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ORIGINAL ARTICLE

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Radiological evaluation of the longitudinal arch after posterior tibial tendon transfer

Avaliação radiológica do arco longitudinal após transferência do tendão tibial posterior

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ABSTRACT

Objectives: To evaluate radiographic findings of medial longitudinal arch decreases of the foot based on examinations performed before and after posterior tibial transfer surgery to treat motor deficits caused by complete lesions of the peroneal nerve.

Methods: A descriptive and analytical study was conducted based on information collected from medical records. Patients with at least two years of follow-up after surgery were included, and their radiographs were evaluated before and after the procedure. In the radiographs with the anteroposterior incidence of the foot, the talocalcaneal, talometatarsal and talonavicular congruence angles were evaluated. In the lateral view, the talocalcaneal, Meary's and calcaneal pitch angles were analyzed. Data were collected regarding patient profiles, trauma mechanisms and follow-up times.

Results: One patient had radiographic results suggestive of a decrease in the plantar arch after posterior tibial tendon transfer. Angular variation among the patients, which was within the normal range, was not significant.

Conclusions: No significant decreases in the longitudinal arch of the foot were observed in the studied patients.

Level of Evidence III; Retrospective Comparative Study.

Keywords: Flatfoot; Tendon transfer; Peroneal nerve.

RESUMO

Objetivos: Avaliar sinais radiográficos de diminuição do arco longitudinal medial do pé com base em exames realizados antes e depois da cirurgia de transferência do tibial posterior para tratar o deficit motor ocasionado pela lesão completa do nervo fibular.

Métodos: Estudo descritivo e analítico com base em informações colhidas em prontuários. Foram inclusos os pacientes com no mínimo dois anos de cirurgia e avaliadas as radiografias antes e depois do procedimento. Nas radiografias em incidência anteroposterior do pé foram avaliados os ângulos talocalcâneo, talometatarsal e a congruência talonavicular. Na incidência de perfil verificou-se os ângulos talocalcâneo, Meary e *pitch* do calcâneo. Foram colhidos dados referentes ao perfil do paciente, mecanismo de trauma e tempo de seguimento.

Resultados: Um paciente apresentou radiografia sugestiva de diminuição do arco plantar após a transferência do tibial posterior. A variação angular ocorrida nos pacientes ainda que dentro da normalidade não apresentou variação estatisticamente significante.

Conclusões: Não houve redução do arco longitudinal do pé de forma estatisticamente significante nos pacientes estudados.

Nível de Evidência III; Estudo Retrospectivo Comparativo.

Descritores: Pé plano; Transferência tendinosa; Nervo fibular.

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INTRODUCTION

Peroneal neuropathy is the most common mononeuropathy of the lower limbs and includes trauma as an etiology[1].

The deep portion of the peroneal nerve supplies the most powerful dorsiflexor of the foot: the tibialis anterior muscle[1-3].

Peroneal nerve injury can occur as a consequence of trauma or even in conditions such as abrupt weight loss (bariatric surgeries), compartment syndrome, and complications of surgical procedures in the spine and lower limbs[1,4].

Foot drop is a classic clinical condition. Patients present with motor deficits related to dorsiflexion of the ankle, the hallux (deficit of the deep peroneal nerve) and foot eversion (superficial peroneal nerve). A sensitive deficit can be observed in the dorsum of the foot and in the first interdigital space[1,3,5,6].

Treatment of peroneal nerve injury is directed toward the cause of the injury. In cases of nerve compression, decompression should be performed; for lacerations, surgical exploration and repair are warranted. The use of orthoses is a highly prescribed therapy, and posterior tibial tendon transfer is a well-known option[1,5,6].

The posterior tibial tendon is innervated by the tibialis and is responsible for supporting the longitudinal and transverse foot arches and for inversion movements (subtalar joint) and plantarflexion (talocrural joint)[2].

Posterior tibial tendon transfer can contribute to the genesis of flatfoot.

Currently, peroneal action without opposition from the tibialis posterior as the cause of flatfoot development remains controversial. One of the main studies supporting this imbalance theory as the primary cause of this deformity was performed by Mizel et al. Subsequently, two additional studies reported on patients submitted to posterior tibial tendon transfer for the treatment of secondary motor deficits and common peroneal neurological injury who developed flatfoot postoperatively[7-9].

