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Calcaneal lengthening for partial traumatic loss of the calcaneus

Bin Wang[a], Xu Zhang[b,*], Yongxin Huo[a], Wei Liu[a], Wei Wang[a], Xinzhong Shao[b]

[a] Orthopaedics Department, The Second Hospital of Tangshan, Tangshan, Hebei, 063000, China
[b] Orthopaedics Department, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, 050051, China

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ABSTRACT

Background: The purpose of this article was to introduce calcaneal lengthening for partial traumatic loss of the calcaneus. Effectiveness with the use of the technique was also assessed.
Methods: From January 2013 to May 2016, calcaneal lengthening was performed in 15 patients who sustained a partial traumatic loss of the tuberosity portion of calcaneus. There were 13 men and 2 women with an average age of 36 years (range, 19–53 years). Combined Achilles tendon rupture was noted in 7 patients, and the tendon was reinserted to the calcaneus before calcaneal lengthening. Calcaneal lengthening was performed using an Ilizarov frame. Clinical outcome was assessed based on the American Orthopedic Foot and Ankle score.
Results: The mean loss of calcaneus was 27% (range, 19%–35%). Calcaneal lengthening (mean total time is157 days; range, 111–226 days) included three periods, i.e., latency (mean 7 days; range, 7–9 days), distraction (mean 43 days; range, 32–57 days), and consolidation (mean 108 days; range, 84–162 days). The mean amount of lengthening was 28% (range, 19%–38%). The mean follow-up duration was 25 months (range, 24–27 months). Based on the American Orthopaedic Foot and Ankle, there were 8 excellent, 6 good, and 1 fair result.
Conclusions: For the treatment of partial traumatic loss of the calcaneus, calcaneal lengthening using an Ilizarov frame is a preferable technique to restore the length of calcaneus and foot function.

Introduction

The heel forms the major component of the foot, which provides posterior pillar for arch of the foot [1]. Partial traumatic loss of calcaneus can significantly impair foot function because the calcaneous plays a key role in standing and gait [2].

Oliver et al [3] found that even 13% loss of calcaneus produced moderate to quite a bit of difficulty for walking. Possible treatments include below the knee amputation and reconstruction with allografts, and vascularized and pedicled bone grafts. As described by Evans [4] and Mosca [5], calcaneal lengthening can be achieved by osteotomy with or without bone grafting [6]. Although the single-staged procedures are reliable, the amount of lengthening is usually less than 1 cm due to the resistance offered by the surrounding soft tissues. Lykoudis et al. [7] treated complex calcaneal defects caused by chronic osteomyelitis with a free fibula-flexor hallucis longus osteomuscular flap. The fibula was osteotomized into two segments to reconstruct the bone defect. The muscular component of the flap was used to resurface the calcaneal skeleton reconstructed [8]. Those micro-surgical procedures are extremely complex and carries the risk of anastomosis failure. Imanishi et al. [9] used a three-dimensional printed calcaneal prosthesis following total calcanectomy for the treatment of grade 2 chondrosarcoma, but long-term stability of the prosthesis is the major concern.

The purpose of this retrospective study was to introduce bone lengthening for partial traumatic loss of the calcaneus and assessed the effectiveness with the use of the technique. In addition, partial traumatic loss of calcaneus may be associated with an Achilles tendon rupture. We also introduce the reinsertion technique used in patients with this injury.

Materials and methods

The institutional review boards of the participating hospitals approved the study. Informed consent was obtained from each patient.

From January 2013 to May 2016, calcaneal lengthening was performed in 15 patients who sustained partial traumatic loss of

* Corresponding author at: Orthopaedics Department, Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, 050051, China.
E-mail addresses: drwangbin@sina.com (B. Wang), ahand@sina.com (X. Zhang).

