Pedobarographic Analysis and Quality of Life After Lisfranc Fracture Dislocation

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ABSTRACT

Background: Few studies on tarsometatarsal fracture dislocations report on plantar pressure analysis and quality of life. The primary aim of this study was to determine the added value of plantar pressure analysis. The secondary aim was to determine quality of life and functional outcome.

Materials and Methods: With a median followup of 76 months, 26 patients with an isolated Lisfranc injury participated. The Short Form 36 (SF-36) was used to determine the health related quality of life. Functional outcome was assessed with the American Orthopaedic Foot Ankle Society (AOFAS) midfoot score and a Visual Analog Scale (VAS). A Wilcoxon Signed Rank test was used to assess whether plantar pressure and foot position variables differed between the injured and uninjured foot. Correlations between outcome data were identified using Spearman Rank Correlation.

Results: With respect to the plantar pressure analysis, a reduced contact time of the forefoot was found for the injured foot compared with the contralateral side (p=0.045). The injured side showed reduced contact surface of the forefoot (p=0.048) and an increased contact surface for the midfoot (p=0.019). The latter was paralleled by a higher maximum pressures at the midfoot (p=0.016). Patients reported a median score of 101 points for the SF-36, 72 point for the AOFAS midfoot score, and 7 for the VAS.

Conclusion: Plantar pressure measurements showed an adjusted walking pattern. Despite a fair outcome score, the quality for life of patients with a Lisfranc fracture dislocation returned to normal compared with normative data for the general population.

Key Words: Lisfranc; Tarsometatarsal; Plantar Pressure Analysis; Outcome

INTRODUCTION

Tarsometatarsal (Lisfranc) fracture dislocations occur infrequently, with an estimated incidence of one per 55,000 persons per year, compiling one percent of all fractures.[1,3,7-8] Many authors have attributed this low incidence to misdiagnosis, especially in polytrauma patients. Percentages of missed Lisfranc injuries range from 19 to 39 %.[3,10,27,31] Misdiagnosed injuries may result in a painful malunion and impaired function of the foot.[19] Early diagnosis and treatment are a prerequisite for an optimal result.[3-4]

Overall there are four different treatment modalities for Lisfranc injuries; cast immobilization with or without closed reduction, closed reduction with percutaneous fixation, open reduction with internal fixation, and primary arthrodesis.[5]

Most studies on tarsometatarsal fracture dislocations concern operative treatment,[2,9,12-13,18,20-22,24,30] in which correlations with outcome and remaining joint incongruence have shown the importance of an anatomical restoration as primary goal of treatment.[6,15] Several studies have indicated that Lisfranc injuries treated with closed reduction and cast immobilization often dislocated secondarily, which could lead to a worse long-term functional outcome.[3,12,17] Thus the second aim of treatment is a stable fixation after realignment, and therefore conservative treatment is mainly reserved for minimally displaced fracture-dislocations.[32]

Plantar pressure and foot position analysis are gaining in interest in various areas of foot and ankle surgery.[23,26] The analysis of changes in plantar pressure loading of the foot following a severe injury can be considered an objective outcome measure which may also provide guidance for patient-specific aftercare.[26] However, in the analysis of Lisfranc fracture dislocations, pedobarography has been used infrequently. Only 2 studies were found in which one used an in-shoe pressure monitoring system.[30] Mittlmeier et al showed that a correct restoration of foot axis and foot columns is of paramount importance.[14] The potential advantage of pedobarographic analysis is that it provides objective outcome data, as opposed to the patient-reported outcome measures (i.e., questionnaires) that are frequently reported in literature.

Therefore the aim of the current study was to determine the long-term static standing and dynamic walking pattern characteristics in patients who sustained a fracture dislocation of the tarsometatarsal joint. Secondary aims were to assess quality of life and functional outcome in these patients using validated outcome scores. The clinical relevance of plantar pressure and foot position was determined by determining its correlation with the functional outcome scores.