This study aims to evaluate radiographic findings of medial longitudinal arch decreases of the foot in patients submitted to posterior tibial tendon transfer.

METHODS

This study was approved by the Research Ethics Committee and was registered in the Brazil Platform under the CAAE number 46115415.6.0000.5273. This is a descriptive, analytical study of patients with common peroneal neurological deficits submitted to surgery for tibialis posterior transfer to the foot dorsum[10].

From the surgery registry centers of our institution and the foot and ankle surgery group, patients who underwent a surgical procedure between February 2011 and July 2015 were selected.

The inclusion criteria were patients submitted to posterior tibial tendon transfer using the same surgical technique with at least two years of postoperative follow-up.

Patients without a complete peroneal neurological injury, those in whom another muscle group was used for transfer, and those with a history of other surgical procedures, previous deformities or stiffness in the investigated foot were excluded from the study.

Patients were contacted by telephone and were invited to attend a medical appointment. After signing an informed consent form, they were evaluated for radiographic features.

In addition to radiographic features, epidemiological data were also collected, which are shown in Table 1.

Surgeries were performed by foot and ankle orthopedic surgeons of the corresponding department. The surgical technique used was described in the book *Operative Techniques in Foot and Ankle Surgery* published in 2011 by Mark E. Easley. The technique consists of making an incision on the medial navicular bone, identifying and disengaging the tibialis posterior of the navicular bone, and suturing the stump with the technique described by Kenneth A. Krackow[11,12].

A second incision is made in the region corresponding to the myotendinous junction of the tibialis posterior in a more proximal and medial region of the leg, and the tendon is identified and transferred to this more proximal site. Laterally, proximal to the tibiofibular syndesmosis, a third incision is made; the interosseous membrane is identified, a window is created in the membrane, and the tendon is transferred from medial to lateral. Then, with the aid of radiography, the intermediate cuneiform bone is identified, and a final incision is performed over this bone. The tendon is transferred from the lateral region to the anterior region of the foot under the extensor retinaculum and is attached to the cuneiform with an interference screw[11,12].

Postoperative radiographic examinations were performed with and without load, and the angles were measured on the evaluation day and compared with the measurements obtained during the preoperative examination, which were available in the database or in a folder in the

Table 1. Sample data

Patient	Gender	Age (years)	Time: injury-surgery (months)	Delta surgery-evaluation (months)	Laterality	Etiology	Dominant limb
1	M	23	13	34	D	Cutting injury	D
2	M	17	8	37	D	Knee Sprain	D
3	F	53	96	30	D	Tibial Plateau Fracture	D
4	M	21	24	36	E	Acetabular Fracture	D
5	M	45	84	42	D	Acetabular Fracture-Dislocation	E
6	M	52	24	64	D	Spine Surgery	D
7	M	68	24	24	E	Proximal Fibula Osteosynthesis	D
8	M	43	50	41	D	Leg SGP	E
9	M	25	13	25	D	Knee Sprain	D
10	M	38	18	39	D	Knee Dislocation	E
11	M	34	24	48	D	Knee Dislocation	E
12	M	45	24	25	D	Tibial Plateau Fracture	D
13	M	20	15	24	D	Tibial Fracture	D
14	M	40	33	37	E	Acetabular Fracture	D
15	M	21	37	24	D	Distal Femur Fracture	D
16	F	22	14	28	D	Tibial Fracture	D
17	F	78	26	41	D	Postoperative THA	D
Mean (age): 37.94 years, Standard deviation (age): 17.78 years, Median (age): 38 years. Mean (injury-surgery time): 31 months, Mean (surgery-evaluation time): 35.24 months. Laterality: 82.35% Right Lower Limb, 17.65% Left Lower Limb.							

SGP: Shotgun projectile. THA: Total Hip Arthroplasty.

form of developed film. MDicom Viewer version 3.0.0® software was used to measure the angles on the radiographs. All exams were measured by the same orthopedic evaluator who is a member of the specialization program in foot and ankle surgery at the institution where the study was performed.

