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ORIGINAL PAPER

Flexor digitorum longus transfer and medial displacement calcaneal osteotomy for the treatment of stage II posterior tibial tendon dysfunction: kinematic and functional results of fifty one feet

Reinhard Schuh · Florian Gruber · Axel Wanivenhaus · Nikolaus Hartig · Reinhard Windhager · Hans-Joerg Trnka

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Abstract
Purpose Stage II posterior tibial tendon dysfunction (PTTD) can be treated by flexor digitorum longus (FDL) tendon transfer and medial displacement calcaneal osteotomy (MDCO). Numerous authors have studied the clinical and radiographic results of this procedure. However, little is known about the kinematic changes. Therefore, the purpose of this study was to assess plantar-pressure distribution in these patients.
Methods Seventy-three patients with PTTD stage II underwent FDL tendon transfer and MDCO. Plantar pressure distribution and American Orthopaedic Foot and Ankle Society (AOFAS) score were assessed 48 months after surgery. Pedobarographic parameters included lateral and medial force index of the gait line, peak pressure (PP), maximum force (MF), contact area (CA), contact time (CT) and force-time integral (FTI).
Results In the lesser-toe region, PP, MF, CT, FTI and CA were reduced and MF in the forefoot region was increased. These changes were statistically significant. We found statistically significant correlations between AOFAS score and loading parameters of the medial midfoot.
Conclusions Study results reveal that FDL tendon transfer and MDCO leads to impaired function of the lesser toes during the stance phase. However, there seems to be a compensating increased load in the forefoot region.

R. Schuh (✉) · A. Wanivenhaus · R. Windhager
Department of Orthopaedics, Medical University of Vienna, Vienna, Austria
e-mail: reinhard.schuh@meduniwien.ac.at

F. Gruber
Department of Orthopaedic Surgery, Herz Jesu Krankenhaus, Vienna, Austria

N. Hartig · H.-J. Trnka
Foot and Ankle Center, Vienna, Austria

Keywords Stage II posterior tibial tendon dysfunction · FDL transfer and calcaneal osteotomy · Kinematic and functional results

Introduction

Posterior tibial tendon dysfunction (PTTD) is the major cause of acquired flatfoot deformity in adults [1, 2]. Without activity of the tibialis posterior, there is no stability at the midtarsal joint and the forward propulsive force of the complex of gastrocsoleus acts at the midfoot instead of at the metatarsal heads. This action creates excessive midfoot stress that leads to medial longitudinal arch collapse, subtalar joint eversion, heel valgus and abduction of the foot at the talonavicular joint [3, 4]. PTTD has been divided into three discrete stages by Johnson and Strom [5] and modified by Myerson [6]. Stage I is an inflammatory phase. Stage II is marked by painful acquired pes planovalgus deformity that can be corrected passively. From a pathological perspective, as the PTT weakens, antagonistic tendons, such as the peroneus brevis, go unopposed, leading to the development of hindfoot valgus and forefoot abduction [1, 7, 8].

Several studies have investigated the effects of surgical reconstruction for this condition using cadaveric models and examining detailed foot motion in an in vitro setting [9]. Three-dimensional gait analysis performed in vivo assesses changes after surgical correction of PTTD stage II [9, 10]. Measuring plantar pressure provides critical information of foot and ankle function during gait and other activities. Data obtained from this established technique are used to evaluate and manage patients with a wide variety of foot impairments [11, 12]. In contrast to measurements with a force platform, plantar-pressure analysis provides detailed information about

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contact of the entire foot and loading during the stance phase of gait [13].

Several authors have studied plantar-pressure changes after various types of reconstructive procedures of the hindfoot (e.g. ankle arthrodesis, subtalar arthrodesis, subtalar distraction arthrodesis, triple arthrodesis, lateral ligament reconstruction) [14–19]. However, to our knowledge, plantar-pressure changes after medial displacement calcaneal osteotomy (MDCO) and flexor digitorum longus (FDL) tendon transfer have not been investigated. Therefore, the purpose of our study was to: (1) assess plantar-pressure distribution in patients who had undergone MDCO and FDL tendon transfer for PTTD stage II, and (2) correlate plantar-pressure parameters with clinical results in terms of American Orthopaedic Foot and Ankle Society (AOFAS) score. We hypothesised that toe function is compromised and therefore plantar-pressure distribution is altered in these feet.

