated leg was called the “Normal leg.” The active range of movement of the great toe at the IP joint was measured in degrees using a goniometer with ankle at neutral position, that is, 0 degrees of dorsiflexion, plantarflexion, inversion, and eversion.

### Statistical Analysis

Statistical analysis was done by using descriptive and inferential statistics using paired *t*-test, McNemar test, Pearson correlation, and linear regression. Descriptive statistics are done for demographic variables and presented with plot and



**Fig. 2** (A and B) Partial flexor hallucis longus (FHL) harvest; (A) Pedicle of flap; (B) cuff of muscle around the pedicle and bone.



**Fig. 3** Nerve supply; (A) Branch of tibial nerve innervating preserved flexor hallucis longus (FHL) muscle in partial FHL harvest.

chart. The variables in nonnormal form are presented as number (*n*) and percentage (%). Mean and standard deviation of scores are presented. Software used in the analysis were SPSS version 25.0 and MS Excel. A *p*-value of <0.05 was considered as level of significance.

## Results

A total of 40 patients were included in the study. The results obtained are as follows.

### Patient Characteristics

Mean age of patients was  $50.5 \pm 11.71$  years with most patients (62.5%) in the age range of 41 to 60 years. Males (28, 70%) outnumbered females (12, 30%) with a M:F ratio of 2.33:1.

### Perforators

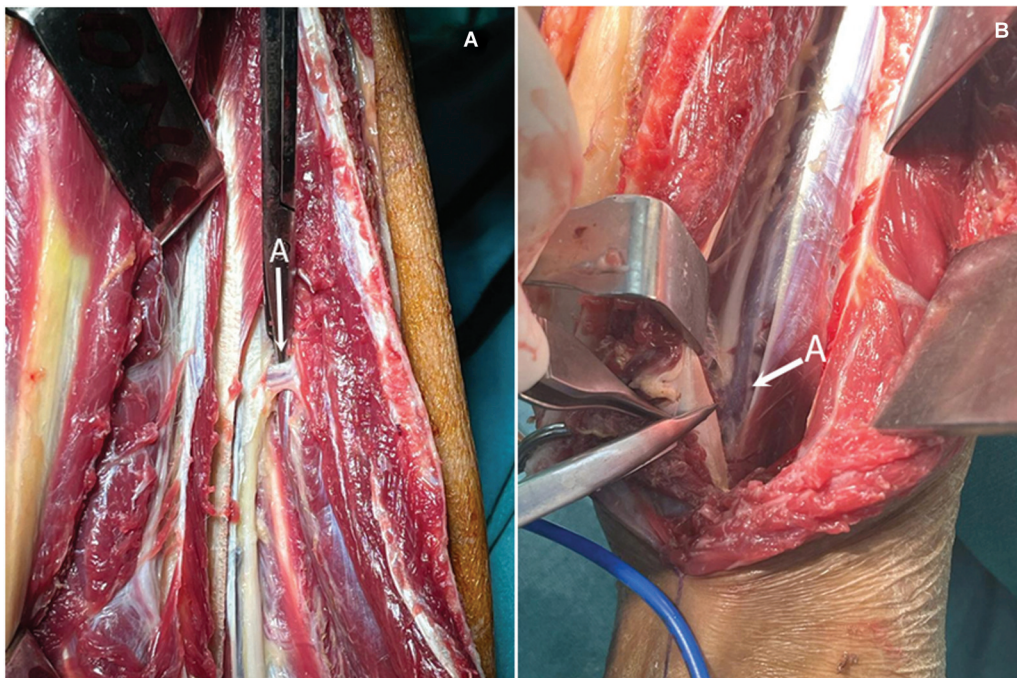
Note that 92.5% of patients had two to three perforators in the operated leg while 7.5% patients had one perforator from the posterior tibial artery supplying the FHL muscle (► **Graph 1**).