In the anteroposterior radiographic evaluation with load, the angles described in the following paragraphs were measured.

Talocalcaneal angle (Kite's angle): the normal value is 15 to 30 degrees, and values higher than 30 degrees are compatible with valgus hindfoot and consequently with a decrease of the longitudinal arch of the foot[5,6,13].

Talometatarsal axis: measured by drawing a line along the longitudinal axis of the talus and the first metatarsus, with a normal value between 0 and 15 degrees. Measurements greater than 15 degrees are compatible with flatfoot[5,13].

Angle of talonavicular (TN) joint congruence: normal values range from 1.8 to 19.3 degrees (men) and 6.7 to 21.7 degrees (women)[5, 13].

In the lateral view, we evaluated the angles described below.

Talocalcaneal axis (normal ranging from 25 to 50 degrees): values greater than 50 degrees are compatible with flatfoot[6,13-15].

Talometatarsal angle (-4 to +4 degrees): tends to present increased values in flatfoot[5, 13].

Calcaneal pitch (high sensitivity, positive and negative predictive values): varies from 20 to 30 degrees in a normal foot. Values below 20 degrees are attributed to flatfoot[5,13,16].

The descriptive analysis provided the data shown in the text and tables, which are expressed by the median and interquartile range (IQR)[17,18].

The inferential analysis was based on the Wilcoxon signed-rank test, which verified whether significant variation was present between pre- and postoperative findings[19].

A non-parametric test was applied because the incidence measurements did not present a Gaussian distribution as the normality hypothesis was rejected according to the Shapiro-Wilks test in at least one of the evaluation time points. The criterion adopted for determining significance was a 5% level. The statistical analysis was performed by SAS 6.11 software (SAS Institute, Inc., Cary, NC)[19, 20].

Due to the lack of a normal distribution of the measurements in at least one time point of the study, a non-parametric method (Wilcoxon test) was applied[18, 19].

RESULTS

A total of 18 patients were selected, but one was excluded due to transfer of the short peroneal tendon. Therefore, 17 patients were evaluated. No patient underwent nerve grafting or neurolysis prior to tendon transfer.

Most patients were male (14 patients) and the right lower limb was the most frequently affected extremity. The oldest patient (78 years old) was a woman, and the etiology of her neurological deficit was a sciatic nerve complication during a hip arthroplasty procedure.

The time between neurological injury and surgery ranged from 8 months to 8 years. The earliest postoperative evaluation was performed 2 years after surgery, and the latest evaluation was performed 5 years and 4 months after surgery.

Table 2 shows the descriptive statistics (the mean, standard deviation, median, interquartile range and minimum and maximum values) of the numerical variables in the total sample, and Table 3 shows the frequencies (n) and percentages (%) of the categorical variables.

The main etiology of the injury was trauma, which accounted for 82.35% of the cases (14 patients). The remaining cases were related to surgical complications (17.65%). When related to trauma, 50% of the cases involved knee injuries, including knee sprain (2 patients), knee dislocation (2 patients), tibial plateau fracture (2 patients) and distal femur fracture (1 patient). Acetabular fracture was the cause of injury in three patients, including one patient who experienced a cutting injury in the side of the leg with direct damage to the peroneal nerve, and another patient who sustained a shotgun injury in the proximal and lateral regions of the leg. In two patients, diaphyseal tibial fracture was the origin of the deficit.

In the non-trauma cases, one patient developed a neurological deficit following hip arthroplasty, one patient developed a deficit after fixation of the proximal fibula for a Maisonneuve fracture, and a third patient developed a deficit after arthrodesis of the L4-L5 and L5-S1 vertebrae.

Only one patient had a deficit attributed to occupational activity; a 25-year-old male pugilist sustained varus stress of the right leg during a fight and developed a deficit related to ankle dorsiflexion.

The radiographs in the Hospital system (software mDicom Viewer, version 3.0.0®) performed prior to surgery and those performed on the evaluation day were analyzed.