PATIENT AND METHODS

Patients

Patients treated for an isolated Lisfranc injury at our institution between January 1995 and July 2007 were identified from the computerized hospital records. A total of 104 patients with a fracture dislocation at Lisfranc were identified. Exclusion criteria were the presence of concomitant injuries at the ipsilateral and contralateral lower extremity (n=31), amputation (n=4), mental retardation (n=1), tarsometatarsal arthrodesis (n=8), foreign or unknown last address (n=27), and death (n=1). Altogether 32 patients met the inclusion criteria and were contacted by mail.

Patients were asked to visit the outpatient department once for radiographic analysis and measurement of Range of Motion of both feet, for pedobarographic assessment and to complete a questionnaire related to health related quality of life (SF-36) and function outcome (AOFAS hindfoot score and VAS). A short physical examination (presence of callous at the plantar aspect of the foot, range of motion (ROM) of the ankle using a goniometer, height and weight) was performed. Data regarding trauma mechanism, treatment modality, smoking habits and co-morbidities like diabetes were taken from medical charts. Smoking behavior and co-morbidities were unchanged at the time of followup measurements. Informed consent was obtained prior to participation and the study was approved by the local medical ethics committee.

Radiologic assessment

The Lisfranc injuries were classified from the initial radiographs according to the classification systems of Myerson et al.[16] and Quenu and Küss.[22] The distance between the base of the first metatarsal and the second metatarsal was measured.

At followup, standardized radiographs (anteroposterior (AP), oblique and weight bearing lateral) were taken of both feet. From the AP radiographs, the first intermetatarsal angle and Kite’s (talus -first metatarsal) angle were digitally measured. From the lateral radiographs Meary’s (talus-first metatarsal) angle, Hibbs’ (calcaneal-first metatarsal) angle and the medial cuneiform- 5th metatarsal distance were measured (Figure 1).

Plantar pressure and foot position analysis

A plantar pressure plate (Footscan®, RSscan International, dimensions (L x W x H): 2 m x 0.4 m x 0.02 m, 16,384 sensors, 2 sensors per square cm, 100 Hz) was used for plantar pressure measurements. Patients were asked to stand still on the plate to make a static recording of both feet. Subsequently, patients were asked to walk across the plate five times at a free-walking velocity; the first pass was considered a test recording. Each of the four recordings used for analysis contained a complete print of the injured and the uninjured foot.

Data were analyzed using the Footscan® software (Version 7), which automatically identified the anatomic regions of interest. The following items were determined: the weight distribution between injured an uninjured foot while standing, the weight distribution between the front and the back of the injured and uninjured foot while standing (Figure 2a), the maximum distance-change in medial-lateral direction of the centre of pressure line from the reference line (Δx COP) (Figure 2b) was determined, which gives an idea of the movement of the foot. A larger Δx COP indicates more movement in the foot, the foot axis angle (abduction related to the walking direction) (Figure 2c), contact area of the forefoot, midfoot and rearfoot, the maximum pressure (Pmax) beneath the medial heel (HM), lateral heel (HL), midfoot (MF) metatarsals (M1 to M5), hallux (T1), and remaining toes (T2-5) (Figure 2d). From these items the maximum pressure beneath the forefoot was calculated by adding up the maximum pressure of the hallux, the remaining toes and metatarsals 1 to 5. The maximum pressure beneath the rearfoot was calculated by adding the pressure underneath the medial heel and lateral heel. The percentage initial meta contact time (IMC) of last foot contact time (LFC) was determined, this value indicates which percentage of the total time of which the foot strikes the floor is spent onto the metatarsals, where a high percentages mean less contact time.

The test recording was not analyzed; the remaining four recordings were averaged. The values of the injured foot were dived by the values of the uninjured foot in order to correct for interpersonal differences, creating an injured/uninjured ratio. As one patient was unable to walk without his adjusted footwear; only a static analysis was preformed for this patient.

