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Proximal femoral nail shows better concordance of gait analysis between operated and uninjured limbs compared to hemiarthroplasty in intertrochanteric femoral fractures

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ABSTRACT

Purpose: The purpose of this study was to compare the results of pedobarographic gait analysis between the patients treated by proximal femoral nail or bipolar partial hemiarthroplasty due to intertrochanteric fractures.

Methods: Thirty-seven patients with a minimum 1-year follow-up who had been operated for intertrochanteric fractures were evaluated clinically, radiologically and with pedobarographic gait analysis. Proximal femoral nail had been performed to 21 patients (group A), whilst 16 patients had been operated by partial bipolar hemiarthroplasty (group B). Pedobarographic analysis was performed by measuring plantar pressure, force and contact area values in both static and dynamic manner. Pedobarographic results of operated limb were compared among groups. Same data's also were compared between operated and uninjured limbs in each group to determine any asymmetry on weight-bearing.

Results: Average follow-up period in group A and group B was 36 (12–56) and 30 (12–48) months, respectively. There were no statistically significant differences among groups in terms of age, gender, body mass index, type and side of fracture, follow-up period, leg length discrepancy and postoperative hip scores. When the pedobarographic results of operated limb were compared, group B showed much more plantar force and pressure values than group A, on both static and dynamic evaluations. If the evaluation was taken into consideration to comparison of pedobarographic results between operated and uninjured limbs in each group, we found asymmetry in static load bearing, caused by higher load on uninjured limb in both groups. However, there was no statistically significant asymmetry between operated and uninjured limbs in respect to dynamic pedobarographic parameters for patients in group A. On the contrary, operated limbs in group B exposed much more plantar force and pressure values than uninjured limbs, which indicated asymmetric weight-bearing on dynamic evaluation.

Conclusions: Assessment of pedobarographic parameters can be another way of measuring the results of treatment in intertrochanteric fractures. Uninjured limbs of patients expose much more loading than operated limbs in postoperative static evaluation for both treatment options. However in dynamic evaluation, there is a better concordance of gait analysis between both limbs in patients operated by proximal femoral nail.

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Introduction

Intertrochanteric fractures of the hip joint are one of the most common fractures in elderly population and becoming more frequent in parallel with increasing human lifespan [1]. They are one of the most important causes of mortality and morbidity among elderly patients [2,3]. The aim of the treatment is to prevent possible complications by providing early mobilisation and to help the patients in returning to their daily living activities.

Intertrochanteric fractures must be treated with considering the age, physical and mental status of the patient, bone quality and type of the fracture. There is clear consensus in the literature for treatment of stable intertrochanteric fractures, which usually involves internal fixation methods [4,5]. However, optimal treatment modality of unstable fractures still remains controversial. Internal fixation with intramedullary nailing and partial hemiarthroplasty are two main treatment options for these fractures. Despite the variety of surgical intervention in unstable fractures, postoperative goals are the same; restore the gait biomechanics and rehabilitate the patients to their highest level of function [6,7].

Intramedullary fixation by using proximal femoral nail (PFN) is usually the preferred surgical method for internal fixation in unstable intertrochanteric fractures [5,8–10]. The purposes of PFN usage are to preserve the hip joint and to prevent complications associated with hemiarthroplasty. PFN is related with shorter duration of surgery, minimal invasive surgical technique, good union rates and lower blood loss and postoperative morbidity [1,2,11–13]. Despite these advantages of PFN, elderly patients with severe osteoporosis and unstable intertrochanteric fractures can sometimes experience a higher failure rate after internal fixation [14]. On the contrary, the advantages of hemiarthroplasty are to provide early mobilisation and to prevent systemic complications due to immobilisation [15,16]. However, limiting factors of hemiarthroplasty include intraoperative necessity for wide surgical exposure, greater blood loss, postoperative risk of dislocation, infection, acetabular erosion and prosthetic loosening [1,17].

Walking is the most essential modality of human life and thus disturbances of gait have a significant impact on the quality of life. Therefore, assessment of gait might be as sensitive tool to monitor the progress of fracture healing, as well as success of the treatment. There are a lot of studies [1,2,11–13,15–17] in the literature which compare the results of two treatment modalities according to general complications, operation time, functional outcomes, time to weight-bearing, mortality rate, hospital costs etc. However, the number of studies [6,18] about the comparison of the same modalities by using gait analysis is limited.