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Fig. 1. A. A34-year-old male patient sustained 28% traumatic loss of the calcaneus. The broken line (from the calcaneal tuber at an oblique angle approximately 1 to 2 cm posterior to the subtalar joint and calcaneocuboid joint) represents a loss of 50% of calcaneus. B. The soft tissue defect of the heel was reconztructed with the distally based sural fasciocutaneous flap. C. Calcaneal lengthening will start after swelling had diminished.

tuberosity portion of calcaneus. Pre-operative radiographs were obtained in all patients (Fig. 1A). The amount of calcaneus loss was calculated from the difference in two-dimensional surface area comparing on the injured and uninjured feet on lateral radiographs using the PictZar® Digital Planimetry Software (Biovisual Technologies, Elmwood Park, NJ, UAS). CT images were obtained as needed to better understanding of the injuries for classification and pre-operative planning.

Patients in our study met all of the following inclusion criteria: 1) age between 18 and 55 years old; 2) a partial traumatic loss of tuberosity portion of calcaneus; 3) either open or closed injuries, involving Achilles tendon or not; 4) amount of calcaneus loss between 10% and 35%; 5) type III or IV open fractures based on Gustilo classification system [10,11]; 6) and all types soft-tissue injuries based on AO soft-tissue grading system [12]. Patients were excluded if they had one of the following items: 1) patients younger than 18 years were excluded because of immature skeleton; 2) patients older than 55 years were excluded because the pins for lengthening may cut out of the calcaneus due to osteoporosis, and also excluded similarly patients with osteoporosis; 3) a loss of calcaneus less than 10% was excluded because the morbidity was minimal [3]; 4) a loss greater than 45% was excluded because of a limited space for installing traction pins; 5) multiple fractures; 6) type I or II open fractures based on Gustilo classification system because the injuries were mild; 7) combined calcaneus fractures, such as Sanders' types [13] I to IV, AO/OTA types [14] B and C, and Essex-Lopresti's depression and tongue types [15], which need to fix with implants; 8) pathological fractures; 9) patients with abnormal mental health conditions that precluded to receive external fixation; or 10) an associated infection or underlying diabetes, rheumatoid arthritis, or gout. All operations were performed by the same senior surgeon.

Surgical technique

The heel wounds were conventionally debrided. If there was a combined rupture of Achilles tendon, the tendon was reinserted to the calcaneus. If there was a tendon defect, a tendon flap was harvested from the proximal part of the tendon and then overturned it to reconstruct the defect. To do reinsertion, a transverse tunnel was drilled using a 1.5 mm K-wire in the posterosuperior portion of the remaining calcaneus. The Achilles tendon and the avulsed small bony fragment (in case with presence of a small bony fragment) were sutured to the posterosuperior portion of the remaining calcaneus with non-absorbable sutures (#2 FiberWire®, Arthrex, Inc., FL, USA). The other combined injuries to the tendon, nerve, and vessels, if any, were also repaired. Then, one to two applications of negative pressure wound therapy (vacuum sealing drainage) were applied. The wound was resurfaced with the distally based sural fasciocutaneous flap after negative pressure wound therapy (Fig. 1B). In order to decrease the risk of infection, calcaneal lengthening was performed three months after wound had healed when swelling had diminished (Fig. 1C). In order to avoid tearing down the wound during lengthening, a 1.5-cm incision was made parallel to the axial of the body of calcaneus. The incision was planned on either the original skin or the flap, depending on the exact osteotomy site. Under fluoroscopic guidance, corticotomy was accomplished through a small incision, so as to minimally disrupt the soft tissues enveloping the bone. Our standard bone cut was perpendicular to the anatomical axis of the body of calcaneus and at the level just distal to the posterior margin of the common tendon sheath of peroneus longus and brevis. A four-ring Ilizarov frame (Beijing Instrument of External Fixation Technology, Beijing, China) was constructed to hold the calcaneus and tibia. Each ring was stabilized with two 1.8-mm Ilizarov wires. Among them, two

rings were placed on the distal and proximal fragments of calcaneus separately for calcaneal lengthening. (Fig. 2A) After a latency period, distraction was begun by turning the nuts on the threaded rods 0.25 mm four times per day, resulting in a total lengthening of 1 mm a day. (Fig. 2B) When the desired calcaneus length had been achieved, the distraction was stopped, but the fixator was place in situ to allow consolidation of the new bone. (Fig. 2C) Lengthening and consolidation was done with the same device. Consolidation was achieved when bone had bridged in three cortical areas on radiographs. (Fig. 3A, B) Weight bearing on the calcaneus was started thereafter.