Quality of life and functional outcome

The Short Form 36 (SF-36) was used to determine the health related quality of life.[33] The SF-36 consists of 36 questions, and measures functional health and well being, dived in eight domains: physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role and mental health. From these sub-scores, physical (PCS) and mental (MCS) component scores were calculated. These scores were converted to a norm-based score and compared with the norms for the general population of the United States (1998). In the US population each scale was scored to have the same average (50 points) and the same standard deviation (10 points). Calculating norm based scores using the Dutch and US populations provided similar results for the eight health domains. Since the weighing factors for calculating PCS and MCS for the Dutch population were not available, the US population was used as reference.

Functional outcome was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) midfoot score.[11] This score consists of seven items (pain, activity limitations, footwear, walking distance, walking surface, gait abnormalities, and alignment) and ranges from zero to 100 points, with 100 points indicating an excellent or maximum outcome.

A Visual Analogue Scale (VAS) was used to determine patient satisfaction with overall functional outcome. Patients were asked to rate the current function of their foot on a scale from zero to ten. Ten indicated an excellent result with no pain and optimal functioning and zero a total handicap and extreme pain.

Statistic Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 16.0 (SPSS, Chicago, IL). The Kolmogorov-Smirnov test was used to test for normality of the data. The Levene's test was applied to assess homogeneity of variance between data of injured and control feet. Since most numeric variables did not show normal distribution or equal variance, all items were regarded as nonparametric for the statistical analysis. A Mann-Whitney U-test (numeric data) or Chi2 analysis (nominal and ordinal data) was performed to show that baseline and fracture characteristics of patients treated operatively and conservatively were similar. Numeric data are expressed as medians with P_{25}-P_{75}; nominal and ordinal data are shown as numbers with percentages. A Wilcoxon signed ranks test was used to assess whether plantar pressure and foot position variables differed between the injured and uninjured foot.

Logistic regression models were subsequently developed in order to correct for gender, age, trauma mechanism, time of followup, Body Mass Index, smoking, diabetes and fracture classification. Data were similar for both the Myerson and the Quenu and Küss classification. Therefore all data were corrected for the Myerson classification, because this classification is used more frequently in literature.

Correlations between outcome data were assessed using Spearman Rank Correlation. For all statistical analyses, a *p*-value <0.05 was taken as level of statistical significance.

RESULTS

Patient and fracture characteristics

Thirty-two patients met the inclusion criteria and were invited to participate. Six patients were not willing to participate, leaving 26 patients available for clinical review. Patient and fracture characteristics are shown in Table 1. The median age at injury was 53 years (P_{25}-P_{75} 39-57). Fourteen patients were male, the left foot was involved in 16 patients, and in 13 patients a high-energy trauma was the trauma mechanism. Median followup time was 76 months (P_{25}-P_{75} 45-120).

According to the classification by Myerson et al,[16] ten feet showed total incongruity (type A), one type B1, 13 had partial incongruity with lateral dislocation (type B2) and one type C1 (Table 1). According to the classification of Quenu and Küss 10 were homolateral (type A), one type B, and 14 were divergent (type C).[22] From one patient initial radiographs were not available. There were no statistically significant differences in radiological analysis between the operative and conservative groups.

Thirteen patients were treated operatively, four of which were managed with closed reduction and percutaneous pinning. Nine patients were managed with open reduction and internal fixation. Fixation was done in two cases with screws only, in eight cases with Kirschner wires only, and in three cases with both. The other 13 patients were treated with closed reduction with cast immobilization. Of all patient and fracture characteristics only the numbers of male patients was statistically significantly different between both groups.