Patients and methods

Patients

Between September 1998 and November 2009, 73 patients (nine men and 64 women; 75 feet) with PTT insufficiency stage II underwent MDCO and FDL transfer by a single surgeon (HJT). The diagnosis was made clinically and with plain weight bearing anterior–posterior and lateral radiographs of the foot. Additionally, every patient underwent magnetic resonance imaging (MRI) to ensure PTT pathology. Mean age was 59.9 (43–79) years, and mean follow-up was for 48 (12–146) months. All patients failed to respond to previous nonoperative treatment, including orthotics, shoe modification and systemic nonsteroidal anti-inflammatory drugs. Patient demographics are indicated in Table 1.

Forty-nine patients (51 feet) were available for follow-up. Two patients had died; 13 had moved, five received subsequent fusion of the hindfoot, one suffered a cerebral insult, one had Alzheimer's disease, one had peroneal nerve palsy due to disc herniation and another could not participate in the functional evaluation due to severe osteoarthritis of the knee. The remaining patients were evaluated using dynamic plantar-pressure assessment using the AOFAS Hindfoot Score preoperatively and at follow-up. Additionally, patient satisfaction was assessed.

Table 1 Patient demographic parameters

	Mean	Range
Age	59.9	43–79
Sex (male/female)	9/64	–
Follow-up (months)	48.8	12–146

Surgical technique

The patient was positioned supine with a bolster under the ipsilateral hip. A tourniquet was applied, and a four centimetre oblique incision over the lateral aspect of the calcaneal tuberosity behind the peroneal sheath was performed. The tuberosity was cut from lateral to medial with a sagittal saw and completed with an osteotome. The tuberosity fragment was displaced medially by about one centimetre and was fixed with a cannulated 7.3-mm cancellous lag screw (Synthes GmbH, Salzburg, Austria) percutaneously after inserting a guide wire. A medial incision was then performed down to the medial column of the foot, beginning behind the medial malleolus, passing over the navicular tuberosity and following the inferior border of the first metatarsal. The sheath of the posterior tibial tendon was opened and the tendon debrided. The flexor digitorum longus tendon sheath was opened just below the medial malleolus. The knot of Henry was identified, a distal tenodesis of flexor hallucis longus (FHL) and FDL was made and the FDL was cut. A dorsal to plantar drill hole was made at the navicular tuberosity, and a lead stitch was attached to the PTT and passed through and sutured in the deep periosteum.

Postoperative regimen

Postoperatively, a cast in equinovarus position was applied for two weeks. After this, partial weight bearing was allowed in a cast in slight equinus position for four weeks. Until the end of this period, the foot was positioned in neutral. Patients were placed in an ankle orthosis (Push Ortho Aequi, Arcus Orthopaedie, OFA Barmberg Gmbh, Germany) for another four weeks. Plain radiographs of foot (anterior–posterior and lateral) were obtained six weeks postoperatively. After the cast was removed, patients underwent physical therapy, including lymphatic drainage, mobilisation, manipulation and strengthening exercises.

Pedobarography

Plantar loading parameters were assessed using a capacitive pressure measurement platform (Novel Ges m b H, Munich). The platform has a total area of 610 mm × 323 mm enclosing a sensor area of 240 mm × 380 mm. Because of the 18 mm depth of the platform, the test arrangement enclosed the entire platform in the centre of a polyethylene ramp five metres long. Because normal gait speed has a high individual variance, patients were told to walk at their normal walking speed and maintain a constant velocity. To represent the most natural gait patterns, the midgait method was chosen for pedobarographic assessment [11, 16]. This setting provides high validity and reproducibility. Five measurements per foot were recorded in order to obtain reliable measurements [16]. The foot was divided into geometric regions of interest (ROI) according to the anatomical areas of the hallux, second toe, lesser toes, forefoot, medial midfoot, lateral midfoot and heel (Fig. 1). The complete object was also considered in the calculation. The following variables for each region were generated by the software: lateral and medial force index of the gait line, peak pressure (kPa), maximum force (N), contact area (cm^2), contact time (ms) and force-time integral. According to Orlin et al., these parameters are the most clinically relevant [16]. Previous studies revealed that this pedobarographic assessment device provides high measurement reliability, validity and reproducibility [11, 16].