Evaluation of outcomes and statistical analysis

We assessed severity of open fractures based on Gustilo classification system [10,11], We assessed severity of associated soft-tissue damages based on AO soft-tissue grading system [12], which divided injuries into 5 groups (1= least severe and 5= most severe), and open (IO) injuries and closed injuries (IC). Calcaneal pitch and Böhler angle were measured on lateral radiograph [16]. By referring to the opposite normal foot on radiographs, the amount of calcaneus lengthening required was also calculated using the PictZar® Digital Planimetry Software. Pin site infection was defined minor or major according to the Checketts-Otterburn classification [17]. Hindfoot alignment angle was measured on long axial view [18]. Active motion of the ankle joint was assessed using a goniometer. Calf circumference was measured as muscle wasting of the lower leg [19]. Patients reported satisfaction using the 100-mm visual analog scale (0 mm = totally unsatisfied, 100 mm = completely satisfied) [20]. Patients psychological impact was evaluated using the SCL-90-R (Symptom Checklist-90-Revised), which is a relatively brief self-report psychometric questionnaire published by the Clinical Assessment division of the Pearson Assessment & Information group in 1994 [21]. We evaluated clinical outcome based on the American Orthopedic Foot and Ankle score [22] as excellent (90–100), good (75–89), fair (50–74), and poor (<50). We compare both feet on calcaneal pitch and hindfoot alignment, and range of motion of ankle. Differences were considered statistically significant at $p < 0.05$. The collected data were analyzed with SPSS Version 13.0 (SPSS, Inc., Chicago, Ill.) and PASS Version 14 (NCSS LLC, Kaysville, Utah).

Results

The study comprised of 13 men and 2 women with an average age of 36 years (range, 19–53 years). The injuries occurred during working (n = 10) and road traffic accident (n = 5). Achilles reinsertion was performed directly in 5 patients, and with an overturned tendon flap in 2 patients. The mean time from injury to calcaneal lengthening was 28 days (range, 17–43 days). There were 8 type

Fig. 2. A. After corticotomy, an Ilizarov frame was constructed for calcaneal lengthening. B. Required length of calcaneus was achieved. C. The Ilizarov frame was removed.

Fig. 3. A. Lateral radiograph of calcaneus after consolidation. B. Axial view. C. Two years after surgery, the amount of lengthening was 32 cm. D. Axial view.

IIIA and 7 type IIIB open fractures based on Gustilo classification system. There were 10 IO-3 and 5 IO-4 soft-tissue injuries based on AO soft-tissue grading system. (Table 1) The mean loss of calcaneus was 27% (range, 19%–35%). Calcaneal lengthening (mean 157 days; range, 111–226 days) included three periods, i.e., latency (mean 7 days; range, 7–9 days), distraction (mean 43 days; range, 32–57 days), and consolidation (mean 108 days; range, 84–162 days). The mean amount of lengthening was 28% (range, 19%–38%). (Table 2) Minor pin site infection was observed in 2 patients (3 sites), which was cured by pin care.

All patients returned for follow-up. No patient required insoles or arch support. The mean follow-up duration was 25 months (range,

Table 1
Patient demographics and injuries of 15 patients.