Radiographic evaluation

At time of followup radiographs were taken from 11 of the 13 operatively managed patients and five of the 13 conservatively treated patients. The first intermetatarsal angle in the AP radiograph measured 8.2 degrees (P_{25}-P_{75} 6.1-9.0) at the injured side and 9.4 degrees (P_{25}-P_{75} 8.4-10.7) at the uninjured feet. Kite's (talus -first metatarsal) angle was 5.5 degrees (P_{25}-P_{75} 2.4-11.1) at the injured side and 4.2 degrees (P_{25}-P_{75} 1.0-6.8) at the uninjured feet. In the lateral photographs Meary's (talus-first metatarsal) angle was 5.8 degrees (P_{25}-P_{75} 4.1-13.1) at the injured side and 5.6 degrees (P_{25}-P_{75} 1.4-9.0) at the uninjured side. Hibbs' (calcaneal-first metatarsal) angle was 46.0 degrees (P_{25}-P_{75} 42.4-58.3) at the injured side and 49.4 degrees (P_{25}-P_{75} 44.8-53.9) at the uninjured side. The medial cuneiform- 5th metatarsal distance measured 10.8 mm (P_{25}-P_{75} 9.3-14.1) at the injured side and 11.4 mm (P_{25}-P_{75} 9.2-15.0) at the control side. No statistically significant differences were found between the injured and uninjured side, or between the operatively and conservatively treated patients.

Plantar pressure analysis

The results of the plantar pressure and foot position analysis of the injured versus the uninjured foot for the entire study population are shown in Table 2. In the static standing analysis, patients put statistically significantly more weight onto the rear of their injured foot compared to the front (p=0.004). In the dynamic walking analysis, the injured foot had a significantly larger contact surface of the midfoot (p=0.019), whereas the forefoot has a significantly smaller contact surface (p=0.048). Besides the larger contact surface, the maximum pressure shifted towards the midfoot at the injured side (p=0.016). The injured foot had a significantly larger percentage initial metatarsal contact time to last foot contact time (p=0.045).

Quality of life and functional outcome

A median SF-36 score for the entire study population was 101 (P_{25}-P_{75} 88-106). Patients reported scores below 50 for the physical domains: physical functioning, bodily pain and general health, leading to a below normal physical component score of 45 (P_{25}-P_{75} 36-51) for the total group. The mental component score was above 50 with a median score of 55 (P_{25}-P_{75} 52-58) for the total group (Figure 3).

Patients reported a median AOFAS of 72 (P_{25}-P_{75} 65-90) and a median VAS score of 7 (P_{25}-P_{75} 5-9) points.

Correlations between outcome measures

No apparent correlation between plantar pressure items and quality of life, functional outcome scores and radiographic angles could be found. There was a strong correlation between the VAS score and the AOFAS overall score (Rs = 0.721, p <0.001) and AOFAS pain (Rs = 0.599, p = 0.001) and AOFAS function subscore (Rs = 0.766, p <0.001). VAS and AOFAS scores did not correlate statistically significantly with the SF36 (sub)scores. The intermetatarsal angle from the AP image (angle A, see Figure 1) correlated with the SF-36 total score (*Rs* = 0.639, p = 0.006) and SF-36 PCS subscore (*Rs* = 0.634, p = 0.006).

DISCUSSION

The aim of this study was to determine the long-term static standing and dynamic walking pattern characteristics and quality of life in patients who sustained a fracture dislocation of the tarsometatarsal joint, and to correlate these with other validated (functional) outcome scores. The general finding was that patients tried to avoid putting weight onto the Lisfranc joint by shifting their weight to the back of their foot. This led to a reduced contact surface of the forefoot and a reduced contact time of the metatarsals, and thus the Lisfranc joint, with the floor. Patients had a larger midfoot contact surface on their injured side, which is indicative for an increased flatfoot.

Hardly any data of pedobarographic data in Lisfranc fracture dislocation as described in this study exists. In a previous study using a plantar pressure plate, Mittelmeier showed that patients with a Lisfranc or Chopart fracture dislocation (N=25) put more pressure on the non-injured column (medial or lateral) of the injured foot.[14] In a second study (N=11 patients with a Lisfranc fracture dislocation), using an in-shoe pressure-monitoring system, Teng et al. showed that no differences between injured and uninjured feet could be detected if anatomical reconstruction was obtained.[30]

The median SF-36 score of 101 indicates that quality of life after a Lisfranc fracture dislocation had returned to normal compared with normative data for the general population. This overall score consists of a physical component that is just below 50 points, and a mental component that is slightly over 50 points. One previous study used the SF-36 in the evaluation of tarsometatarsal fracture dislocations. They however failed to mention the results of their measurements.[18]