Clinical assessment

The AOFAS Hindfoot Score was obtained for clinical evaluation preoperatively and during the final follow-up [20]. This outcome measurement assesses pain, function, hindfoot motion and alignment.

Statistical analysis

Statistical comparison of pedobarographic measurements were made between operated and nonoperated feet using the paired t test. Correlation of plantar-pressure parameters and the AOFAS score was calculated using Pearson's correlation coefficient (r). Probability distributions were determined using the Kolmogorov–Smirnov test. Data were distributed normally. All analyses were performed using SPSS 16.0 for Mac OS X (SPSS Inc, Chicago, IL, USA), and the level of significance was set at 0.05. A post hoc power analysis was performed using G*Power 3.1.software. Achieved power was calculated with Cohen's d, alpha and sample size.

Results

Pedobarographic results

In the heel region, peak pressure was 275.6 [standard deviation (SD) 85.8] kPa compared with 302.4 (SD 102.6) kPa in the nonoperated foot ($p<0.05$). In the lesser toe region, peak pressure decreased in the operated feet (105.6; SD 57.4) compared with nonoperated feet (156.7; SD 73.8) ($p<0.05$). Also, maximum force (25.6; SD 17.2), contact time (58.8; 15.3), force-time integral (8.8; SD 7.9) and contact area (5.7; SD 2.1) were reduced in operated feet compared to the nonoperated foot [39.4; (SD 23.8); 64.4; (SD 15.1); 14.7; (SD 11.6); 6.4; (SD 2.2)]. All differences were statistically significant. Maximum force in the forefoot region was 707.5 (SD 158.0) N in the operated foot and 677.1 (SD 164.7) in the nonoperated foot, with a statistically significant difference ($p<0.05$). Also, we found significant alterations for peak pressure in the heel region: 275.6 (SD 85.8) N in the operated foot and 302.4 (SD 85.8) in the nonoperated foot ($p<0.05$). We found statistically significant correlations between AOFAS score and medial force index (−0.363; $p=0.01$), force-time integral of the medial midfoot (−0.294; $p=0.043$), force-time integral of the great toe (−0.302; $p=0.037$) and contact time of the medial midfoot (−0.309; $p=0.032$).

