Dynamic Footprints: Adjuvant Method for Postoperative Assessment of Patients after Calcaneal Fractures

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Abstract

Background: Open reduction and internal fixation are the current trends of treatment for comminuted calcaneal fractures. Assessing treatment results is often difficult due to discrepancy between objective parameters such as range of movement, and subjective results such as pain.

Objectives: To test the reliability of footprint analysis as an adjuvant method of postoperative assessment of patients who sustained calcaneal fractures.

Methods: Dynamic and static footprint analysis was used as an adjuvant additional method to objectively assess operative results. This method is simple and is independent of the patient's initiatives. This modality was used in 22 patients followed-up 9–90 months post-operatively.

Results: We found a good correlation between footprint analysis and objective and subjective parameters of results expressed by the American Orthopedic Foot and Ankle Society hind foot score. In certain cases, this method can be used to distinguish between uncorrelated parameter results, such as malingering, and workmens' compensation claims.

Conclusion: We recommend the use of this simple, non-invasive objective test as an additional method to assess the results of ankle and foot surgery treatment.

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Compared to other bones, the operative treatment of calcaneal fracture is relatively new. Objective evaluation of the functional outcome is still not ideal, due to the well-known discrepancy often seen in clinical, radiologic and patient well-being [1–3]. Static objective results are easy to evaluate by radiographic results of X-rays or computerized tomography. Another form of static, semi-objective evaluation is physical examination. Major importance is attributed to subjective parameters, e.g., pain and walking abilities [4–6], by most modern evaluation systems of foot and ankle, such as the American Orthopedic Foot and Ankle Society scores [7].

In this study we used dynamic footprint analysis as an adjuvant, objective parameter to evaluate the outcome of calcaneal fracture surgery. These objective parameters were compared to patient satisfaction as expressed by the AOFAS Orthopedic score.

Patients and Methods

During a period of 2 years, 30 patients with 32 intraarticular displaced calcaneal fractures were treated in our department by open reduction and internal fixation. The study group comprised 22 patients, 20 males and 2 females, with 24 calcaneal fractures [Table 1]. The excluded patients were those who were lost to follow-up, since our hospital is a referral center. Most of the fractures were caused by falls from heights. Six patients had other injuries that required surgery. The patients" ages ranged from 14 to 51 years, mean 35 years. Follow-up ranged from 9 to 90 months on average, with a mean of 60 months.

Fractures were classified according to Essex-Lopresti and Paley classifications [8,9]. The two systems are based on X-rays enhanced by CT. Operated fractures were distributed as follows: 1 of B1, 3 of B2, 9 of C1, and 11 were C2 type by Paley [Table 2].

Patients with undisplaced fractures were treated conservatively with a cast or elastic bandage. All the other fractures were surgically treated using the extended lateral approach, which facilitated good access and vision of the subtalar joint. Screws and plates accomplished fixation. The average operating time was about 100 minutes, and hospitalization time ranged from 4 to 10 days. The postoperative protocol was physiotherapy and no weight-bearing for 6 weeks, then gradually partial to full weight-bearing at 3 months postsurgery.

For evaluation of treatment we used the protocol and hind foot scoring system published by the AFAOS [7]. This protocol includes subjective parameters, i.e., daily activity, occupation, and sports activity, walking in different areas, walking a distance, and using assist devices for walking such as canes. The objective parameters include range of movements of the ankle and subtalar joints, limping, and radiographic findings. Each parameter had a cumulative score of maximum 40 points for pain, 50 points for function and 10 points for alignment, altogether a maximum of 100. A score between 90 and 100 was considered excellent, 70–89 good, 41–69 fair and 40 as poor.

Radiographic evaluation consisted of anterior-posterior, lateral and axial X-rays of the heel. The congruency of the subtalar joint, osteoarthritic changes, calcaneal width, and Bohler and Gissane's angles were evaluated. Static and dynamic footprint analysis was performed with the Parotec System (Paromed Medizintechnik GmbH, 83115 Markt Neubeuren, Germany), which has electronic pressure sensors throughout the sole of the shoes. The system can measure and demonstrate qualitatively and quantitatively the load and press distribution between the left and right foot and in different areas of the same foot. It can be done statically and dynamically (e.g., in the stance phase) and can compare the abnormal foot to the other, and to normal known controls. It was done between 3 and 6 months postoperatively, as soon as the