The load-bearing aspect of the feet during standing and walking can be measured by pressure platforms. Pedobarography analyses the force across a defined surface by providing several parameters of interest including plantar pressure, force and contact area and is an objective test for static (on standing) and dynamic (by walking) evaluations of foot functions. Pedobarography is a simple, rapid and non-invasive technique and can also investigate possible changes in gait pattern. It has been mainly used for the evaluation of foot deformities and for surgical decision making in these pathologies to demonstrate postoperative results [19]. To the best of our knowledge, there are no studies that have investigated possible alterations in gait patterns by using pedobarography in patients who have been treated for intertrochanteric fracture.

The purpose of the present study was to objectively evaluate gait pattern by using pedobarographic analysis following PFN and bipolar partial hemiarthroplasty (BPH) for intertrochanteric fractures. We hypothesised that patients treated with PFN would have better gait analysis results, because of preserving the hip joint. Therefore, we aimed to compare the results of pedobarographic gait analysis between the patients treated by PFN or BPH due to intertrochanteric femoral fractures.

Patients and methods

Between May 2009 and January 2012, the orthopaedic trauma database was retrospectively reviewed to identify all patients who sustained an intertrochanteric femoral fracture. A total of 80 patients had been treated with PFN or BPH. Among them, 65 patients with a minimum 1-year follow-up, who were 60 years of age or older and who had ambulatory status before hip fracture were evaluated. Of these 65 patients, 28 were dropped from the study because of the following reasons: (1) diagnosis of a pathologic hip fracture or a fracture from something other than a fall, (2) fractures associated with polytrauma, (3) patients who died within the first postoperative year, (4) lost of follow-up, (5) inability to move outdoors without assistance and co-morbidity that influenced mobility, (6) cognitive dysfunctions, (7) comorbid psychological or psychiatric conditions that might potentially influence the subjective evaluation of the outcome or compliance with gait analysis, (8) lower limb abnormalities that could be expected to influence gait pattern, (9) previous internal fixation or arthroplasty of the contralateral hip, (10) previous surgery to the lower extremity or if they required revision surgery for definitive treatment of their intertrochanteric fracture, (11) lack of informed consent or unwillingness to participate in gait analysis. According to these criteria, a total of 37 patients were included in the study and evaluated clinically, radiologically and with pedobarographic gait analysis. Among them, 21 (15 females, 6 males; mean age 78 years) patients underwent PFN (group A) and 16 (13 females, 3 males; mean age 79 years) patients underwent BPH (group B) (Table 1). All patients received verbal and written information about the study and provided written consent. The Human Studies Ethics Committee at first author's institution provided ethical approval for the study.

Preoperative radiological assessments involved anteroposterior (AP) and lateral radiographs of the hip and pelvis. Fractures were classified according to the Orthopaedic Trauma Association (OTA) classification system [20] (Table 1). The average time period from injury to osteosynthesis and hemiarthroplasty was 1.2 (range; 0–3) and 1.5 (range; 0–3) days, respectively. BPH or PFN was performed based on the surgeon's choice. However, internal fixation was only performed if the fracture could be properly repositioned and there was no evidence of osteoarthritis. Bone quality was also taken into consideration in the decision-making process. BPH (Spectron or Echelon, Smith & Nephew, Memphis, TN, USA) was performed through a posterolateral modified Gibson approach with the patient in lateral decubitis position. The fractured trochanter was attached to the prosthesis with one or two titanium cable wires of trochanteric plates in six (37.5%) patients. Bone cement was used in all cases. PFN (PROFIN, TST SAN, Istanbul, Turkey) was performed on a traction table, with the patient in supine position and under fluoroscopy. Closed reduction was achieved in all patients. Two proximal locking screws (8.5 mm dia) and one distal locking screw (3.5 mm dia) were inserted to the PFN in all applications. Prophylactic first-generation cephalosporin was administered for 48 h postoperatively to prevent infection. Low-molecular-weight heparin was started 12 h before the operation and continued at least for 10 days. Knee and ankle joint flexion and extension exercises were begun immediately after the operation and weight bearing with two crutches or a walker was allowed in all patients on the first postoperative day.