### IP Joint Movement

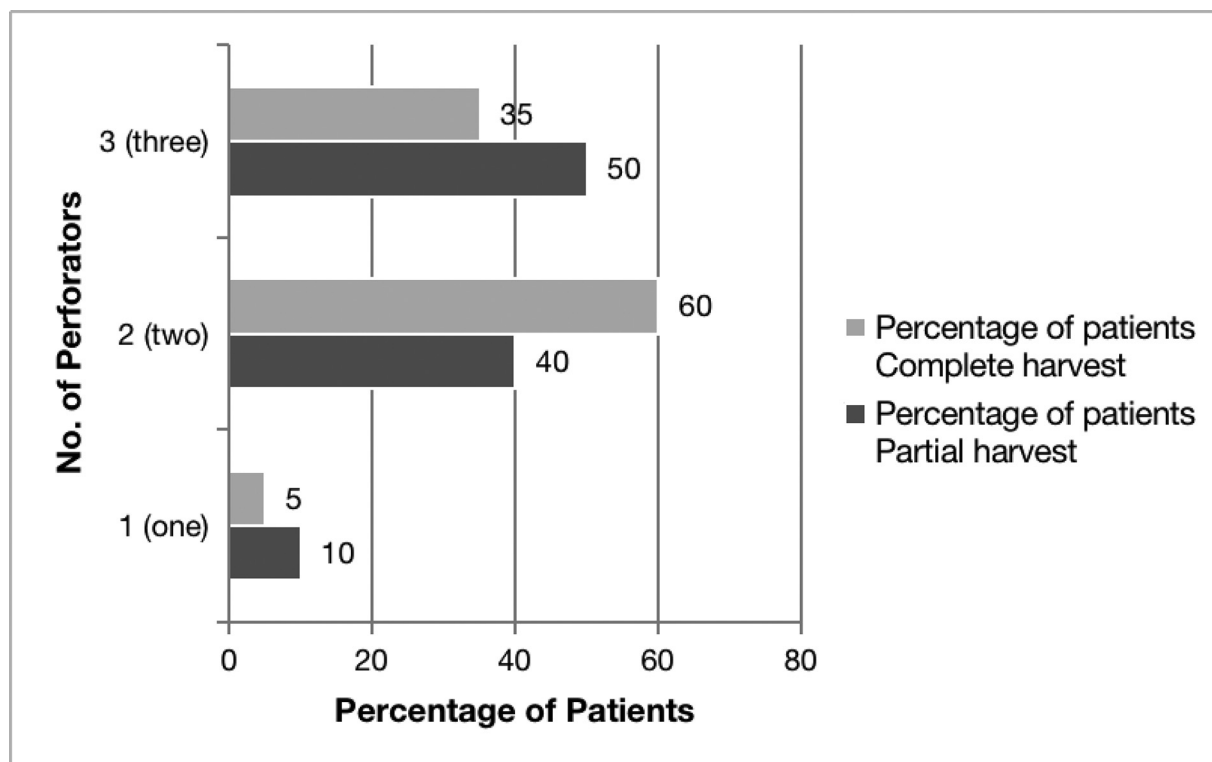
1. *Normal versus donor side*: The average degree of flexion of the IP joint on the normal side was  $31.45 \pm 11.23$  degrees (range: 11–60 degrees). The mean degree of motion of the IP joint on the donor side postsurgery was  $11.9 \pm 13.87$  degrees (range: 0–51 degrees) (► **Table 1**). The difference in the range of flexion at the great toe IP joint between the two sides is statistically significant ( $p < 0.05$ ).

Flexion of IP joint on normal side and donor side are weakly and positively correlated ( $r = 0.312$ ,  $p < 0.049$ ). There is a significant average difference between IP joint flexion in normal and donor sides ( $t_{39} = 8.312$ ,  $p < 0.001$ ). On average, flexion at IP joint was 19.55 degrees more in the normal leg compared to the donor leg (95% confidence interval 14.79, 24.31) (► **Table 2**).

2. *Partial versus complete harvest*: The average degree of flexion of the IP joint in patients with partial FHL harvest was  $23.8 \pm 9.84$  degrees (range: 0–51 degrees) (► **Video 1**). No movement was observed at the great toe IP joint in patients belonging to the complete harvest group (► **Graph 2**) (► **Video 2**). This difference is statistically significant ( $p < 0.05$ ).



**Fig. 4** (A and B) Perforator from posterior tibial artery supplying flexor hallucis longus (FHL) muscle marked by “A.”



Graph 1 Number of Perforators observed in the operated leg.

Table 1 IP joint movement: normal side vs. donor side

Degree of movement of IP joint (degrees)	Normal side	Donor side	Partial harvest		Complete harvest	
			N	D	N	D
0–10	0	22	0	2	0	20
11–20	8	6	3	6	5	0
21–30	12	9	6	9	6	0
31–40	12	2	7	2	5	0
41–50	7	0	3	0	4	0
51–60	1	1	1	1	0	0
Total (n)	40	40	20	20	20	20

Abbreviations: D, donor; IP, interphalangeal; N, normal.