AFAOS = American Foot and Ankle Orthopedic Society

Table 1. Postoperative results according to age and fracture type

Patient	Age	Fracture type	Follow-up time (mo)	Pain	Function	Score anatomy	Total	Work	X-ray	Footprint
1	35	C2	60	40	49	10	99	Retired	Normal	Almost normal
2	35	C2	60	30	49	10	89	Retired	Normal	Almost normal
3	37	Cl	31	30	47	10	87	FT	Normal	Normal
4	47	C2	74	30	47	10	87	Retired	Normal	Almost normal
5	50	Cl	72	30	43	5	78	PT	s/p subtalar arthrodesis	Almost normal
6	24	C2	60	40	47	10	97	FT	Normal	Normal
7	48	B2	80	20	33	5	58	PT	Mild subtalar changes	Almost normal
8	38	Cl	78	10	35	5	50	Retired	Normal	Abnormal
9	22	Bl	60	30	50	10	90	Unempl	Normal	Normal
10	22	Cl	60	30	50	10	90	Unempl	Normal	Normal
11	47	Cl	64	30	10	10	50	Unempl	Normal	Abnormal
12	34	C2	60	30	32	5	67	Retired	Normal	Abnormal
13	48	C2	54	30	37	10	77	PT	Subtalar loose bodies, talonavicular OA	Almost normal
14	14	Cl	54	40	49	10	99	Unempl	Normal	Almost normal
15	44	B2	60	30	39	10	79	FT	Normal	Normal
16	32	Cl	60	30	7	5	42	FT	Normal	Normal
17	29	Cl	60	30	7	5	42	FT	Normal	Almost normal
18	30	C2	48	30	50	10	90	Unempl	Normal	Normal
19	39	Cl	90	30	7	5	42	Retired	Normal	Abnormal
20	14	B2	24	30	33	5	68	FT	Suboptimal	Abnormal
21	43	C2	84	30	42	10	82	FT	Normal	Normal
22	18	C2	58	30	50	10	90	FT	Normal	Normal
23	39	C2	9	0	12	5	17	Retired	Normal	Abnormal
24	51	C2	70	30	48	10	88	FT	Normal	Almost normal

S/p = status post, FT = full-time employment, PT = part-time employment, Unempl = unemployed before and after

patient began walking with weight-bearing. Measurement is carried out over a short period by remote control that is operated by an objective technician so that the patient does not know the exact time of the test.

The results are shown graphically for the two feet. We recorded and evaluated load distribution during standing, as well as dynamic changes during walking. The results of the injured foot were compared to the other healthy foot of the patient, except for the two patients with bilateral calcaneal fractures, and to the known normal control of the measuring system. All patients were examined with the same equipment and by the same technician, and with the same type of shoes (varying only by size). One of the advantages of this system is the ability to measure static and dynamic loads objectively and without the knowledge of the patient.

Results

Two patients (nos. 18 and 21, Table 1) had superficial wound infections, which resolved after oral antibiotic treatment. Three patients (nos. 12, 16 and 17) had mild sloughing of the skin border of the wound, which recovered after conservative local treatment. None required further surgery. In one patient (no. 1) fixation had to be removed because of pain and irritation of the peroneal tendons. In another patient (no. 7) internal fixation failed, resulting in loss of reduction. Two patients (nos. 4 and 23) developed causalgia (reflex sympathetic dystrophy).

Table 2. The results of operative treatment, according to American Orthopedic Foot and Ankle Society Score, were subdivided by Paley classification

	Excellent	Good	Fair	Poor
B-1	1			
B-2		1	2	
C-1	2	2	5	
C-2	4	5	1	1
Total (%)	7 (29.2)	8 (33.3)	8 (33.3)	1 (4.2)

Radiographic evaluation showed incongruency in the subtalar joint in one patient. Two patients had osteoarthritic changes in the talonavicular joint, and three had calcaneal widening. Boehler and Gissane angles were restored to normal postoperatively in all but one patient.

Functional scoring, according to the AFAOS score for hind foot, was excellent in seven, good in eight, fair in eight and poor in one. Subdivision of the results according to the Paley classification is shown in Table 2. Footprints showed similar pressure distribution of the paired feet in the cases rated as excellent and good, compared to uneven distribution in those rated as fair and poor. Two illustrative cases are presented here.