All patients were followed clinically and radiologically with 3-month intervals for the first year and 6-month intervals for the following years. In group A, fracture was determined to have healed when the fracture site was filled with callus and the patient

Table 1
Comparison of baseline characteristics among the groups.

	Group A (PFN)	Group B (BPH)	
Age*	78 ± 6.8 (60–91)	79 ± 5.7 (65–90)	$p = 0.442$
Gender	15 females, 6 males	13 females, 3 males	χ^2: 4.78 $p = 0.416$
BMI (kg/m^2)*	27.5 ± 3.2 (16.5–35.3)	28.4 ± 6.61 (23.7–33.7)	$p = 0.565$
Fracture side	Six left, 15 right	Four left, 12 right	χ^2: 4.5 $p = 0.393$
Fracture type	31-A1 – 5 patients	31-A1 – 4 patients	χ^2: 2.29 $p = 0.591$
	31-A2 – 13 patients	31-A2 – 12 patients	
	31-A3 – 3 patients	31-A3 – none	
Follow-up period (months)*	36 ± 8.4 (12–56)	30 ± 7.3 (12–48)	$p = 0.396$
Leg length discrepancy between operated and uninjured limbs (cm)*	0.5 ± 1.2 (0–2.5)	1 ± 0.8 (0–2)	$p = 0.457$
Harris hip score*	67.4 ± 19.7 (40–94)	68.2 ± 20.4 (54–91)	$p = 0.602$

BMI: body mass index, χ^2: Chi-square test, PFN: proximal femoral nailing, BPH: bipolar partial hemiarthroplasty.
* The values are given as the mean and standard deviation with the range in parentheses.

did not feel any pain at the fracture site. All fractures in this group healed and the average consolidation time was 14 (range; 9–18) weeks.

On the final follow-up, same radiographs including full-length views of the prosthesis or PFN were obtained. In group A, the quality of reduction was classified as anatomical (<5° of varus, valgus, anteversion, or retroversion), acceptable (5°–10°) or poor (>10°) (11). Clinical outcomes were assessed according to the Harris Hip Score (HHS) [21]. Leg length discrepancy was determined by using a direct tape measurement method. The distance between the anterior superior iliac spine and the medial malleolus on each limb was measured twice. The average value was used to compare the length of the leg between the operated and uninjured limbs. Additionally, body mass index (BMI, kg/m^2) were recorded for each patient.

Pedobarographic analysis was performed by TekScan pedobarography device (TekScan Inc., South Boston, Massachusetts, USA), which measured plantar pressure, force and contact area in a static and dynamic manner. The system consisted of a 5 mm thick floor mat (432 × 368 mm), which comprised 2288 resistive sensors (1.4 sensors/cm^2) with sampling data at a frequency of 40 Hz. The gait analysis procedure was always carried out with the patient barefoot. Before taking each measurement, the pressure-sensitive mat was calibrated for patient's body weight as recommended by the manufacturer [22].

For the static analysis, patients were asked to stand on the platform for 10 s whilst they were asked questions to prevent concentration to the foot and to prevent the wrong tended posture from causing over-pressure on one side of the foot (Fig. 1A). They were asked to look at a constant point on the wall, which was 1.5 m away. Whilst standing on the platform, the average width of stride was arranged to be 8 cm. In the dynamic analysis, patients walked at the normal gait speed on the same platform and the stance phase of walking (from initial contact to the end of preswing) was then analysed for at least 60 s (Fig. 1B). To be able to record the natural gait of the patients, they performed several practice walking trials with a self-selected speed and normal walking rhythm to accommodate to the environment and refrain from looking down in order to avoid targeting of the force platform. Each patient performed at least six successful walking trials on the force platform. Patients were asked to retry in case of a fixed stride and wrong foot position on the platform. The first and final foot falls from the recordings of each foot were omitted in order to eliminate potential partial trials and measurement errors resulting from momentary loss of equilibrium at startup. This method was described in the literature as the mid-gait measurement method [23].