Case	Age (yr)	Sex	Side	BMI	Cause	Combined injuries	Gustilo classification	AO STGS	TFITL (d)
1	29	M	R	24.3	RTA	FDT/FHT	Type IIIB	IO-4	32
2	53	M	R	27	Machinery		Type IIIA	IO-3	21
3	19	F	L	19.8	Machinery	AT/ FT	Type IIIB	IO-3	37
4*	34	M	R	25.4	RTA	AT	Type IIIB	IO-3	22
5	47	M	R	31.2	RTA	AT/FDT/FHT	Type IIIB	IO-4	29
6	29	M	R	26.3	RTA		Type IIIA	IO-3	20
7	34	M	L	24.9	Machinery		Type IIIA	IO-3	23
8	23	M	R	18.6	RTA		Type IIIA	IO-3	31
9	38	M	R	26.2	Machinery	FT	Type IIIA	IO-3	25
10	43	M	L	29.1	RTA	AT/ FT	Type IIIB	IO-4	33
11	32	M	R	26.3	RTA		Type IIIA	IO-3	28
12	34	M	R	24.5	RTA		Type IIIA	IO-3	27
13	38	F	L	24.3	Machinery	AT/ FHT	Type IIIB	IO-4	37
14	38	M	R	27.1	RTA	AT	Type IIIB	IO-3	22
15	49	M	L	28.6	RTA	AT/ FT	Type IIIB	IO-4	43
Mean	36			25.6					29

*, represented in Figures; BMI, body mass index; RTA, road traffic accident.
TFITL, time from injury to lengthening; AT, Achilles tendon; FT, fibularis tendon.
FDT, flexor digitorum tendons; FHT, flexor hallucis tendons.
AO STGS, AO soft-tissue grading system.

Table 2
Patient surgical details of calcaneal lengthening.

Case	Amount of loss	Amount of lengthening	Periods of lengthening (day)			
	(%)	(%)	Latency	Distraction	Consolidation	Total
1	30	32	7	47	134	188
2	27	29	8	45	96	149
3	26	26	7	42	96	145
4*	28	29	7	39	84	130
5	20	19	8	31	72	111
6	30	30	8	46	96	150
7	19	22	7	36	110	153
8	25	26	7	39	84	130
9	29	31	8	46	110	164
10	32	35	8	52	148	208
11	31	33	7	50	148	205
12	26	27	7	45	96	148
13	26	26	9	32	110	115
14	35	38	7	57	162	226
15	18	21	7	38	84	129
Mean	27	28	7	43	108	157

24–27 months) for this study. (Fig. 3C, D) At the final follow-up examination, all patients were able to wear normal shoes. All patients obtained a satisfactory gait through clinical observation without any assistance. No patients had to use a walker for ambulation. The mean calcaneal pitch and hindfoot alignment were 22° (range, 17°–26°) and 3° (range, 0°–7°), reaching 100% and 75% of opposite feet, respectively. The mean Böhler angle was 30° (range, 25°–37°), and the measurement on the opposite feet was 32° (range, 26°–39°). Hindfoot range of motion in sagittal, coronal, transverse planes were 10° (range, 8°–12°), 5° (range, 3°–6°), and 5° (range, 3°–6°) for the affected side compared to 14° (range, 17°–20°), 7° (range, 6°–9°), and 6° (range, 5°–7°) for the unaffected side, respectively ($p = 0.000$), corresponding to 71%, 71%, and 83% of opposite foot, respectively The mean dorsiflexion and plantarflexion were 24° (range, 21°–27°) and 53° (range, 50°–56°), reaching 96% and 98% of opposite foot, respectively. The mean calf circumference of the injured side was 99% of the opposite side. The mean patient satisfaction was 90 (range, 83–96) (Table 3) (Fig. 4A, B) Based on SCL-90-R questionnaire, all patients' mental status were within the normal range. There were no significant difference with regard to pre- and post-lengthening treatments. (Table 4) The average total of American Orthopaedic Foot and Ankle Score were 88 (range, 71–100). There were 8 excellent, 6 good, and 1 fair result. (Fig. 3C) In comparison of both feet, we found no significant difference with regard to calcaneal pitch ($p = 0.068$), hindfoot alignment ($p = 0.604$), or dorsiflexion ($p = 0.11$) or plantarflexion ($p = 0.094$) of the ankle. (Table 5)

