ORIGINAL ARTICLE

The comparison of pedobarographic parameters after calcaneal fractures

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ABSTRACT

BACKGROUND: This study aims to reveal surgical treatment's effect on plantar load restoration and clinical outcomes compared to conservative treatment in intra-articular calcaneal fractures.

METHODS: Thirty-two patients (Group 1) who underwent surgery for unilateral intra-articular calcaneal fractures and 28 patients who received conservative treatment (Group 2) were included in the study. Detailed static pedobarography examinations were performed on all patients. Plantar load distribution was evaluated based on the forefoot maximum and mean pressure, hindfoot maximum and mean pressure, and distribution of pressure in the heel area in the mediolateral direction. Clinical results were evaluated with the American orthopedic foot and ankle association (AOFAS) score and visual analog scale (VAS) scores.

RESULTS: While the mean contact area between injured and non-injured sides did not differ in Group 1, there was a significant difference between the two sides in Group 2 ($p=0.009$). Furthermore, on the injured side, the mean contact area ($p=0.023$) and forefoot pressures ($p<0.001$) were significantly higher in Group 2 compared to Group 1. Hindfoot pressure on the injured side was significantly lower in Group 2 compared to the uninjured side ($p<0.001$) and the injured side in Group 1 ($p<0.001$). A significant anterolateral shift in plantar load was detected in Group 2 ($p<0.001$). There was a significant difference between the two groups in terms of mean VAS and AOFAS scores in favor of Group 1 ($p<0.001$).

CONCLUSION: Surgical treatment of calcaneus intra-articular fractures should be preferred primarily as it provides better clinical results and better plantar load distribution in midterm follow-up.

Keywords: Calcaneus; fracture; load distribution; pedography.

INTRODUCTION

Calcaneus fractures are the most common fractures of the tarsal bones.[1] They generally occur due to falling from a height, which are mostly intra-articular fracture, and the subtalar joint is also affected.[2] Intra-articular calcaneal fractures have longer healing time and, as in patients following myocardial infarction, heart, lung, or liver transplantation during healing, negatively affect the quality of life.[3] Although conservative treatment provides earlier return to work, it has been shown that open reduction and internal fixation (ORIF) provide better function and increase shoe-wearing comfort due to better restoration of calcaneus and heel morphology.[4,5] Despite improved post-operative function, gait abnormalities have been widely demonstrated in post-operative plantar pressure analysis in calcaneal fractures.[6,7] The previous studies have compared the plantar load distribution of ORIF with the uninjured side in unilateral intra-articular calcaneus fractures and correlated good plantar load restoration with good clinical and functional outcomes.[7,8]

However, a limited number of studies with a small number of patients in the literature compared conservative treatment with surgical treatment to achieve plantar load distribution, and similar results were reported after comparing both groups.[9] Our hypothesis is that surgical treatment in

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intra-articular calcaneal fractures provides better plantar load distribution as well as better functional results and better pain relief. We think that our study will contribute to the literature about the pedobarographic measurement of surgical treatment and conservative treatment for calcaneal fractures. This study aims to reveal the effect of surgical treatment on plantar load restoration compared to conservative treatment in intra-articular calcaneal fractures.

MATERIALS AND METHODS

The Institutional Review and Ethics Board approval was obtained for this study (Approval number: 35/5, approval date: 12/09/2018). This study has been performed following the 1964 Declaration of Helsinki and its latest updates. The medical records were scanned retrospectively and patients who had undergone conservative or surgical treatment between January 2012 and January 2017 for unilateral intra-articular calcaneal fractures were identified. A total of 78 patients were reached. Informed consent was obtained from the patients after the study details were explained. Eighteen of the patients were excluded from the study due to accompanying lower extremity fractures, calcaneal non-union, history of another foot surgery, wound healing problems, and neurological diseases. The distribution of the fracture according to the Sanders classification was performed. Age, gender, fracture side, and body mass index of the patients were evaluated. After excluding those who were not eligible for the study, 32 patients (seven females and 25 males) who underwent surgical treatment were determined as Group 1, and 28 patients (five females and 23 males) who received conservative treatment were determined as Group 2. Pedobarographic view and pre-operative and post-operative X-ray images of a patient in Group 1 are shown in Figures 1 and 2, and a patient in Group 2 is shown in Figures 3 and 4.

Conservative treatment indications were clearly defined. These were as follows: comorbidities that preclude good surgical outcomes such as smokers, diabetes, peripheral vascular diseases, high stage cancer patients (such as lung and prostate), patients that did not accept surgical treatment, and patients with soft-tissue problems such as dermoabrasions. Closed reduction and short cast were applied in the eqinus position to all patients in Group 2. Cast treatment was maintained for 6 weeks with avoiding weight-bearing.