Case 1

A 37 year old soldier who had fallen from a height suffered a C1 calcaneal fracture. He underwent open reduction internal fixation and returned to full activity within 3 months. Functional scoring was

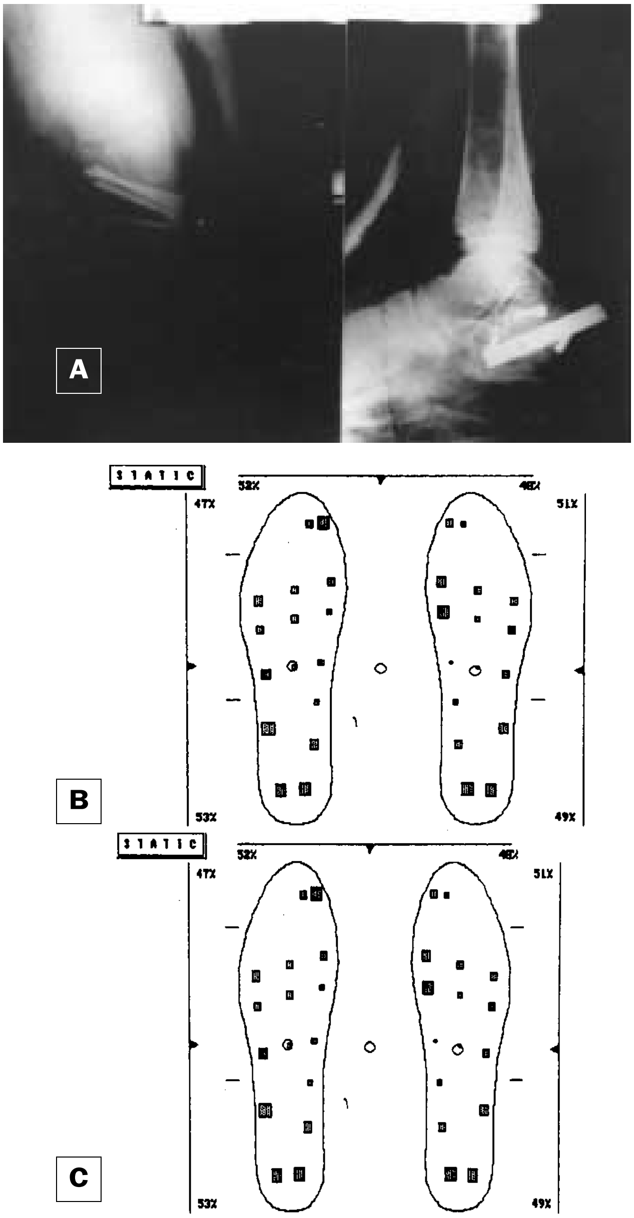

Figure 1. Patient 1. **[A]** Postoperative result of C1 calcaneal fracture. **[B]** Footprint and gait analysis. **[C]** Dynamic footprint and gait analysis.