There is a significant difference in IP joint flexion on donor side between the partial and complete harvest groups ( $t_{19} = 10.812, p < 0.001$ ). The average IP joint flexion (donor side) was 23.80 degrees more in the partial harvest group than the complete harvest group (►Table 3).

3. *Partial harvest group – normal donor side:* The mean IP joint flexion on the donor side was  $23.8 \pm 9.84$  degrees which is significantly less than that on the normal side ( $32.35 \pm 12.12$  degrees);  $p < 0.05$  (►Fig. 5). There is a significant average difference between IP joint flexion in normal and donor sides in the partial harvest group ( $p = 0.001$ ). On average, flexion at IP joint was 8.55 degrees more in normal leg compared to donor leg (►Table 4, ►Graph 3).
4. *Complete harvest group – normal versus donor side:* No flexion was noted on the operated side (►Fig. 6).

Table 2 IP joint movement: normal vs. donor side—tests of significance

Paired samples statistics			
	Normal side (n = 40)	Donor side (n = 40)	–
IP joint flexion (in degrees)	$31.45 \pm 11.23$	$11.9 \pm 13.87$	–
Paired samples correlation			
	Correlation	Significance	–
IP joint normal side and IP joint donor side	0.312	$< 0.049$	–
Paired samples test			
	Mean of difference	t	Significance (two-tailed)
IP joint normal side and IP joint donor side	$19.55 \pm 14.87$	8.312	$< 0.001$

Abbreviation: IP, interphalangeal.

The degree of flexion on the normal side was  $30.55 \pm 10.51$  degrees;  $p < 0.05$ . There is a significant average difference between IP joint flexion in normal and donor sides in the complete harvest group ( $p < 0.001$ ). On average, flexion at IP joint was 30.55 degrees more in normal leg compared to donor leg (►Table 5, ►Graph 4).

**Video 1**

Great toe IP joint movement in patients of Partial FHL harvest showing near normal flexion in the donor leg compared to the non-operated leg. Online content including video sequences viewable at: <https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1786989>.

**Video 2**

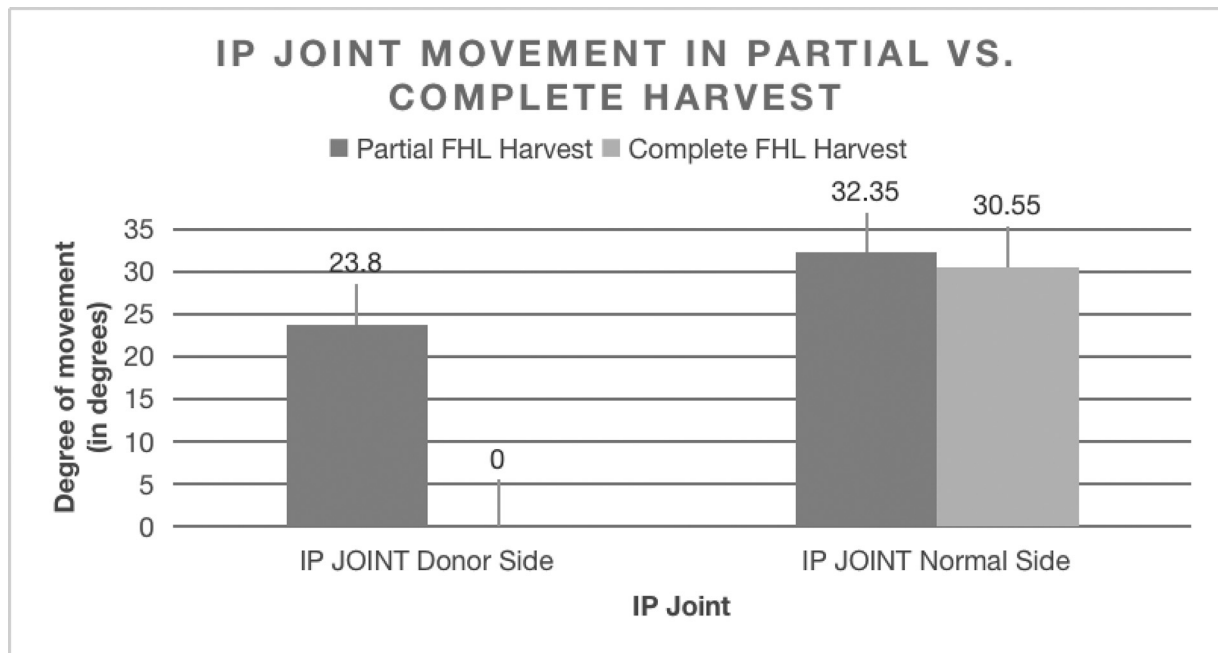
Great toe IP joint movement in patients of complete FHL harvest showing no flexion in the donor leg compared to the non-operated leg. Online content including video sequences viewable at: <https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0044-1786989>.