The data's that were obtained during static and dynamic pedobarographic evaluations were then analysed by using F-Scan Mobile Research program. The footprint image of each foot was manually superimposed with 12 masks, which allowed calculating standardised pedobarographic values (plantar pressure, force and contact area) for each individual area of the foot. The sole of the foot was then divided into three main areas (forefoot, midfoot and

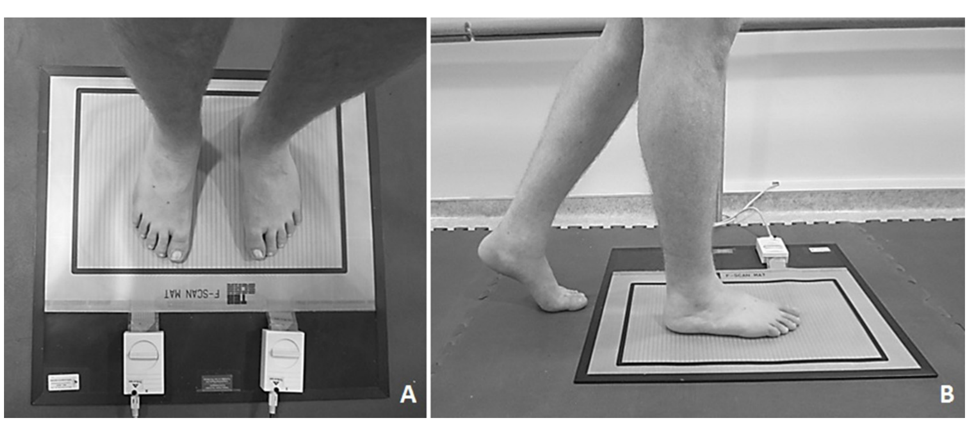

Fig. 1. Static pedobarographic analysis (A) refers to the collection and analysis of time series pedobarographic data's for 10 s on standing position. In the dynamic pedobarographic analysis (B), patients walk at the normal gait speed on the same platform for at least 60 s.

hindfoot) according to the International Guidelines for Plantar Measurements [24] (Fig. 2). The following parameters were evaluated during static measurement: total plantar force (TPF, N) as well as plantar force (PF) percentages (%), contact area (CA) percentages (%) and peak pressure (PP) values (N/cm^2) in forefoot, midfoot and hindfoot areas. During dynamic measurement, pressure–time integral (PTI, N/cm^2 × s), force–time integral (FTI, N × s), contact area (CA, cm^2) and peak pressure (PP, N/cm^2) values in the same areas were recorded. The mean and standard deviation were calculated for all parameters.

Two groups were compared to the study data's including age, gender, BMI, fracture side and type of fracture, follow-up period, leg length discrepancy and postoperative HHS. Additionally, pedobarographic results of operated limb were compared among the groups; as well as the same data's were compared between the operated limb and contralateral side in each group to determine any asymmetry on weight-bearing. The statistical analyses were performed using the NCSS 2007 program (NCSS Statistical Software, Kaysville, UT, USA). Descriptive statistics (mean and standard deviation) were computed. Paired *t* test was used to compare pedobarographic data's among the groups. Tukey's honest significance test was used to compare the same data's within the groups. Repeated one-way analysis of variance was used to compare clinical results among the groups. Qualitative data's were compared by using the Chi-square test and Fisher's exact test. A p value of <0.05 was considered to be statistically significant.

Results

The average follow-up period in group A and group B was 36 (range; 12–56) and 30 (range; 12–48) months, respectively. In group A, the quality of reduction was anatomical in 18 (85.7%) patients and acceptable in 3 (14.3%) patients. No statistically significant differences were found among the groups in terms of age, gender, BMI, fracture side and type of fracture, follow-up period, leg length discrepancy and postoperative HHS (Table 1). Therefore, two groups were accepted as comparable by the pedobarographic data's.

When the pedobarographic results of the operated limb were compared among the groups, forefoot PF, CA and PP values on the static evaluation; midfoot FTI and PTI values on the dynamic evaluation were significantly greater in group B than those in group A. The remaining pedobarographic parameters did not differ statistically significant on the operated limb among the groups (Table 2).

If the evaluation was taken into consideration to the comparison of pedobarographic results between the operated and uninjured limbs in each group, we found asymmetry in static load bearing, caused by higher load on the uninjured limb in both groups. Generally, PF and PP values were significantly higher in uninjured limb than those in operated limb. Additionally, forefoot CA value was significantly higher in uninjured limb than those in operated limb for group A (Table 3). There were no statistically significant differences in gait pattern between the operated and uninjured limbs based on the dynamic parameters in group A. However, forefoot FTI, CA and PP values were significantly higher in the operated limb than those in uninjured limb in group B, which indicated asymmetric weight-bearing on dynamic evaluation (Table 4).