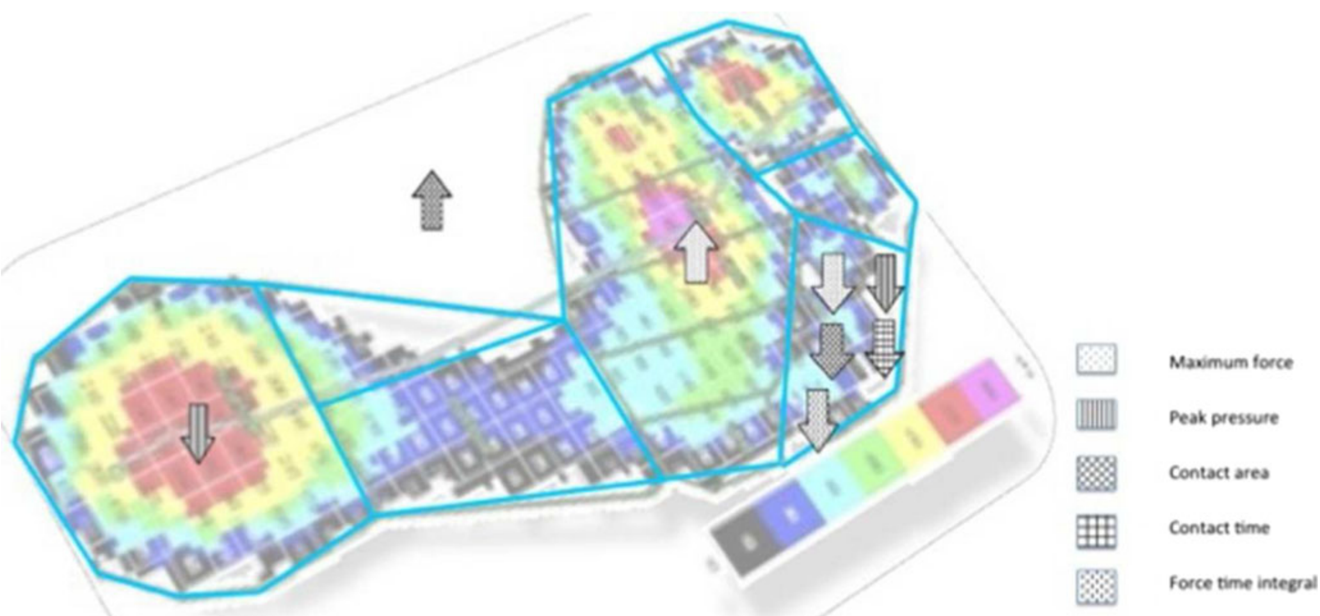

Fig. 1 Statistically significant changes of plantar-pressure distribution for regions of interest: total foot, heel, medial midfoot, lateral midfoot, forefoot, hallux, second toe and toes 3–5. *Arrows* indicate increase or decrease in plantar-pressure parameter compared with the unaffected side

Statistically significant results are shown in Fig. 1; complete data are shown in Table 2.

Clinical results

Mean AOFAS Hindfoot Score was 39 (range, 25–78) preoperatively and 91 (range, 77–100) at final follow-up ($p < 0.001$). According to the rating, all patients attained good or excellent scores postoperatively.

Complications

Nonunion and delayed union did not occur in any patient; no deep infection, wound breakdown or haematoma occurred. One patient developed a superficial wound infection that was treated orally with antibiotics and subsequently resolved. In two patients, a lesion of the sural nerve occurred: one due to scar adhesion and the other to the overlying venous plexus. In another patient, the calcaneal osteotomy was made too far medially and hindfoot varus occurred; the patient subsequently underwent a Dwyer osteotomy.

Discussion

Results of this study indicate plantar-pressure changes after MDCO and FDL transfer for PTTD stage II. The major finding is decreased function of the lesser toes in terms of load bearing during the stance phase of gait. Also, we found increased force transmission in the medial midfoot and forefoot, whereas there was decreased peak pressure at the heel. There was an association between loading parameters of the medial midfoot region and AOFAS score.

Our study has several limitations. Firstly, plantar pressure was not assessed preoperatively in the majority of patients because the pedobarographic analysis system was not available during the period of treatment. However, we believe we can draw conclusions by comparing plantar-pressure parameters with the unaffected foot. There was consistency in results when the surgically treated limb was compared with the contralateral side. A new, ongoing prospective study will make a direct comparison. Secondly, we did not perform a direct comparison to other treatment options for PTTD stage II (e.g. limited fusion). This is because, in our opinion, MDCO with FDL tendon transfer represents the gold standard for treating PTTD stage II. Therefore, it would not have been possible to obtain an ethics committee approval for joint-sacrificing procedures such as limited fusion.