**Discussion**

The FFF is a workhorse flap for bony reconstruction and one of the primary reasons for the popularity of this flap is a low donor site morbidity, following harvest. Donor site morbidity albeit common, is not disabling and coupled with the excellent outcomes of FFF, morbidities are often underreported. Reduced muscle strength, weakness, and contracture of the FHL have been reported.<sup>2,7,8,10,16-21</sup> Weakness of great toe flexion leads to minor clinical consequences<sup>14,22</sup> but contracture of the FHL and the consequent flexion of the IP joint of the great toe can represent a significant complication. In this scenario, a much higher pressure is loaded by the hallux in the mid-late phase of the gait cycle<sup>23</sup> and can lead to severe pain, which requires either tenolysis or division of the FHL tendon if conservative treatment is not effective.<sup>19,21,24</sup>

In a study by van den Heuvel et al,<sup>5</sup> plantar flexion at the IP joint was significantly lower in the donor leg compared to the control leg. However, contrary to findings of the present study, the study by van den Heuvel et al found no significant difference in the joint movement in osteomyocutaneous donor leg with the osteocutaneous donor leg. Ni et al<sup>6</sup> published that plantar flexion of the hallux was significantly reduced 3 and 6 months after the procedure in the group in which FHL was harvested but no other significant differences between the two groups were noted.

In the present study, statistically significant difference was noted in IP joint flexion in (1) donor versus non-donor legs ( $p < 0.001$ ), (2) donor and non-donor legs in the partial harvest group, and (3) donor and non-donor legs in the complete harvest groups ( $p < 0.001$ ). In the partial harvest group, albeit reduced, IP joint flexion is present (►Fig. 5). However, in the complete harvest group, there is no flexion at the IP joint of the great toe (►Fig. 6) as the muscle responsible for that movement has been completely removed. Our study correlates with the anatomy and is in concordance with findings of Sassu et al.<sup>24</sup> This difference furthermore proves that preserving the FHL will preserve the function of



Graph 2 IP joint movement : Partial vs Complete harvest.