The talocalcaneal angle in the anteroposterior (AP) incidence was greater than 30 degrees in 5 patients after surgery, 3 of whom already had measurements suggestive of valgus hindfoot and compatible with flatfoot before the procedure. Regarding this parameter, 2 patients developed abnormal radiographic measurements after the procedure;

Table 2. Characterization of the sample: numerical variables

Variable	N	Mean	SD	Median	IQR	Minimum	Maximum
Age (years)	17	37.9	17.8	38	21.5 - 48.5	17	78
Injury-surgery interval (months)	17	31.0	24.5	24	14.5 - 35	8	96
Surgery-evaluation interval (months)	17	35.2	10.6	36	25 - 41	24	64

SD: standard deviation; IQR: interquartile range (Q1-Q3).

Table 3. Characterization of the sample: categorical variables

Variable	Category	N	%
Gender	Male	14	82.4
	Female	3	17.6
Laterality	Right	14	82.4
	Left	3	17.6
Dominant limb	Right	13	76.5
	Left	4	23.5
Suggestive of flatfoot postoperatively (radiographically)?	Yes	6*	35.3
	No	11	64.7

*These patients presented radiographic evidence suggestive of flatfoot before surgery.

in one patient, the measurement increased from 10 degrees before surgery to 32 degrees 3 years and 3 months after surgery. The other patient had a smaller change, with an increase from 25 degrees to 32 degrees after surgery. The latter patient already presented a reduced calcaneal pitch prior to the procedure.

The calcaneal pitch, measured in the lateral view, suggested a decrease in the longitudinal arch of the foot in 5 patients, all of whom already had abnormal measurements before surgery. However, 3 of these patients showed even smaller measurements postoperatively, including two patients who also showed a change in the AP talocalcaneal angle before and after the transfer.

All patients had normal talometatarsal (AP view), talonavicular congruence (AP view), talocalcaneal (lateral view) and Meary's (lateral view) angles.

Table 4 shows all measurements performed and highlights the two patients mentioned in the above paragraph.

After analyzing the tables created with these data, we verified that only 1 patient presented radiographical evidence suggestive of a decrease in the plantar arch after tibialis posterior transfer, which corresponds to 5.88% of the sample[20].

DISCUSSION

In the study of flatfoot pathophysiology, the theory of imbalance of the muscular forces is important. In the case of peroneal nerve injury, the foot is not subjected to the forces of its primary evertor (short peroneal muscle), and therefore, although the tibialis posterior fails to exercise its original role (primary foot invertor), the absence of force imbalances contributes to maintenance of the medial longitudinal arch. The same concept is also used to explain foot deformities in other conditions such as Charcot-Marie-Tooth disease (CMT)[21, 22].

Some authors have published reports of patients submitted to posterior tibial tendon transfer to the dorsum of the foot in the presence of peroneal nerve injury and have reported no postoperative flatfoot development.

Table 4. Radiographic measurements performed

Patient	Anteroposterior (AP) incidence						Lateral (L) incidence					
	Talocalcaneal		Talometatarsal		Tn congruence		Talocalcaneal		Meary's		Calcaneal pitch	
	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
1	17°	20°	2°	3º	6°	4º	44°	42º	5°	5º	20°	23º
2	13°	14°	12°	12°	8°	5°	44°	40º	6°	4°	*12°*	*18°*
3	**25°**	***32°***	15°	12°	14°	8°	30°	36°	2°	2°	***4°***	***8°***
4	14°	20°	14°	2°	15°	8°	44°	50°	13°	9°	20°	22º
5	*32°*	*33°*	14°	12°	4°	2°	37º	35°	4º	2,7°	*6º*	*4°*
6	18º	14°	10°	12°	5º	5°	25º	29°	3º	4°	22º	27º
7	*32°*	*33°*	7°	13°	13°	14°	48°	43°	3°	3,2°	*11°*	*7°*
8	15°	18°	19°	4°	6°	17°	43°	50°	8°	8°	27°	24°
9	21°	17°	10°	6°	13°	6,5°	35°	36°	3,2°	2°	*12°*	*8°*
10	**10°**	***32°***	15°	14°	4°	2°	43°	43°	3,4°	6°	**20º**	**21º**
11	15°	20°	12°	12°	9º	8°	26º	29°	1º	0º	30º	31º
12	14°	16º	14°	11º	9º	12º	40º	35°	3º	4º	22º	27º
13	30º	29º	3º	5º	3º	3º	43°	39º	8°	2°	20°	20º
14	*32°*	*33°*	10°	12°	10º	11º	33º	37º	3°	5º	31	34º
15	22º	25º	14°	12°	15°	10º	25º	31º	2°	1º	29º	31º
16	16º	16º	15°	15º	8°	6º	26º	28º	2°	3º	22º	25º
17	27º	25º	6º	8º	4°	5°	23º	25º	4º	4°	21º	24°
Preoperative - AP Angles (mean | median | SD): Talocalcaneal (20.8 | 18 | 7.5), Talometatarsal (11.29 | 12 | 4.59), TN Congruence (8.59 | 8 | 4.14)												
Preoperative - L Angles (mean | median | SD): Talocalcaneal (35.8 | 37 | 8.5), Meary's (4.29 | 3 | 3), Pitch (19.3 | 20 | 8).												
Postoperative - AP Angles (mean | median | SD): Talocalcaneal (23 | 20 | 7.3), Talometatarsal (9.71 | 12 | 4.12), TN Congruence (7.41 | 6 | 4.24)												
Postoperative - L Angles (mean | median | SD): Talocalcaneal (36.9 | 36 | 7.3), Meary's (3.8 | 4 | 2.32), Pitch (20.8 | 23 | 9.1)												