Discussion

Loss of weight bearing tuber is usually the result of a direct trauma to the heel and ensures disruption to normal foot biomechanics and gait. [23–28], Restoring heel length is a reasonable choice to get better functional outcomes and cosmetic appearance [29,30]. Liu et al [31] reconstructed four composite heel defects (4 patients with calcaneal loss ranged from 25% to 50%) using a parallel fibular osteoseptocutaneous flap. All bony flaps survived, and normal length of calcaneus was restored. However, the technique is complex, requires microsurgical anastomosis, and carries a risk of anastomosis failure. Xu et al [32] and Doğan et al [33] performed calcaneal Z lengthening osteotomy for reconstruction of severe adolescent flexible flatfoot. Those single-staged lengthening techniques are safe, but maximal amount of lengthening is usually less than 1 cm.

Our lengthening technique using an Ilizarov frame can gradually lengthen the calcaneus. According to Ilizarov's principles

Table 3
Outcomes after 2 years.

Case	Calcaneal pitch (°)		Hindfoot Alignment (°)		Hindfoot motion (°)						Dorsiflexion (°)		Plantarflexion (°)		CC (cm)		Patient satisfaction
					Sagittal		Coronal		Transverse								
	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	(VAS)
1	22	22	4	6	8	14	3	6	4	6	25	25	52	56	34	34	85
2	25	26	0	2	12	20	6	9	5	7	22	23	55	55	31	31	95
3	18	19	2	0	9	15	4	7	3	5	27	27	52	52	26	28	92
4*	21	20	4	6	15	19	6	8	5	7	23	24	56	56	35	35	93
5	18	19	1	2	9	16	3	7	4	5	26	24	54	54	37	38	83
6	17	17	6	4	9	17	4	6	5	6	25	26	53	55	29	29	87
7	25	25	6	5	10	19	5	7	5	6	23	23	54	56	36	36	90
8	23	23	2	5	8	18	4	6	4	6	23	25	56	56	35	35	91
9	22	24	0	2	10	17	4	6	5	7	23	23	51	52	33	35	93
10	26	27	4	4	11	18	5	5	6	7	22	22	53	53	29	29	92
11	20	22	3	2	12	19	6	8	6	7	21	23	56	55	35	36	95
12	19	19	6	4	7	16	6	8	4	5	25	25	53	53	32	32	88
13	24	25	5	8	10	19	4	7	5	6	24	26	56	54	26	26	94
14	21	20	7	6	12	18	6	9	5	7	28	28	50	53	29	29	96
15	23	23	2	0	9	16	5	8	3	5	26	26	50	52	33	33	83
Mean	22	22	3	4	10	17	5	7	5	6	24	25	53	54	32	32.3	90
p value	0.07		0.604		0.000		0.000		0.000		0.11		0.094		0.055		

Fig. 4. Showing range of motion of the ankle after one year. Muscle wasting of the right leg was back to normal after 2 years. A. Dorsiflexion of ankles. B. Plantarflexion. C. Posterior view of the heels.

Table 4
Patients psychological impact assessed using Symptom Checklist-90-Revised (SCL-90-R) questionnaire.