**Table 3** IP joint movement (donor side): partial vs. complete harvest—tests of significance

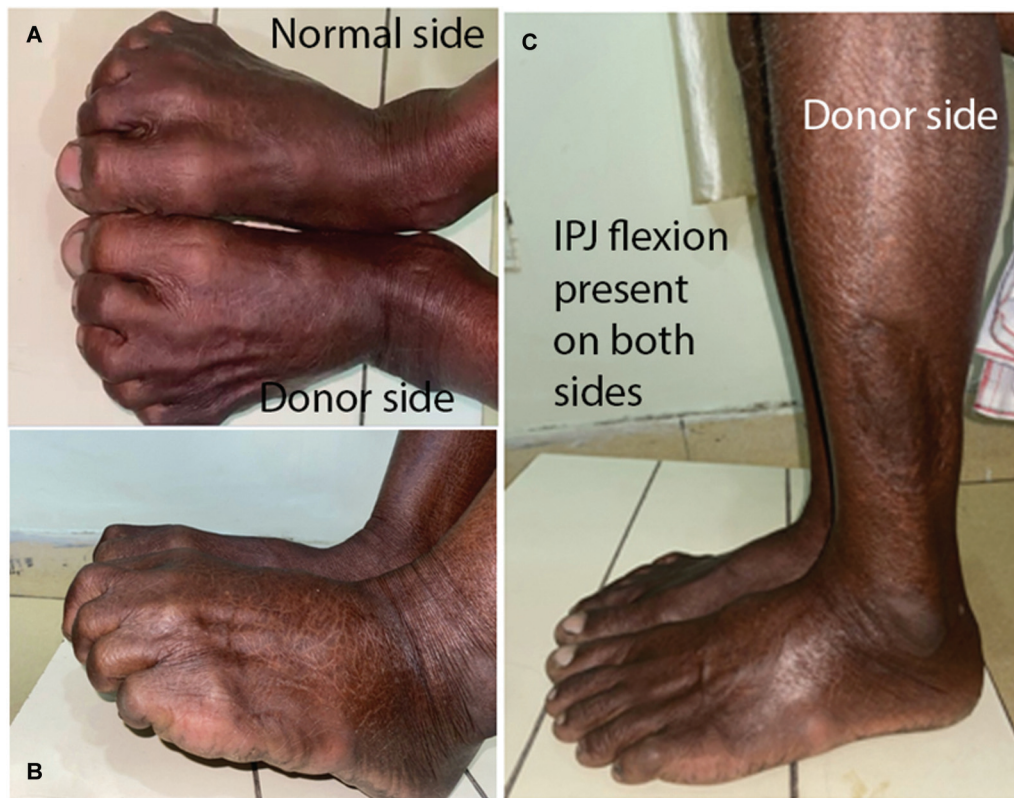
Group statistics			
	Partial group	Complete group	p-Value
Mean	23.80 ± 9.844	0	< 0.001
Independent samples test			
	t	Significance	Mean difference
IP joint movement (donor side) – partial vs. complete harvest	10.812	< 0.001	23.80

Abbreviation: IP, interphalangeal.

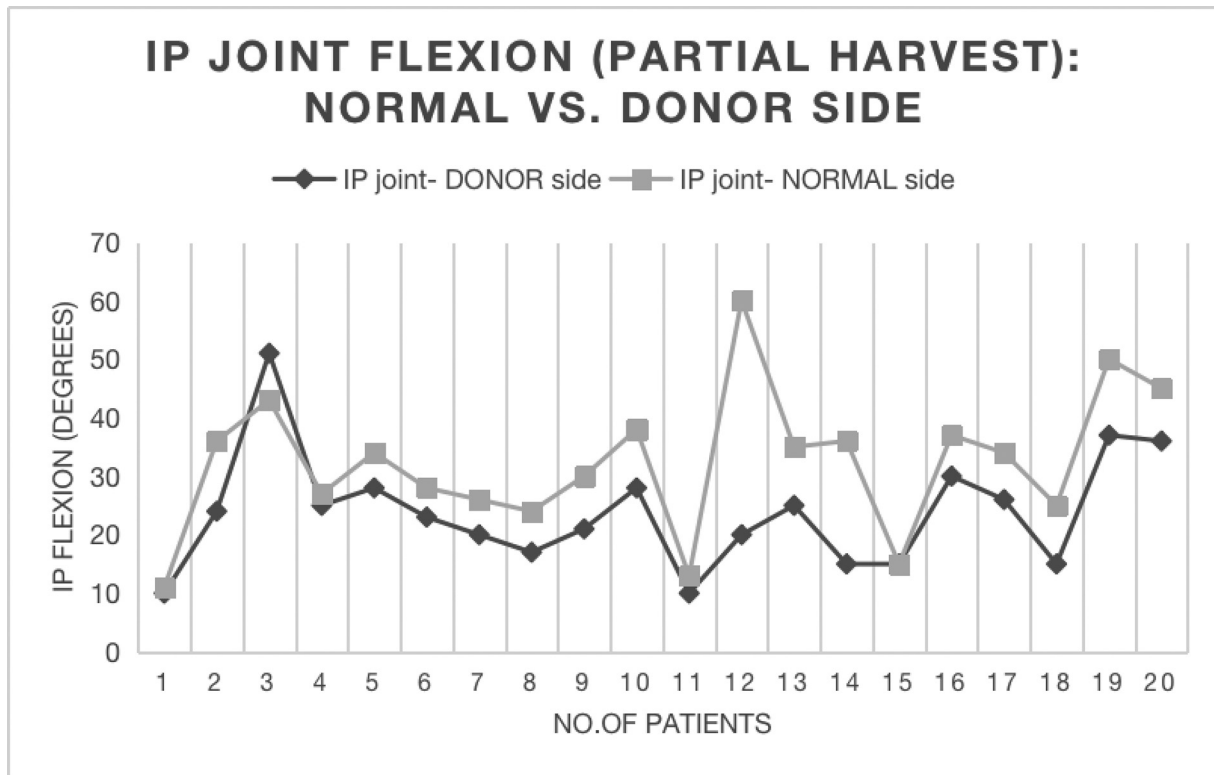
**Table 4** IP joint movement (partial group): normal side vs. donor side—tests of significance