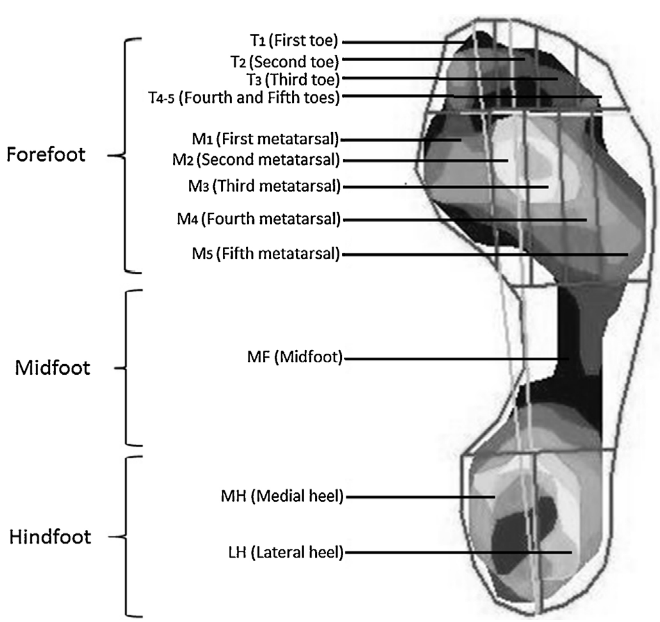

Fig. 2. Specific anatomical areas on the footprint image include first toe (T1), second toe (T2), third toe (T3), fourth and fifth toes (T4–5), first metatarsal (M1), second metatarsal (M2), third metatarsal (M3), fourth metatarsal (M4), fifth metatarsal (M5), midfoot (MF), medial heel (MH) and lateral heel (LH). The forefoot area is defined as the sum of the total area of the toes and metatarsals. The midfoot is defined in itself and hindfoot is defined as the sum of medial and lateral heels.

Discussion

In the treatment of intertrochanteric fractures, it is crucial to have an implant, which has a minimal invasive operation technique, a possibility of postoperative full weight-bearing and a low complication rate. On the other hand, successful operation does not always correlate with a successful functional outcome.

Table 2
Comparison of static and dynamic pedobarographic results of the operated limb among the groups.

		Group A (PFN)	Group B (BPH)	*p* value
Static evaluation*				
Total PF (N)		345.6 ± 98.1	356.4 ± 107.3	0.457
PF (%)	Forefoot	14.6 ± 5.3	18.7 ± 8.1	**0.012**
	Midfoot	7.5 ± 4.1	5.9 ± 2.9	0.089
	Hindfoot	17.7 ± 4.4	18 ± 4.8	0.274
CA (%)	Forefoot	20.3 ± 3.3	24.3 ± 4.2	**0.002**
	Midfoot	10.4 ± 2.8	9 ± 2.1	0.476
	Hindfoot	15 ± 4.4	15.6 ± 4.7	0.654
PP (N/cm^2)	Forefoot	29.5 ± 11.2	36.4 ± 14.8	**0.003**
	Midfoot	5.2 ± 2.7	4.6 ± 2.5	0.083
	Hindfoot	17.4 ± 3.9	16.6 ± 3.3	0.075
Dynamic evaluation*				
PTI (N/cm^2 × s)	Forefoot	49.2 ± 16.4	50 ± 17.2	0.105
	Midfoot	3.8 ± 0.8	5 ± 2.1	**0.029**
	Hindfoot	10.9 ± 3.9	13.6 ± 4.1	0.056
FTI (N × s)	Forefoot	47.5 ± 10.7	49.2 ± 11.9	0.233
	Midfoot	9.9 ± 3.1	14.3 ± 7.2	**0.0001**
	Hindfoot	20.6 ± 7.4	21 ± 7.4	0.368
CA (cm^2)	Forefoot	58.5 ± 9.4	59.1 ± 9.5	0.128
	Midfoot	22.1 ± 8.7	23.2 ± 9.8	0.244
	Hindfoot	27.9 ± 4.7	24.3 ± 3.3	0.074
PP (N/cm^2)	Forefoot	150.1 ± 30.2	148 ± 30.8	0.238
	Midfoot	11.2 ± 6.9	12 ± 7.2	0.601
	Hindfoot	33.2 ± 9.2	35.3 ± 9.5	0.067

PF: plantar force, CA: contact area, PP: peak pressure, PTI: pressure–time integral, FTI: force–time integral, PFN: proximal femoral nailing, BPH: bipolar partial hemiarthroplasty.
* The values are given as the mean and standard deviation.