Overall patients had an median AOFAS midfoot score of 72 points and a VAS of 7 points, indicating a fair long-term functional outcome.[25] Patients reported reduced scores for the pain and activity domain of the AOFAS score. This AOFAS score is comparable to scores found in the literature.[22,30] The weighted average of the AOFAS score in recent studies including more than ten patients is 77 points (range 71 to 93).[2,9,12-13,18,20-22,24,30] There is however significant variation in number of patients, duration of followup and treatment modalities.The lower pain and activity scores seen in the AOFAS midfoot score were also reported in the SF-36.

No correlations between plantar pressure items and quality of life, functional outcome scores or radiographic angles could be found. The VAS and AOFAS correlated well, but there was no correlation between the SF-36 quality of life score and the disease specific AOFAS score, nor with the patient satisfaction VAS score.

Other studies in which the AOFAS was correlated to the SF-36 showed overall good correlations on the function (PF) and bodily pain (BP) domain.[29,34] This correlation appears to be stronger for hindfoot than for forefoot pathologies.[28]

Plantar pressure and foot position analysis increase in popularity in foot ankle surgery, and can be used as an objective outcome measure. It was shown earlier to have a near perfect reproducibility and repeatability, indicating high accuracy.[26] Although no correlations between outcome scoring systems and pedobarographic measurements were detected, important differences were found between injured and uninjured feet. This implies that pedobarographic analysis represents an objective and reliable test that may be used in addition to disease-specific functional outcome and quality of life scores.

Although comparing outcome after operative versus conservative treatment was not the aim of this study, a larger foot axis was found in the operative group (p=0.008; data not shown). This is probably due to more rigidity at the Lisfranc joint; by exorotation of the injured foot less movement is needed from the Lisfranc joint at the medial column, and more at the flexible lateral column. This is in concurrence with other investigations.[14,30]

Due to the limited patient numbers this study lacked statistical power to test for differences between treatment modalities. With the current dataset no differences in AOFAS and VAS scores between operatively and conservatively treated patients could be detected (data not shown). At least 102 patients per group would be required in order to proof superiority of either one of the treatment modalities with sufficient statistical power (alpha 0.05, beta 0.8 and two-sided testing).

CONCLUSION

With the use of plantar pressure analysis it could be concluded that, at an average of six years after trauma, patients showed an adjusted stance and walking pattern to relieve pressure off the Lisfranc joint. This most likely due to persisting pain, as could be deduced from the SF-36 and AOFAS pain subdomains. Besides the general adjustments seen in both patient groups, operatively treated patients have a larger foot axis, most likely caused by increased stiffness of the Lisfranc joint, leading to more supination at the foot towards the more flexible lateral column. Despite a fair AOFAS midfoot score, the patient-reported quality of life had returned to normal within the followup period.

Acknowledgement

This research was supported by a grant from the Fonds NutsOhra.

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Table 1. Patient and fracture characteristics

Patient and fracture characteristics

Parameters	Total N=26	Operative N=13	Conservative N=13	P-value
Male [a]	14	10	4	0.047*
High energy trauma [a]	13	9	4	N.S.*
Smoking [a]	13	8	5	N.S.*
Diabetes [a]	3	1	2	N.S.*
BMI (kg/m^2) [b]	26 (24-31)	25 (23-33)	27 (25-30)	N.S.***
Left side affected	16	7	9	N.S.*
Median age at injury (year) [b]	53 (39-57)	54 (37-61)	52 (39-56)	N.S.***
Median followup (months) [b]	76 (45-120)	67 (44-129)	78 (43-120)	N.S.***
Dorsiflexion (degrees) [b]	85 (80-90)	85 (80-90)	85 (80-90)	N.S.***
Plantar flexion (degrees) [b]	140 (130-150)	140 (130-150)	140 (133-148)	N.S.***
Myerson classification [a]				
Type A	10	7	3	N.S.**
Type B1	1	0	1	
Type B2	13	5	8	
Type C1	1	1	0	
Quenu and Kuss classification [a]				
Type A	10	7	3	N.S.**
Type B	1	0	1	
Type C	14	6	8	
Dislocation before treatment (mm) [b]	3 (2-5)	2 (2-5)	3 (2-5)	N.S.***

Patient and fracture characteristics for the overall group, and for the operatively and conservatively treated patients.