Paired samples statistics			
	Normal side (n = 20)	Donor side (n = 20)	-
IP joint flexion (in degrees)	32.35 ± 12.12	23.8 ± 9.84	-
Paired samples correlations			
	Correlation	Significance	-
IP joint normal side and IP joint donor side	0.649	0.002	-
Paired samples test			
	Mean of difference	t	Significance (two-tailed)
IP joint normal side and IP joint donor side	8.55 ± 9.43	4.05	0.001

Abbreviation: IP, interphalangeal.



**Fig. 5** (A–C) Presence of interphalangeal (IP) joint flexion in donor leg of patients of complete flexor hallucis longus (FHL) harvest 6 months postop.



Graph 3 IP joint flexion (Partial Harvest group) : Normal vs Donor side.

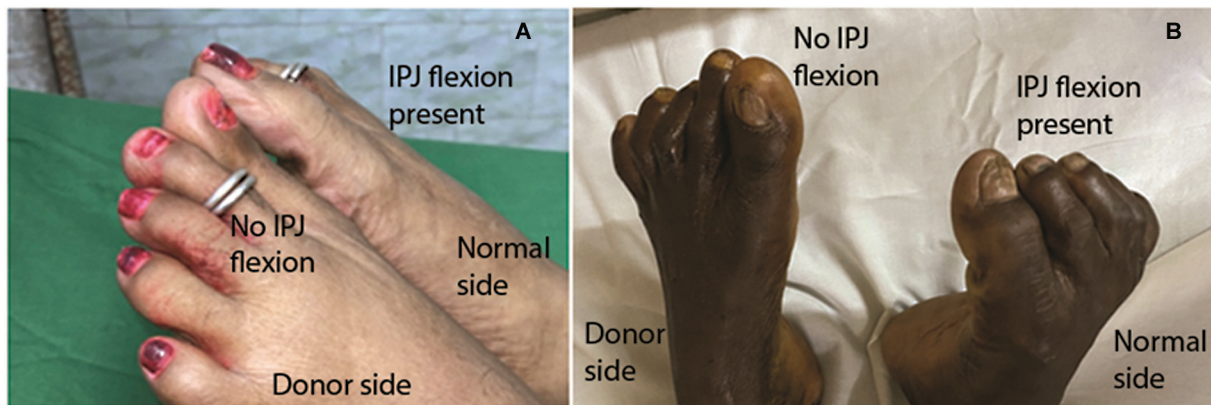
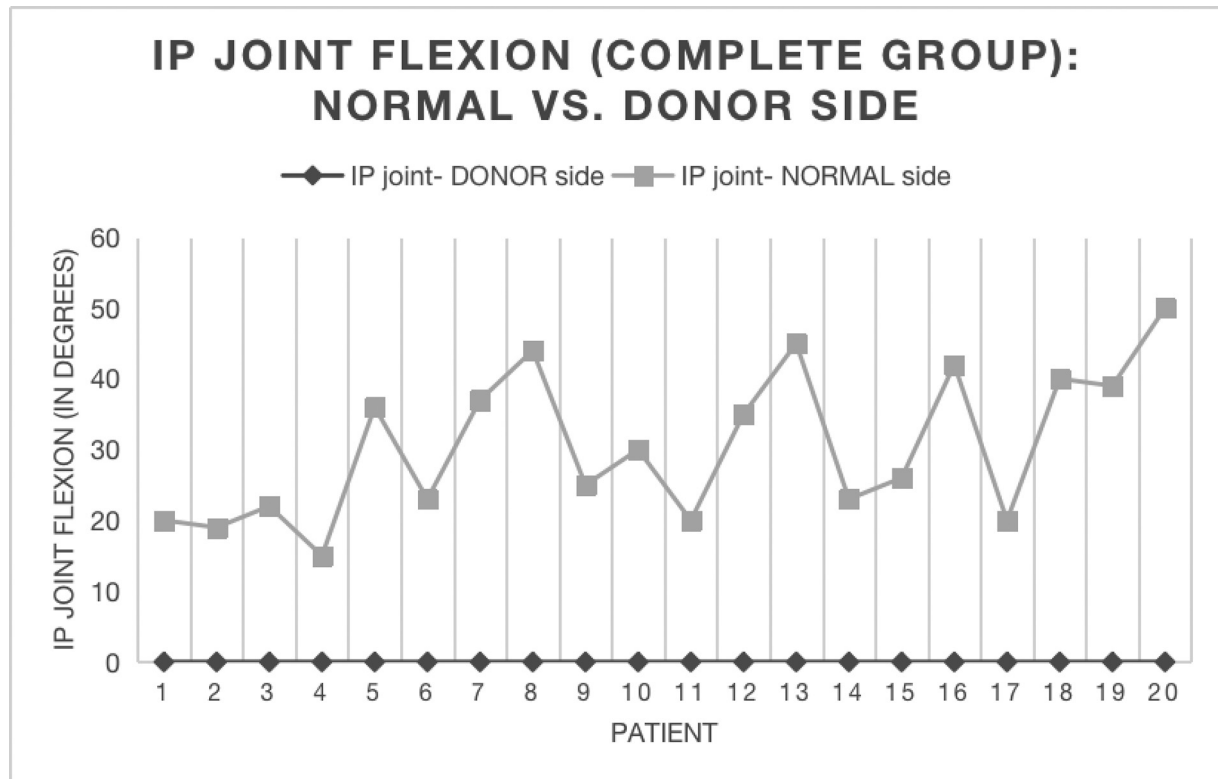