Table 3
Comparison of static pedobarographic results between the operated limb and contralateral side in each group.

	Group A (PFN)			Group B (BPH)		
	Operated limb*	Uninjured limb*	*p* value	Operated limb*	Uninjured limb*	*p* value
Total PF (N)	345.6 ± 98.1	512.9 ± 118.2	**0.0001**	356.4 ± 107.3	512.6 ± 117.3	**0.0001**
Forefoot PF (%)	14.6 ± 5.3	20.7 ± 9.9	**0.002**	18.7 ± 8.1	22.4 ± 12.3	**0.003**
Midfoot PF (%)	7.5 ± 4.1	9.7 ± 6.2	0.081	5.9 ± 2.9	11.1 ± 7.3	**0.001**
Hindfoot PF (%)	17.7 ± 4.4	28.5 ± 8.3	**0.0001**	18 ± 4.8	23.7 ± 9.7	**0.001**
Forefoot CA (%)	20.3 ± 3.3	24.8 ± 3.9	**0.038**	24.3 ± 4.2	25.4 ± 4.5	0.118
Midfoot CA (%)	10.4 ± 2.8	11.5 ± 3.2	0.411	9 ± 2.1	10.2 ± 2.9	0.386
Hindfoot CA (%)	15 ± 4.4	17 ± 5.5	0.062	15.6 ± 4.7	15.8 ± 4.8	0.288
Forefoot PP (N/cm^2)	29.5 ± 11.2	37.7 ± 17.2	**0.006**	36.4 ± 14.8	45.4 ± 21.1	**0.004**
Midfoot PP (N/cm^2)	5.2 ± 2.7	6.5 ± 2.8	0.083	4.6 ± 2.5	9.2 ± 7.1	**0.001**
Hindfoot PP (N/cm^2)	17.4 ± 3.9	27.6 ± 7.7	**0.001**	16.6 ± 3.3	23.6 ± 7.3	**0.005**

PF: plantar force, CA: contact area, PP: peak pressure, PFN: proximal femoral nailing, BPH: bipolar partial hemiarthroplasty.
* The values are given as the mean and standard deviation.

Table 4
Comparison of dynamic pedobarographic results between the operated limb and contralateral side in each group.

	Group A (PFN)			Group B (BPH)		
	Operated limb*	Uninjured limb*	*p* value	Operated limb*	Uninjured limb*	*p* value
Forefoot PTI ($N/cm^2 \times s$)	49.2 ± 16.4	51.9 ± 18.4	0.128	50 ± 17.2	49.7 ± 16.5	0.233
Midfoot PTI ($N/cm^2 \times s$)	3.8 ± 0.8	4.1 ± 2.6	0.058	5 ± 2.1	5.6 ± 2.2	0.568
Hindfoot PTI ($N/cm^2 \times s$)	10.9 ± 3.9	10.5 ± 3.8	0.446	13.6 ± 4.1	13.1 ± 3.8	0.328
Forefoot FTI ($N \times s$)	47.5 ± 10.7	49.1 ± 11.8	0.264	49.2 ± 11.9	44.6 ± 7.3	**0.005**
Midfoot FTI ($N \times s$)	9.9 ± 3.1	10.2 ± 3.9	0.152	14.3 ± 7.2	14.3 ± 7.1	0.628
Hindfoot FTI ($N \times s$)	20.6 ± 7.4	18.6 ± 6.8	0.068	21 ± 7.4	20.6 ± 6.7	0.122
Forefoot CA (cm^2)	58.5 ± 9.4	56.3 ± 9.1	0.204	59.1 ± 9.5	51.3 ± 2.5	**0.0001**
Midfoot CA (cm^2)	22.1 ± 8.7	22.8 ± 8.8	0.798	23.2 ± 9.8	20 ± 6.1	0.078
Hindfoot CA (cm^2)	27.9 ± 4.7	27.2 ± 4.3	0.692	24.3 ± 3.3	22 ± 2.8	0.766
Forefoot PP (N/cm^2)	150.1 ± 30.2	155.8 ± 32.1	0.238	148 ± 30.8	128 ± 16.5	**0.0001**
Midfoot PP (N/cm^2)	11.2 ± 6.9	11.7 ± 7.3	0.744	12 ± 7.2	11.3 ± 7.1	0.848
Hindfoot PP (N/cm^2)	33.2 ± 9.2	34.3 ± 9.8	0.396	35.3 ± 9.5	32.3 ± 8.9	0.078