[a] Data are given as numbers; [b] Data are given as median with the 1st and 3rd percentile between brackets.

Data were analyzed using the * Fisher's Exact Test, ** Chi-Square Test, or *** Mann-Whitney U-Test.

BMI, Body Mass Index; N.S., not significantly different.

Table 2. Plantar pressure data comparing injured and uninjured foot

Plantar pressure data comparing injured and uninjured foot

Parameters	**Injured**	**Uninjured**	**P-value**
Weight distribution (%)			
Total	48 (46-52)	52 (48-54)	N.S.
Front	27 (24-28)	27 (23-30)	N.S.
Back	22 (20-25)**	25 (21-26)	N.S.
Max Δx COP (mm)	25 (17-39)	29 (24-32)	N.S.
IMC/LFC (%)	8 (6-10)	8 (6-9)	0.045*
Contact surface (cm^2)			
Rearfoot	23 (21-24)	23 (22-25)	N.S.
Midfoot	24 (21-27)	23 (18-26)	0.019*
Forefoot	53 (50-56)	55 (52-58)	0.048*
Pmax (N/cm^2)			
Toe 1	5 (2-7)	5 (3-7)	N.S.
Toe 2 to 5	1 (1-2)	1 (1-2)	N.S.
Metatarsal 1	9 (6-12)	7 (5-11)	N.S.
Metatarsal 2	14 (10-18)	17 (11-18)	N.S.
Metatarsal 3	19 (11-23)	18 (14-21)	N.S.
Metatarsal 4	14 (10-19)	15 (11-17)	N.S.
Metatarsal 5	6 (5-9)	7 (5-11)	N.S.
Heel, medial	12 (11-14)	13 (11-16)	N.S.
Heel, lateral	12 (9-13)	13 (11-14)	N.S.
Forefoot[1]	70 (55-83)	69 (56-79)	N.S.
Midfoot	4 (3-6)	3 (3-4)	0.016*
Rearfoot[2]	25 (20-28)	26 (21-31)	N.S.
Foot axis (°)	12 (8-16)	12 (5-15)	N.S.

Data are given as median with the 1st and 3rd percentile between brackets.

Wilcoxon Signed rank test was used for statistical analysis. * Significant at $p < 0.05$.

[1] Forefoot calculated as T1+T2-5+M1+M2+M3+M4+M5. [2] Rearfoot calculated as HL+HM.

Max Δx COP, maximum deviation of the centre of pressure line; IMC/LFC, percentage initial meta contact of last foot contact; Pmax, maximum pressure of a specific area under the foot; Foot axis, degrees of abduction in relation to the walking direction.

N.S., not significantly different.

Figure 1. Radiographic measurements

Radiographic measurements at followup of the injured and uninjured feet. A, first intermetatarsal angle; B, Kite's (talus -first metatarsal) angle; C, Meary's (talus-first metatarsal) angle; D, Hibbs' (calcaneal-first metatarsal) angle; E, medial cuneiform- 5th metatarsal distance.