Fig. 6 (A and B) Absence of interphalangeal (IP) joint flexion in donor leg of patients of complete flexor hallucis longus (FHL) harvest 6 months postop.

Table 5 IP joint movement (complete group): donor side vs. normal side—tests of significance

Paired samples statistics			
	Normal side	Donor side	-
IP joint flexion (in degrees)	30.55 ± 10.51	0	-
Paired samples correlations			
	Correlation	Significance	-
IP joint normal side and IP joint donor side	-	-	-
Paired samples test			
	Mean of difference	t	Significance (two-tailed)
IP joint normal side and IP joint donor side	30.55 ± 10.51	12.99	< 0.001

Abbreviation: IP, interphalangeal.



Graph 4 IP joint flexion (Complete Harvest group) : Normal vs Donor side.

the IP joint of the great toe, resulting in lesser donor site morbidity.

Movement at the IP joint, in some cases, despite complete harvest of the FHL can possibly be explained by the fact that interconnections between the tendons of FHL and FDL exist in 17<sup>25</sup> to 100%<sup>26</sup> of population. It was hypothesized by Lee and Hur that in the event of transection of the FHL proximal to the FDL connection to the great toe, the IP joint of the great toe can still be flexed through the pull of the FDL.<sup>27</sup> Although in our study, we did not find any.

Statistically significant differences were noted between the two sides (normal vs. donor legs) of IP joint in both the groups (partial and complete harvest groups).

The findings of the present study thus conclusively suggest that movement at the IP joint of the great toe is preserved to varying degrees when the FHL muscle is left in situ and only a small cuff is harvested along with the fibula during a FFF reconstruction. Complete harvest of the muscle results in loss of flexion at the IP joint in all patients in the study.

It was a popular belief that the FHL muscle should be harvested with the FFF as leaving it in situ is unlikely to have any added advantage. It was believed that the muscle would eventually undergo ischemic changes followed by fibrosis and eventually contracture. The FHL muscle was also believed to increase chances of flap survival. Several anatomical studies have shown that the FHL indeed has a tenuous blood supply from branches of the peroneal artery and minor arterial supply from branches of the posterior tibial artery or the perforators. Preserving the blood supply from the

perforators, the nerve supply from the tibial nerve, the origin, and the insertion, the FHL muscle will not undergo fibrosis and will have reasonable IP joint function.

## Conclusion

The findings of our study suggest that when bulk is not required, FHL can safely be left behind retaining great toe function without causing any morbidity.

### Institutional Review Board Approval

Study approved by the Institutional Ethics Committee (IEC) of S.C.B. Medical College and Hospital, Cuttack, Odisha, India (IEC Application no. 1018).

### Financial Disclosure

None.

### Financial Support and Sponsorship

None.

### Conflict of Interest

None declared.

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