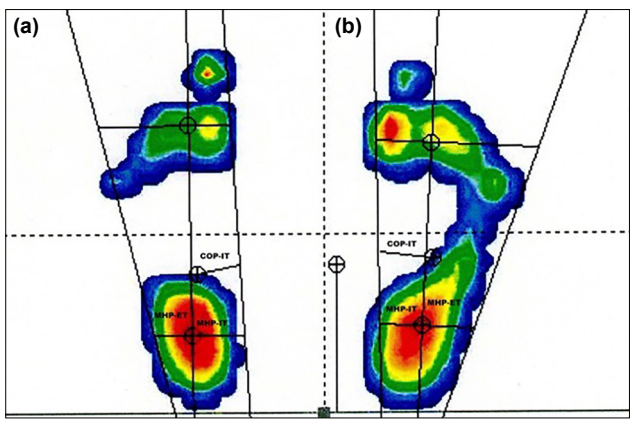

Figure 1. Pedobarographic view of a patient in Group 1. **(a)** Uninjured side, **(b)** operated side.

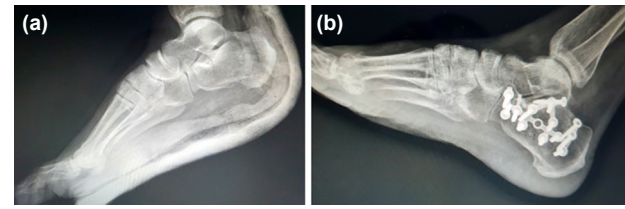

Figure 2. (a) Pre-operative X-ray of a patient in Group 1. **(b)** Post-operative X-ray image of a patient in Group 1.

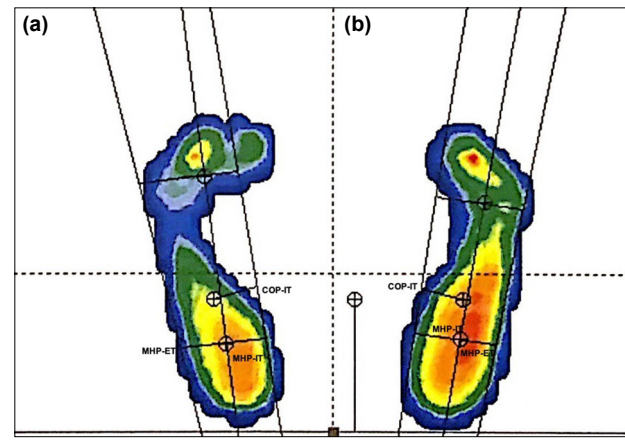

Figure 3. Pedobarographic view of a patient in Group 2. **(a)** Uninjured side, **(b)** injured side.

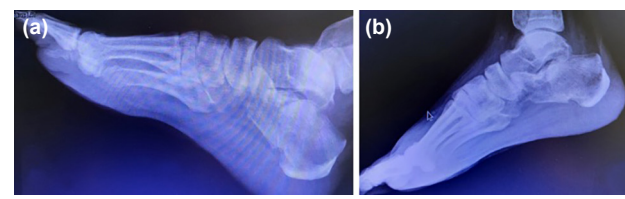

Figure 4. (a) Pre-treatment X-ray of a patient in Group 2. **(b)** Post-treatment X-ray image of a patient in Group 2.

All 32 patients in Group 1 were operated on with calcaneal plate-screw fixation using the standard extended lateral approach. Plantar pressure distribution was compared between the two groups by detailed static pedobarography. Measurements were made between January 2019 and April 2020.

Static Pedobarographic Evaluation

Detailed static pedobarographic examination was performed on both groups of patients using the Win-Track (Medicapteurs, Balma, France) system at least 24 months after the fracture. All patients were called for clinical examination, and baropedographic measurements were performed at their last follow-up examinations. Mean follow-up time was 38.4±4.73 months. In the detailed static analysis, foot contact area, plantar load, mean forefoot pressure (MnFP), mean hindfoot

pressure (MnHP), maximum forefoot pressure (MFP), maximum hindfoot pressure (MHP), MHP-internal tangent distance (MHP-IT), MHP-external tangent distance (MHP-ET), and the COP-internal tangent distance (COP-IT) data were obtained digitally. MnFP, MnHP, MFP, and MHP mean values were used to evaluate the anteroposterior distribution of plantar pressure, and MHP-IT, MHP-ET, and COP-IT mean values were used to evaluate the mediolateral plantar pressure distribution. Increase in MHP-IT and COP-IT values and decrease in MHP-ET values are associated with anterolateralization of plantar load.