PTI: pressure–time integral, FTI: force–time integral, CA: contact area, PP: peak pressure, PFN: proximal femoral nailling, BPH: bipolar partial hemiarthroplasty.
* The values are given as the mean and standard deviation.

It was reported that only about 50% of patients could regain their preinjury functional level, and the others became more dependent in some manner [25,26]. Additionally, the ideal implant for these fractures is still a matter of discussion [2]. There is no clear evidence from clinical research to indicate that hemiarthroplasty is more effective than intramedullary nailing and vice versa.

The number of studies, which evaluate the results of treatment in intertrochanteric fractures by using gait analysis, is very limited. Koval et al. [18] compared different treatment modalities in femoral neck and intertrochanteric fractures by using computerised gait analysis, which was performed at 1, 2, 3, 6 and 12 weeks postoperatively to quantify weight-bearing. Thirty-two patients were divided into three groups according to whether they had internal fixation of a stable fracture, internal fixation of an unstable fracture, or a primary hemiarthroplasty. The average amount of weight that these patients placed on the injured limb increased progressively with time. During the first 3 weeks, the patients who had had internal fixation showed substantially less weight than those who had had a hemiarthroplasty. By 6 weeks, they could detect no significant differences among the groups with regard to weight-bearing or other measured gait parameters. They concluded that elderly patients who are allowed to bear weight as tolerated after operative treatment of a fracture of the femoral neck or an intertrochanteric fracture appear to voluntarily limit loading of the injured limb. In another study, Bakker et al. [6] investigated dynamic weight loading in older people with hip fractures. They concluded that the loading rate was a sensitive weight loading parameter for analysis of dynamic weight loading during rehabilitation in elderly hip fracture patients. This parameter correlated with clinical improvement and could differentiate between fast and slow rehabilitation.

Pedobarography is a specific kinetic assessment tool that uses static (on standing) and dynamic (by walking) measurements of plantar pressure, force and contact area distributions on the bottom of the foot through all stages of the gait cycle. The analysis is focused on these parameters and seeks to identify abnormalities or asymmetries between the legs [27]. Measurements of ground contact forces and plantar pressures can be used to assess the loads to which the human body is subjected in normal activities, like walking or running [6]. The most commonly analysed pedobarographic variable is peak pressure or the maximum pressure experienced at each sensor over the duration of the step. Other variables like contact area, plantar force, pressure–time and force–time integral can also be evaluated by pedobarography [28]. With regard to clinical problems, it is useful to compare the loads in the limb either between injured and uninjured sides.

Although the most widely researched clinical application of pedobarography is foot disorders, it has also been used for assessing the functional outcome and changes in gait pattern after lower extremity fractures located on pilon, calcaneus and metatarsus [27,29,30]. To our knowledge, this is the first study to evaluate the changes of pedobarographic gait parameters at 12 months or more after osteosynthesis or hemiarthroplasty for intertrochanteric femoral fractures. When we compared the loading parameters in the operated limbs among the groups, BPH showed much more plantar force and pressure values than PFN, especially on forefoot and midfoot on both static and dynamic evaluations. This means that patients operated by BPH exposed much more load bearing in the operated limbs than the patients operated by PFN. This could be attributed to the fact that BPH can allow early weight-bearing compared to PFN.