Case	Phobic anxiety T1/T2/T3/T4	Anxiety T1/T2/T3/T4	Depression T1/T2/T3/T4	Somatization T1/T2/T3/T4	Obsessive-compulsive T1/T2/T3/T4	Sensitivity T1/T2/T3/T4	Hostility T1/T2/T3/T4	Insomnia T1/T2/T3/T4	Psychoneuroticism T1/T2/T3/T4
1	1.2/1/1/1	1/1.3/1.1/1	1.2/1.2/1.1/1	1.1/1.2/1.2/1	1.2/1.2/1.1/1.2	1.2/1/1/1	1.2/1/1/1	1.2/1.2/1.1/1.1	1.1/1.2/1.2/1
2	1/1/1/1	1.1/1.1/1.1/1	1/1.1/1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1.2/1/1	1/1/1/1	1/1/1/1	1.2/1.2/1.1/1
3	1/1.2/1.2/1	1/1.3/1.1/1	1/1.2/1.1/1	1/1.2/1.2/1	1.1/1.2/1.2/1	1/1.3/1.1/1	1/1/1/1	1/1/1/1	1/1/1/1
4*	1/1/1/1	1/1.3/1.1/1	1/1/1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1.1/1	1/1/1/1	1/1/1/1	1/1/1/1
5	1/1/1/1	1/1.2/1.2/1.1	1/1.2/1.1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1/1	1/1.1/1/1	1.3/1.3/1.1/1.1	1.1/1/1/1
6	1/1.1/1/1	1/1.4/1.1/1	1/1.2/1.1/1	1.2/1.5/1.3/1.1	1/1.1/1.1/1	1.1/1.2/1.2/1	1/1/1/1	1.1/1.2/1.2/1.1	1/1/1/1
7	1/1.2/1.1/1	1/1.2/1.2/1	1/1/1/1	1/1.2/1.2/1	1.1/1.2/1.2/1	1/1/1/1	1/1.2/1.2/1	1/1/1/1	1/1.2/1.2/1
8	1/1.1/1.1/1	1/1.1/1.1/1	1/1.2/1.1/1	1.3/1.3/1.1/1	1/1.4/1.2/1	1/1.2/1.2/1	1/1/1/1	1/1.2/1.2/1	1.1/1/1/1
9	1/1/1/1	1/1.3/1.1/1	1/1/1.1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1/1	1/1/1/1	1/1/1/1	1/1/1/1
10	1/1/1/1	1/1/1/1	1/1.2/1.1/1	1/1.2/1.1/1	1/1.1/1.1/1	1/1.3/1.3/1	1/1/1/1	1.1/1.1/1.1/1.1	1/1/1/1
11	1/1.1/1/1	1/1.3/1.1/1	1/1.2/1.1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1/1	1/1/1/1	1/1/1/1	1/1/1/1
12	1.1/1.2/1/1	1.2/1.3/1.2/1.1	1.1/1.1/1.1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1/1	1.2/1/1/1	1.1/1/1/1	1.1/1/1/1
13	1/1.2/1/1	1/1.2/1.2/1	1/1.2/1.1/1	1/1.2/1.2/1	1/1.1/1.1/1	1/1/1/1	1/1/1/1	1/1/1/1	1/1/1/1
14	1/1/1/1	1/1.1/1.1/1	1.2/1.4/1.3/1.2	1.1/1.2/1.2/1	1/1.2/1.2/1	1.3/1.3/1.1/1	1/1/1/1	1/1.2/1.2/1	1/1.2/1.2/1
15	1/1.3/1.1/1	1.2/1.3/1.1/1	1/1.2/1.2/1	1/1.2/1.2/1	1/1.2/1.2/1	1.2/1/1/1	1.1/1.3/1.1/1	1.1/1.3/1.1/1.1	1/1.1/1.1/1
Mean	1/1.1/1/1	1/1.2/1.1/1	1/1.2/1/1	1/1.3/1.2/1	1/1.1/1.1/1	1/1.1/1/1	1/1/1/1	1/1.1/1/1	1/1/1/1
*p*1/*p*2/*p*3	0.02/0.048/0.334	0.000/0.012/0.189	0.000/0.012/0.096	0.000/0.012/0.189	0.000/0.011/0.136	0.029/0.486/0.072	1/0.189/0.054	0.334/0.582/0.055	0.068/0.082/0.104

*, represented in Figures.
T1, 2 days before device installed; T2, 2 months after device installed; T3, the day device removed; T4, 2 months after device removed.
*p*1, *p* value between T1 and T2; *p*2, *p* value between T1 and T3; *p*3, *p* value between T1 and T4.

of distraction osteogenesis, the procedure involves cutting and slowly separating bone, allowing the bone healing process to fill in the gap. [34] Usually, 3–4 cm of lengthening is possible, and maximal amount of lengthening is unknown. Compare with the conventional osteotomy with or without bone grafting, the advantage of our technique is larger amount of lengthening. Compare with free fibular transfer, our technique does not need for microsurgical anastomosis, and avoids donor site morbidity.