Clinical and Radiologic Evaluation

Clinical outcomes were assessed by measuring visual analog scale (VAS) and American orthopedic foot and ankle association (AOFAS) scores obtained at the patients' last control in both groups.

Statistical Method

All statistical analyses were performed using SPSS version 22 (SPSS Inc, Chicago, IL, USA). The normal distribution of the data was determined by the Kolmogorov–Smirnov test. The variables are presented as mean and standard deviation or median and range depending on the normality distribution. Student t-test, paired t-test, and the Chi-square test were used to compare continuous and categorical variables, respectively. P<0.05 was defined as statistically significant.

RESULTS

There was no significant difference between the mean age, BMI, fracture side, and gender distribution of the patients in both groups (p>0.05) (Table 1). The mean follow-up time for all patients was 38.4±4.73 months (Group 1; 36.2±2.65 months and Group 2; 40.2 ± 2.89 months) and there was no significant difference between groups (p=0.451). According to the Sanders classification, ten patients had type 2, 11 patients had type 3, and 11 patients had type 4 in Group 1. In Group 2, nine patients had type 2, 12 patients had type 3, and seven patients had type 4 fractures. There was no significant difference between the two groups in terms of fracture type distribution (p=0.657).

Pedobarographic Results

While the mean contact area between injured and non-injured sides did not differ in Group 1, there was a significant difference between the two sides in Group 2. Furthermore, on the injured side, the mean contact area was significantly higher in Group 2 compared to Group 1 (Table 2). A significant decrease in load was observed in both groups on the injured side compared to the opposite side. However, the load reduction on the injured side was significantly higher in Group 2 than in Group 1 (Table 2). The MFP in Group 2 was found to be considerably higher than both the contralateral foot and Group 1 (Table 2). Similarly, the MnFP was significantly higher in Group 2 compared to the opposite foot and Group 1 (Table 2). Maximum and MnHPs were significantly lower in Group 2 than the contralateral side and Group 1. In Group 1, there was no significant difference between the injured and non-injured side in terms of these two measurements (Table 2). In Group 2, foot center pressure was significantly lateralized compared to the opposite foot and Group 1. No significant lateralization was found in the surgically treated group in foot center pressure compared to the opposite foot (Table 2). Similarly, significant lateralization was observed in the hindfoot in Group 2 compared to both Group 1 and the uninjured side. In contrast, in Group 1, there was no significant lateralization on the injured side compared to the non-injured side (Table 2).

Clinical Results

There was a significant difference between the two groups in terms of mean VAS (p<0.001) and AOFAS (p<0.001) (Table 3).

Table 1. Comparison of demographic data between groups

	Surgical treatment Group 1 (n=32)	Non-operative treatment Group 2 (n=28)	p
Age	39.50±10.89 (17–55)	44.10±10.68 (24–69)	0.105*
Gender			
Female	7	5	0.698**
Male	25	23	
Surgical side			
Right	21	14	0.221**
Left	11	14	
Height (cm)	168.65±6.70 (154–178)	171.14±4.36 (163–180)	0.099*
Weight (kg)	74.90±11.05 (54–95)	76.60±8.85 (60–100)	0.517*
BMI (kg/m^2)	26.30±3.54 (20–36)	26.14±2.73 (21–31)	0.844*

*Student t-test; **Chi-square test. BMI: Body mass index.

Table 2. Comparison results of pedobarographic values within and between groups

	Injured	Non-injured	p*
Contact area			
Group 1	74.9±6.5	75.2±7.4	0.502
Group 2	79.4±9.8	75.6±7.7	0.009
p**	0.023	0.286	
Load			
Group 1	34.1±6.4	37.4±4.9	<0.001
Group 2	31.3±5.2	38.3±7.1	<0.001
p**	<0.001	0.113	
MFP			
Group 1	885.25±130.76	868.46±133.85	0.069
Group 2	947.96±97.5	874.89±128.49	<0.001
p**	<0.001	0.287	
MnFP			
Group 1	584.50±136.58	573.09±133.31	0.185
Group 2	616.15±137.36	578.21±126.35	<0.001
p**	<0.001		
MHP			
Group 1	860.53±130.23	874.25±128.24	0.053
Group 2	813.96±101.17	881.96±142.44	<0.001
p**	<0.001	0.332	
MnHP			
Group 1	599.90±134.86	606.28±133.23	0.076
Group 2	516.67±116.45	612.17±138.88	<0.001
p**	<0.001	0.132	
COP-IT distance			
Group 1	2.84±0.48	2.85±0.51	0.064
Group 2	2.88±0.35	2.86±0.5	0.019
p**	0.011	0.231	
MHP-IT distance			
Group 1	2.66±0.34	2.53±0.39	0.101
Group 2	3.01±0.43	2.52±0.42	<0.001
p**	<0.001	0.339	
MHP-ET distance			
Group 1	2.84±0.48	2.90±0.31	0.122
Group 2	2.59±0.19	2.92±0.44	<0.001
p**	<0.001	0.406	