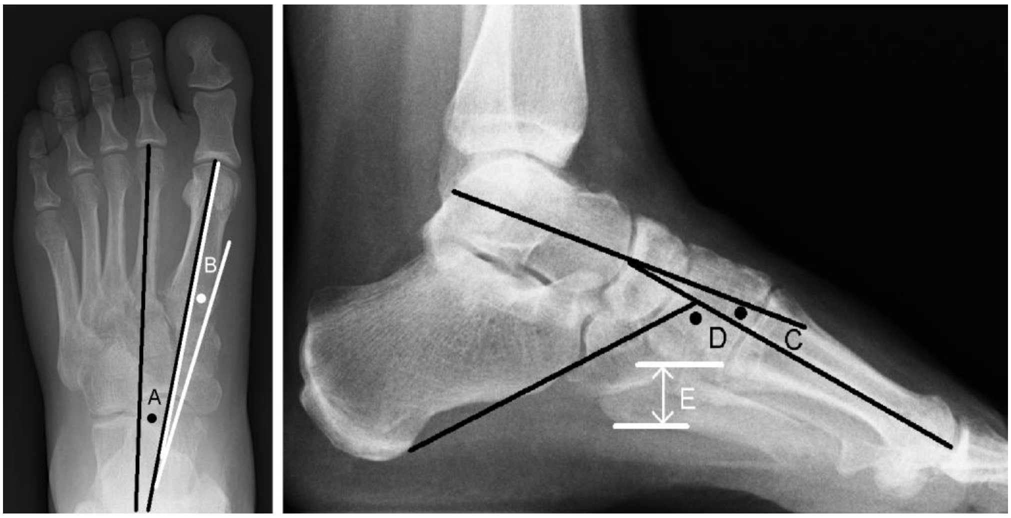

Figure 2. Footscan parameters

a, Weight distribution measured as percentage in four areas under the foot; b, Δx COP; the maximum distance-change in medial-lateral direction of the centre of pressure line from the reference line; c, Foot axis; abduction line through centre of the heel and head of second metatarsal related to the walking distance; d, division of the footprint into 10 areas under which maximum pressure (Pmax) was calculated.

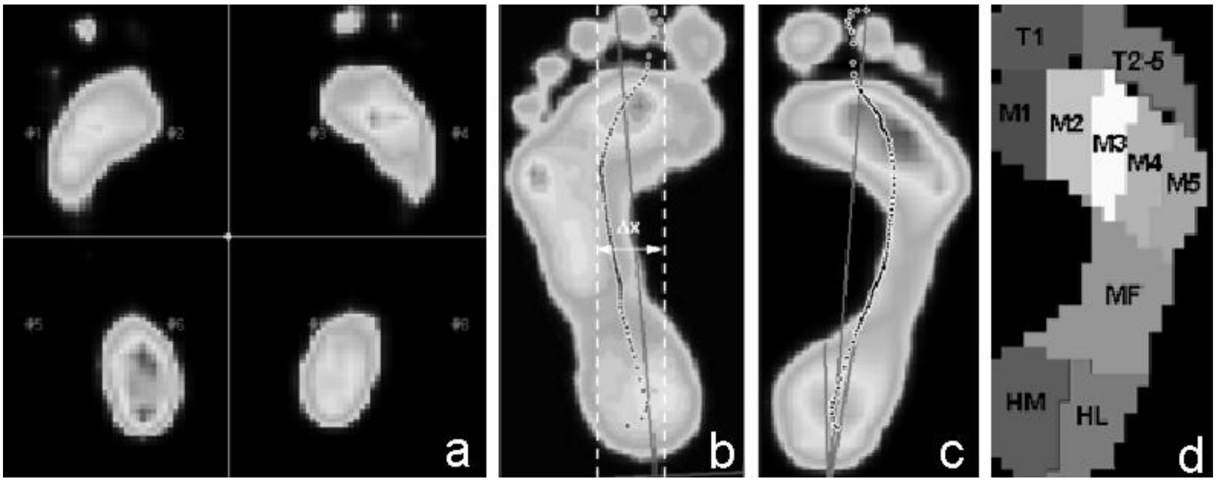

Figure 3. Quality of life in patients who sustained a tarsometatarsal fracture dislocation

Individual data are shown for the four physical domains (panel A) and mental domains (panel B) of the SF-36. For each domain the component scales are also provided. Horizontal lines indicate the median score per domain. The population norm is indicated by a straight line at 50 points.

SF-36, Short Form-36; PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health; PCS, physical component score; MCS, mental component score.