There are tips and tricks relevant to the surgical technique. The best candidates for this technique is a partial loss of the calcaneus with amount of loss between 10% and 35%. Either a traumatic or pathological loss is indicated. For smaller amount of loss, the calcaneus

Table 5
American Orthopaedic Foot and Ankle Score after 2 years.

Case	Pain	Böhlers Angle (°)	ALSR	MWDB	Walking surfaces	Gait abnormality	Sagittal motion	Hindfoot motion	Ankle-hindfoot stability	Alignment	Total	Score
1	40	36	10	5	5	8	8	6	8	10	100	Excellent
2	30	32	7	5	5	8	8	6	8	10	87	Good
3	40	25	7	5	5	4	8	6	8	10	93	Excellent
4*	40	26	10	4	5	8	8	6	8	10	99	Excellent
5	30	37	7	4	5	4	8	6	8	10	82	Good
6	30	36	7	4	3	4	4	3	8	8	71	Fair
7	40	31	7	3	3	8	8	6	8	8	91	Excellent
8	40	27	7	4	5	4	8	6	8	10	92	Excellent
9	40	29	7	4	3	8	8	6	8	8	92	Excellent
10	40	31	10	5	3	8	8	6	8	10	98	Excellent
11	30	25	7	5	5	8	8	6	8	10	87	Good
12	30	30	10	5	5	8	8	6	8	8	88	Good
13	40	28	7	4	5	4	4	3	8	10	85	Good
14	30	25	10	5	3	8	8	6	8	10	88	Good
15	40	36	7	4	5	4	8	6	8	10	92	Excellent
Mean	36	30	8	4	4	6	7	5	8	9	88	

*, represented in Figures; ALSR, activity limitations and support requirement; MWDB, maximum walking distance, blocks.

can be lengthened with single-staged procedures [35]. For larger amount of loss, the remaining posterior body is too small to place the wires. In patients with a combined rupture of Achilles tendon, we used transosseous sutures to reinsert the Achilles tendon, because such reconstruction is strong. After reinsertion, we maintained the ankle joint in the neutral position to minimize contracture of the tendon. Thus, good function of the Achilles tendon can be prospected. In order to avoid reinsertion failure, calcaneal lengthening should be performed at least three months later. Calcaneus consists predominantly of trabecular bone, and its cortical bone is thin. The Ilizarov wires should be positioned across the posterior and inferior parts of the body, where cut-out resistance is stronger. As the generally rule for leg-lengthening procedures, distraction was carried out 0.25 mm four times a day (1 mm a day). For calcaneal lengthening, checking calcaneal pitch and hindfoot alignment on radiographs every month is necessary. Thus, the normal parameters are finally achieved. Muscle wasting often occurs during the long period of treatment, but will gradually improve after two years.

There are strengths of this study. To the best of our knowledge, this is the first study to describe the calcaneal lengthening for partial traumatic loss of calcaneus using an Ilizarov frame. The feet were functional assessed, which may reflect the clinical relevance of outcomes. The limitations of this study are small sample size, a retrospective design, and lack of a comparison group, which are inherently associated with errors. A followed-up of two years is insufficient to assess radiographic osteoarthritic changes of the calcaneus.

Conclusions

In the treatment of partial traumatic loss of the calcaneus, calcaneal lengthening using an Ilizarov frame is a preferable technique to restore the length of calcaneus and foot function.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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