*Dependent sample t-test; **Independent sample t-test. MnFP: Mean forefoot pressure; MnHP: Mean hindfoot pressure; MFP: Maximum forefoot pressure; MHP: Maximum hind foot pressure; MHP-IT: Maximum hindfoot pressure - internal tangent distance; MHP-ET: Maximum hindfoot pressure - external tangent distance; COP-IT: Center of pressure - internal tangent distance.

Table 3. Comparison of VAS and AOFAS values in surgical (Group 1) and non-surgical (Group 2) treatment groups

	Group 1	Group 2	p*
VAS	1.46±1.29 (0–5)	2.96±1.13 (1–7)	<0.001
AOFAS	79±10.03 (57–100)	62.35±8.47 (42–86)	<0.001

*Independent sample t-test. VAS: Visual analog scale; AOFAS: American Orthopaedic Foot and Ankle Society.

DISCUSSION

The most important data obtained from this study is that while surgical treatment may provide better plantar load restoration in calcaneus intra-articular fractures, the plantar load may shift anteriorly and laterally in non-surgical treatment. This situation may adversely affect clinical results.

One of the recent study found that, no significant relationship was found between the clinical scores and the radiological classifications such as the Böhler angle and the X-fragment-Y-joint classification defined by Zwipp et al.,[1] and it was emphasized that these were not a reliable prognostic factor. Only a moderate correlation was found between the Sanders classification and the AOFAS score, and it was evaluated that this classification may have partial prognostic significance.[10,11] Static and dynamic pedobarography are valuable methods to demonstrate the foot's function and balance and evaluate the plantar load on the foot in clinical studies.[12,13] Recent studies of intra-articular calcaneus fractures have found a moderate to a strong correlation between plantar load distribution changes and functional and clinical scores.[7,8,14,15]

Some recent studies revealed that intra-articular calcaneus fractures lead to lateralization of plantar pressure, resulting in increased load in the forefoot and midfoot and decreased pressure in the hindfoot.[6,14,16,17] Furthermore, it has been observed that the contact times in the hindfoot and midfoot are shortened.[8,17] Rosenbaum et al.[9] observed a decrease in the medial foot's maximum pressure and an increase in the lateral foot's maximum pressure in the long-term follow-up of 14 patients operated on for calcaneus fracture; however, they stated that changes in Bohler's angle affect plantar pressure. In some studies, a significant pressure increase was found in the 4th and 5th metatarsals.[8,14,17] On the other hand, Genc et al.[18] found a decrease in plantar pressure in the entire injured foot compared to the healthy side, including the second, third, fourth, and fifth metatarsal maximum pressures. Hetsroni et al.[7] stated that greater pressure lateralization in the midfoot was associated with a greater decrease in toe pressures and greater clinical outcomes deterioration.

In the present study, in Group 2 patients, the plantar load was lateralized in hind- and midfoot. In contrast, in patients operated with an extended lateral approach, no significant plantar load lateralization was observed compared to the non-injured side. However, a significant increase in foot contact area was observed in the non-surgically treated group. There was a

decrease in the maximum and average plantar pressures of the hindfoot in both groups and an increase in the forefoot's maximum and average pressures on the surgical side. These changes were statistically significant in the non-surgical treatment group but not in the surgical treatment group. The surgical treatment group's VAS score was significantly lower than the non-surgical group, while the AOFAS score was considerably higher. Score results in the surgical group were like previous studies.[11] Our data reveal that plantar load distribution is associated with clinical and functional outcomes in calcaneus intra-articular fractures.

Jandova et al.[19] compared gait in terms of foot loading and temporal variables after 2 different operative approaches (the extended lateral approach and sinus tarsi approach). Their results showed that operated limb was less loaded, with the tendency to shift the load toward the midfoot and forefoot. After the less invasive sinus tarsi approach, the dynamic and temporal variables on the operated limb were nearly the same as those on the healthy one. Our study based on only one surgical approach. Further studies for the pedographic results of different approaches will give more reliable results.