Although it was a common opinion that hemiarthroplasty allows early mobilisation, Kesmezacar et al. [12] found out in their study that early mobilisation was related to the patient's general health situation and it was independent of surgical technique. They didn't determine any significant differences among internal fixation and hemiarthroplasty groups according to the postoperative complications, mobilisation time, hip functions and quality of life. They also observed that decreased quality of life and probable complications were due to the systemic problems, which were commonly seen in this age group. In a prospective, randomised study [17], which included 58 patients with a minimum follow-up period of 2 years, the results of long-stem cementless calcar-replacement hemiarthroplasty were compared with those of treatment with PFN for unstable intertrochanteric femoral fractures. The two treatment groups were comparable with regard to demographic and injury variables. There were no significant differences among the groups in terms of functional outcomes, hospital stay, time to weight-bearing or general complications. Patients treated with PFN had a shorter operative time, less blood loss, fewer units of blood transfused, a lower mortality rate and lower hospital costs compared with those treated with hemiarthroplasty. It was concluded that in elderly patients with an unstable intertrochanteric femoral fracture, PFN provides superior clinical outcomes but no advantage with regard to functional outcome when compared with hemiarthroplasty.

In the present study; detailed gait analysis, which compared the pedobarographic results between the operated and uninjured limbs in each group, indicated that patients treated by PFN or BPH had some alterations in their static loading parameters. On the static evaluation, uninjured limbs exposed much more load bearing than operated limbs in both treatment options. This finding is correlated with the previous study reported by Koval et al. [18]. Therefore, we conclude that there are less weight-bearing in the operated limb, leading to asymmetry in standing position for both treatment options, even on the late postoperative period. However, there was no statistically significant asymmetry between the operated and uninjured limbs in respect to dynamic pedobarographic parameters for patients operated by PFN. On the contrary, operated limbs in BPH exposed much more plantar force and pressure values than uninjured limbs, especially on forefoot, which indicated asymmetric weight-bearing on dynamic evaluation. Differences of pedobarographic parameters between the affected and healthy lower limbs can be considered as a good indicator of asymmetry of weight-bearing during walking [31–33]. PFN can be applied with minimal invasive surgical technique using biologic fixation principles through indirect fracture reduction and provide biomechanical advantage due to medial transportation of the lever arm and the diminished deforming forces across the implant [11,34]. However, BPH is much more invasive surgery than PFN and can lead asymmetric distribution of pedobarographic parameters between the both lower limbs.

The present study has some certain limitations that should be considered when interpreting the results. First of all, our study was a retrospectively designed single-centre study instead of a randomised trial. Thus, selection bias was possible. The sample size was too small to fully examine the relevant factors responsible for gait alterations after surgery. It is known that age, fracture type, prefracture activities of daily living, walking ability and cognitive function influence functional recovery after hip fracture in the subacute setting. Fracture patterns according to the OTA classification are correlated with clinical and functional outcomes and therefore may lead to a bias in the pedobarographic results. However, the patient groups were not heterogeneous; age, gender, BMI, fracture type and fracture site, follow-up period, leg length discrepancy and postoperative functional scores were not varied widely. The comparison of two groups thought to be made as much as objectively, because of that the type of the surgery in our patients was decided according to the surgeon's choice and it was independent of fracture type and patient's general situation. The results of this study cannot be generalised to all hip fracture patients because the participants in the present study were all relatively healthy. They were all community dwelling, and those who were unable to walk independently outdoors or had severe diseases or cognitive problems were excluded. Although each patient received detailed information about the home exercise program, we could not monitor adherence to the physical rehabilitation program. Another limitation is the use of pedobarography as the only assessment of gait. Until now, there has been no single gait analysis system that can provide all gait information. Plantar force, pressure and contact area values are only one part of gait analysis and further investigations would be required to fully appreciate the gait pattern after surgical treatment of intertrochanteric fractures. Certain factors other than those examined in the present study might have affected pedobarographic results at the final follow-up. Further long-term follow-up studies of larger group of patients are needed to determine the changes of the gait pattern after osteosynthesis by using intramedullary nailing and hemiarthroplasty in intertrochanteric fractures.

Conclusions

The assessment of pedobarographic parameters can be another way of measuring the results of treatment in intertrochanteric femoral fractures. Uninjured limbs of patients expose much more loading than operated limbs on the static evaluation for both treatment options in the late postoperative period. However in dynamic evaluation, there is a better concordance of pedobarographic gait analysis between both limbs in patients operated by PFN.

Conflict of interest

The authors declare that they have no conflict of interest. No funds were received in support of this study. All authors have approved the manuscript and agree with its submission to "Injury".

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