Recent attention has focused on assessing plantar-pressure distribution in various foot types. Pes planus exhibits higher medial loading parameters than in cavus feet [21, 22]. PTTD stage II is associated with a painful, acquired pes planovalgus deformity [1]. In our study, we found increased loading

Table 2 Mean results of plantar-pressure parameters of operated and nonoperated feet, with standard deviation (SD)

	Operated foot	Nonoperated foot	*P* value
Total object			
Medial force index (N × s)	266.2 (82.0)	274.2 (84.8)	0.255
Lateral force index (N × s)	309.4 (86.3)	308.9 (87.2)	0.945
Maximum force (N)	866.2 (178.4)	865.4 (175.9)	0.902
Peak pressure (kPa)	736.3 (243.6)	709.8 (228.5)	0.303
Contact area (cm^2)	137.1 (16.4)	133.0 (15.0)	0.007*
Contact time (%ROP)	100	100	n.a.
Force time integral (N × s)	667.9 (645.1)	583.0 (164.8)	0.364
Heel			
Maximum force (N)	456.6 (125.1)	465.1 (139.3)	0.332
Peak pressure (kPa)	275.6 (85.8)	302.4 (102.6)	0.026*
Contact area (cm^2)	33.9 (3.8)	33.4 (3.8)	0.101
Contact time (%ROP)	59.1 (9.9)	59.6 (10.1)	0.651
Force time integral (N × s)	145.9 (66.8)	149.7 (63.5)	0.469
Lateral midfoot			
Maximum force (N)	183.3 (83.7)	163.9 (81.9)	0.057
Peak pressure (kPa)	158.7 (56.6)	148.9 (52.4)	0.222
Contact area (cm^2)	24.3(5.1)	23.1 (5.5)	0.079
Contact time (%ROP)	63.2 (8.9)	62.6 (10.2)	0.502
Force time integral (N × s)	64.2 (37.7)	59.3 (49.4)	0.311
Medial midfoot			
Maximum force (N)	43.5 (48.4)	32.5 (24.3)	0.050
Peak pressure (kPa)	122.0 (41.9)	114.5 (41.3)	0.165
Contact area (cm^2)	7.3 (5.9)	6.0 (3.9)	0.073
Contact time (%ROP)	47.0 (12.3)	46.0 (12.1)	0.452
Force time integral (N × s)	15.4 (27.1)	9.4 (9.0)	0.061
Forefoot			
Maximum force (N)	707.5 (158.0)	677.1 (164.7)	0.025*
Peak pressure (kPa)	658.0 (36.8)	660.3 (252.2)	0.945
Contact area (cm^2)	51.9 (5.6)	50.5 (5.7)	0.059
Contact time (%ROP)	82.4 (3.9)	83.2 (3.6)	0.107
Force time integral (N × s)	296.3 (81.8)	349.4 (375.2)	0.329
Great toe			
Maximum force (N)	124.5 (56.3)	124.3 (60.8)	0.978
Peak pressure (kPa)	448.4 (276.3)	442.5 (218.1)	0.876
Contact area (cm^2)	10.0 (2.4)	9.8 (2.5)	0.647
Contact time (%ROP)	64.1 (16.6)	65.7 (19.4)	0.545
Force time integral (N × s)	36.6 (25.4)	41.7 (28.0)	0.135
Second toe			
Maximum force (N)	29.6 (13.4)	29.4 (16.3)	0.944
Peak pressure (kPa)	174.0 (81.0)	196.3 (106.9)	0.168
Contact area (cm^2)	3.9 (1.0)	3.7 (1.0)	0.173
Contact time (%ROP)	57.5 (13.9)	56.7 (15.9)	0.764
Force time integral (N × s)	8.6 (5.4)	9.3 (7.0)	0.463
Lesser toes			
Maximum force (N)	25.6 (17.2)	39.4 (23.8)	0.000*
Peak pressure (kPa)	105.6 (57.4)	156.7 (73.8)	0.000*

Table 2 (continued)

	Operated foot	Nonoperated foot	P value
Contact area (cm^2)	5.7 (2.1)	6.4 (2.2)	0.035*
Contact time (%ROP)	58.8 (15.3)	64.4 (15.1)	0.039*
Force time integral (N × s)	8.8 (7.9)	14.7 (11.6)	0.000*

ROP roll over process

* Statistically significant difference revealed by the paired t test

parameters in the medial midfoot region. However, this is just a tendency, and statistical analysis did not reveal significance. Nevertheless, it seems that MDCO and FDL tendon transfer fails to restore absolutely physiological loading conditions in the medial arch. Based on our study results, decreased loading of the medial arch seems to have an impact on the clinical results. We investigated negative correlations between loading parameters of the medial midfoot region in terms of force-time integral and contact time and the AOFAS score. Therefore, surgical reconstruction of PTTD stage II should aim at restoring physiological load patterns in this region. Also, further research is necessary to evaluate plantar-pressure distribution and changes before and after surgery in this region.