Griffin et al.[20] reported operative treatment compared with non-operative care showed no symptomatic or functional advantage after 2 years in patients with typical displaced intra-articular fractures of the calcaneus, and the risk of complications was higher after surgery. Our results showed that clinical scores (AOFAS and VAS) were better in surgery group. There is no consensus about the surgical or conservative treatment of intra-articular displaced calcaneal fractures.

As a result of our findings, we think that surgical treatment is appropriate for intra-articular calcaneal fractures due to its better midterm functional results. Our study's weakness is the relatively low number of cases and the short follow-up period in both groups. At the same time, the detailed static pedobarography system cannot evaluate the distribution of plantar load as detailed as dynamic pedobarography. Studies to be conducted with a higher number of patients and long-term follow-up results by dividing fractures into subgroups will better demonstrate surgical treatment's effectiveness in intra-articular calcaneus fractures. However, the groups in the present study differ according to smoking rate, comorbidities, peripheral vascular diseases, and high-stage cancer patients (such as lung and prostate). According to the study protocol, patients with these conditions were treated conservatively. These factors alone may negatively affect the gait index.

Conclusion

The surgical treatment of intra-articular calcaneus fractures is useful due to the favored midterm functional and pedobarographic results compared with conservative treatment. Midterm load distribution following comminuted calcaneus fractures is better with surgical treatment, and this outcome is correlated with clinical scores.

Ethics Committee Approval: This study was approved by the Baltalimanı Metin Sabancı Bone Diseases Training and Research Hospital Clinical Research Ethics Committee (Date: 12.09.2018, Decision No: 35/5).

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Authorship Contributions: Concept: T.B.K., K.İ.Y.; Design: T.B.K.; Supervision: T.B.K.; Resource: K.İ.Y.; Materials: T.B.K.; Data: K.İ.Y.; Analysis: K.İ.Y.; Literature search: T.B.K.; Writing: K.İ.Y.; Critical revision: T.B.K., K.İ.Y.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Eklem içi kalkaneus kırıklarının cerrahi ya da konservatif tedavi sonrası plantar basınç dağılım durumunun kıyaslanması

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AMAÇ: Bu çalışmanın amacı, eklem içi kalkaneus kırığında cerrahi tedavinin plantar yük dağılımı restorasyonuna ve klinik sonuçlara etkisini konservatif tedavi ile kıyaslayarak belirlemektir.
GEREÇ VE YÖNTEM: Tek taraflı eklem içi kalkaneus kırığı nedeniyle cerrahi müdahale yapılmış 32 hasta (Grup 1) ve konservatif tedavi edilmiş 28 hasta (Grup 2) çalışmaya alındı. Detaylı statik pedobarografi değerlendirmesi tüm hastalara uygulandı. Plantar yük dağılımı ölçümü; ön ayak maksimum ve ortalama basınç dağılımı, arka ayak maksimum ve ortalama basınç dağılımı ve mediolateral yönde topuk bölgesi basınç dağılımları değerlendirilerek yapıldı. Klinik sonuçlar Amerikan Ortopedik ayak ve ayak bileği derneği (AOFAS) skoru ve görsel analog skala (VAS) ile değerlendirildi.
BULGULAR: Ortalama kontakt alanı kırık olan ve sağlam taraflar arasında Grup 1'de farklılık göstermedi fakat grup 2'de her iki taraf arasında anlamlı farklı idi (p=0.009). Yaralanmanın olduğu tarafta ortalama kontakt alanı (p=0.023) ve ön ayak basınçları (p=0.001) grup 1'e kıyasla grup 2'de daha yüksek idi. Grup 2'deki hastalarda kırık taraf arka ayak basıncı sağlam tarafa (p<0.001) ve Grup 1'deki hastaların kırık tarafına (p>0.001) göre anlamlı olarak düşük idi. Grup 2'de anlamlı olarak plantar yükte anterolaterale kayma saptandı (p<0.001). Grup 1 ortalama VAS ve AOFAS skorları grup 2'ye göre anlamlı olarak yüksek saptandı (p<0.001).
TARTIŞMA: Orta dönem sonuçlarda daha iyi plantar yük dağılımı ve klinik skorlar elde edildiğinden eklem içi kalkaneus kırıkları tedavisinde konservatif tedavi yerine cerrahi müdahale tercih edilebilir.
Anahtar sözcükler: Kalkaneus; kırık; pedografi; yük dağılımı.

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