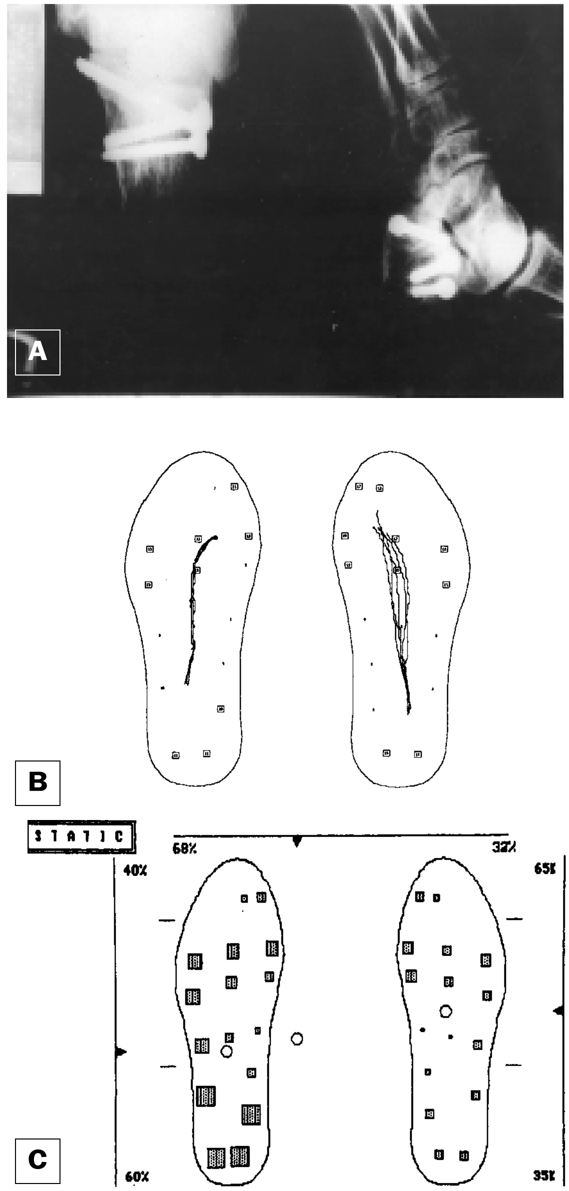

Figure 2. Patient 2. **[A]** Postoperative result of C1 calcaneal fracture. **[B]** Footprint and gait analysis. **[C]** Dynamic footprint and gait analysis.

87 points, which is considered good. Radiographic evaluation showed good reduction of the subtalar joint [Figure 1A]. Footprints showed a symmetric static diagram with symmetric load distribution and gravity center almost equal in both feet [Figure 1B]. The dynamic diagram also showed similar and symmetric loads and weight movement in both feet [Figure 1C].

Case 2

A 38 year old woman was injured in a road accident. She had open reduction internal fixation of a C1 calcaneal fracture. Since the operation she suffers from constant and severe pains in the heel, especially on standing and walking and has not returned to normal activity. At 6.5 years postoperatively the functional score was 50 points, considered as fair. Radiographic evaluation showed good reduction of the subtalar joint [Figure 2A]. Static footprints showed an asymmetric diagram with reduced load and weight carriage in the injured foot, compared to the healthy foot [Figure 2B]. The dynamic diagram showed different and asymmetric load and weight movement in the injured feet [Figure 2C]. In this case, although the anatomic results are good and the score is considered as fair, this correlated to the abnormal footprint.

Discussion

Many calcaneal fractures are displaced intraarticular fractures that cause damage to weight-bearing areas. Since the original work of Essex-Lopresti in 1951, many articles in the orthopedic literature have dealt with a large number of treatment methods for calcaneal fractures [1,4,8,10–18]. Until the last decade, neither conservative nor operative treatment produced superior results [19,20]. However, in the last decade, operative treatment with anatomic reduction and early mobilization has yielded a better outcome [2].

It is difficult to objectively evaluate the end result of surgery in calcaneal fractures since there are many factors that may bias the subjective and objective findings. Among these are intra- and inter-observer variances and often the patient's expectation or "secondary gain." An additional problem is that there may be no correlation between objective and subjective findings. The question is how to obtain the most accurate functional final results.

This study deals with a small number of patients, which precludes good statistical analysis. The results of surgical treatment in this study, i.e., 62.5% good to excellent, 33.3% fair, and 4.2% poor, represent the learning curve. These are similar to other reported results in which the success rate was 27% during the first year of treatment, rising steadily to 84% in the fourth year [1–3]. As in our work, these studies also showed that in about 33% of patients there is not always a direct correlation between radiographic and functional outcome. An interesting report showed that the functional result was better after a 10 year follow-up, compared to a 3 year follow-up in the same patients [21].

The footprint analysis is another objective modality option, which might be very helpful in borderline cases and is also used to estimate the effect of neurologic damage on gait and walking pattern [22–25]. The analysis is performed both statically and dynamically, and since the patients are unaware of the timing of the testing and recording they cannot influence the test purposely or accidentally. To maintain the same database and accuracy, the test is performed by the same technician, on the same machine and with the same shoes for all the patients. In our study, we found a good correlation ($P<0.05$) between the AFAOS score and footprint analysis results (for those who underwent the test), except for one patient whose footprint was good and his score fair, and he returned to work.

Footprint analysis and its correlation to the AOFAS should be explored in a larger series, but even the preliminary results in this small group may add a valuable diagnostic tool. It may also be useful to evaluate the postoperative results of trauma, such as calcaneal, ankle and foot fractures. The analysis may also be used to assess soft tissue injuries and treatment results after elective operations. It should be remembered that the main advantage is the fact that this is an objective, dynamic examination. We therefore recommend its permanent addition to the array of methods for evaluating foot and ankle conditions.

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