A previous study reviewing the function of toes in walking shows that toes are in contact with the walking surface for 75 % of the stance phase of gait. During this phase they exert peak pressures similar to the region of the metatarsal heads. If toe function is affected, the load-bearing potential decreases, and load is shifted to the forefoot region to compensate [23]. In the study reported here, patients presented statistically significant decreased plantar-pressure parameters in the lesser toes compared with the untreated foot. Also, there was significant increased load in the forefoot region. The compensation mechanism of the above-mentioned study [23] could serve as an explanation for these changes. It is crucial that lesser-toe function is impaired due to transfer of the FDL tendon. However, to the best of our knowledge, this is the first study to confirm these alterations by a biomechanical objective assessment method; both surgeon and patient must be aware of such changes.

Our results in terms of plantar-pressure alterations compare favourably with other investigations of limited fusions of the hindfoot. Diezi et al. found decreased load forces of the heel and increased load of the midfoot after isolated subtalar arthrodesis. Also, they described overloading of the lateral column, as physiological pronation during midstance is locked in by subtalar joint fusion. Rammelt et al. investigated plantar contact-pressure parameters in patients with bone block distraction arthrodesis of the subtalar joint and compared them with the unaffected side. They described reduced loading of the heel and increased loading of the midfoot and lateral hindfoot after operation. Additionally, there was a lateral shift in gait line. The pressure time integral for the total foot showed a positive correlation with AOFAS score, indicating interaction of foot function and impulse [24]. The results of these studies indicate that limited fusion affects hindfoot kinematics in terms of plantar-pressure distribution. We did not find these significant changes in the hindfoot regions of patients in our study.

A number of authors studied the clinical effects of FDL tendon transfer and MDCO for treating PTTD stage II [1, 25–30]. Results of these studies revealed significant improvement in clinical parameters in terms of AOFAS score. Patients in our study showed an increases AOFAS from 39 points preoperatively to 91 points at follow-up. This change was statistically significant, and the change corresponds to reported results of this procedure in the current literature.

Based on results of our study, we conclude that reconstructive procedures for PTTD should aim to decrease loading parameters at the midfoot region. Future research is necessary to assess changes in plantar-pressure distribution after surgery compared with a detailed analysis of the presurgical situation in patients with PTTD.

References

1. DiPaola M, Raikin SM (2007) Tendon transfers and realignment osteotomies for treatment of stage II posterior tibial tendon dysfunction. Foot Ankle Clin 12:273–285
2. Roth S, Roth A, Jotanovic Z et al (2013) Navicular index for differentiation of flatfoot from normal foot. Int Orthop 37:1107–1112
3. Trnka HJ (2004) Dysfunction of the tendon of tibialis posterior. J Bone Joint Surg Br 86:939–946
4. Yeap JS, Birch R, Singh D (2001) Long-term results of tibialis posterior tendon transfer for drop-foot. Int Orthop 25:114–118
5. Johnson KA, Strom DE (1989) Tibialis posterior tendon dysfunction. Clin Orthop 239:196–206
6. Myerson MS (1996) Adult acquired flatfoot deformity. J Bone Joint Surg 78A:780–792
7. Lechler P, Graf S, Koch FX et al (2012) Arthrodesis of the talonavicular joint using angle-stable mini-plates: a prospective study. Int Orthop 36:2491–2494
8. Joveniaux P, Harisboure A, Ohl X et al (2010) Long-term results of in situ subtalar arthrodesis. Int Orthop 34:1199–1205
9. Brodsky JW, Charlick DA, Coleman SC et al (2009) Hindfoot motion following reconstruction for posterior tibial tendon dysfunction. Foot Ankle Int 30:613–618
10. Marks RM, Long JT, Ness ME et al (2009) Surgical reconstruction of posterior tibial tendon dysfunction: prospective comparison of flexor digitorum longus substitution combined with lateral column lengthening or medial displacement calcaneal osteotomy. Gait Posture 29:17–22
11. Putti AB, Arnold GP, Cochrane LA et al (2008) Normal pressure values and repeatability of the Emed ST4 system. Gait Posture 27:501–505
12. Jansen H, Fenwick A, Droht S et al (2013) Clinical outcome and changes in gait pattern after pilon fractures. Int Orthop 37:51–58
13. Sinclair MF, Bosch K, Rosenbaum D et al (2009) Pedobarographic analysis following Ponseti treatment for congenital clubfoot. Clin Orthop Relat Res 467:1223–1230

14. Schuh R, Salzberger F, Wanivenhaus AH et al (2013) Kinematic changes in patients with double arthrodesis of the hindfoot for realignment of planovalgus deformity. J Orthop Res 31:517–524
15. Metaxiotis D, Accles W, Pappas A et al (2000) Dynamic pedobarography (DPB) in operative management of cavovarus foot deformity. Foot Ankle Int 21:935–947
16. Orlin MN, McPoil TG (2000) Plantar pressure assessment. Phys Ther 80:399–409
17. Schuh R, Hofstaetter JG, Hofstaetter SG et al (2011) Plantar pressure distribution after tibiotalar arthrodesis. Clin Biomech (Bristol, Avon) 26:620–625
18. Wainright WB, Spritzer CE, Lee JY et al (2012) The effect of modified Brostrom-Gould repair for lateral ankle instability on in vivo tibiotalar kinematics. Am J Sports Med 40:2099–2104
19. Wu WL, Su FC, Cheng YM, Huang PJ et al (2000) Gait analysis after ankle arthrodesis. Gait Posture 11:54–61
20. Kitaoka HB, Alexander IJ, Adelaar RS et al (1994) Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int 15:349–5320
21. Hillstrom HJ, Song J, Kraszewski AP et al (2013) Foot type biomechanics part 1: Structure and function of the asymptomatic foot. Gait Posture 37:445–451
22. Mootanah R, Song J, Lenhoff MW et al (2013) Foot Type Biomechanics Part 2: Are structure and anthropometrics related to function? Gait Posture 37:452–456
23. Hughes J, Clark P, Klenerman L (1990) The importance of the toes in walking. J Bone Joint Surg Br 72:245–251
24. Rammelt S, Grass R, Zawadski T et al (2004) Foot function after subtalar distraction bone-block arthrodesis. J Bone Joint Surg Br 86-B:659–668
25. Deland JT (2001) The adult acquired flatfoot and spring ligament complex. Pathology and implications for treatment. Foot Ankle Clin 6:129–135
26. Guyton GP, Jeng C, Krieger LE et al (2001) Flexor digitorum longus transfer and medial displacement calcaneal osteotomy for posterior tibial tendon dysfunction: a middle-term clinical follow-up. Foot Ankle Int 22:627–632
27. Myerson MS, Badekas A, Schon LC (2004) Treatment of stage II posterior tibial tendon deficiency with flexor digitorum longus tendon transfer and calcaneal osteotomy. Foot Ankle Int 25:445–450
28. Myerson MS, Corrigan J, Thompson F et al (1995) Tendon transfer combined with calcaneal osteotomy for treatment of posterior tibial tendon insufficiency: a radiological investigation. Foot Ankle Int 16:712–718
29. Niki H, Hirano T, Okada H et al (2012) Outcome of medial displacement calcaneal osteotomy for correction of adult-acquired flatfoot. Foot Ankle Int 33:940–946
30. Wacker JT, Hennessy MS, Saxby TS (2002) Calcaneal osteotomy and transfer of the tendon of flexor digitorum longus for stage-II dysfunction of tibialis posterior. Three- to five-year results. J Bone Joint Surg Br 84:54–58