TN: talonavicular, PREOP: preoperative, POSTOP: postoperative.

Mizel et al. published a study after clinical (clinical inspection of the arch and podogram on the Harris mat) and radiographic evaluations of patients submitted to posterior tibial tendon transfer to the dorsum of the foot. Similar to our study, their study included mostly men (60%), right-handed people, and trauma-related causes of injury (80%). In this study, however, the patients were evaluated after a much longer period of exposure to potential deforming forces (74.9 months). Our study period was adequate considering that the time between recognition of posterior tibial deficiency and collapse in a valgus flatfoot is 4 months. None of the patients in the study by Mizel et al. developed flatfoot postoperatively[7].

Yeap, Birch and Singh (2001) and Steinau et al. (2011) clinically evaluated (inspection and podogram) patients with at least 2 years of follow-up after tibialis posterior transfer to the dorsum of the foot and found no progression to flattening of the longitudinal arch of the foot[23,24].

Another important study was published in February 2017 in which 17 patients with a minimum of 3 years of follow-up after tibialis posterior transfer to the dorsum of the foot were retrospectively evaluated, and no loss of the longitudinal arch was observed radiographically or clinically[25].

Male gender, predominance of trauma-related causes, age between the 3rd and 4th decades of life and lack of plantar arch collapse represent important similarities between the studies cited and ours[7,23-25].

Despite the consistent results presented in the studies cited above, some authors have reported flatfoot development after tibialis posterior transfer to the dorsum in cases of peroneal neurological lesions.

In 2008, for example, a 51-year-old patient with a history of neurological deficit after Guillain-Barré syndrome and development of a painful flatfoot 30 years after transfer surgery was reported. The authors implicated the action of the triceps surae in hindfoot eversion during the stage of calcaneal detachment, at which point the tibialis posterior would normally produce inversion. They also implicated tibialis posterior failure in its arch support function to a lesser extent[9].

In 2002, Vertullo and Nunley published a report of a 46-year-old patient with common peroneal nerve injury who developed clinical and radiographic features of a decreased plantar arch 5 months after tendon transfer surgery[8].

Deland et al. demonstrated in cadavers that deformity of the plantar arch in tibialis posterior dysfunction only occurred with relevant ligament injuries. They emphasized that other arch support structures must be lost to cause development of the deformity. Furthermore, they described the genesis of abnormal resulting forces acting on congenital flatfeet and contributing to posterior tibial deficiency[26].

Although muscular imbalance plays an important role in the genesis of an acquired flatfoot and is a factor in the loss of the longitudinal arch of the foot, through analyzing the studies and theories presented above, we believe that the reason that our patients did not develop flatfoot after posterior tibial tendon transfer surgery was not exclusively related to muscle imbalance. Although the studies reporting arch collapse after transfer surgery are essentially case reports, the multifactorial etiology is rather clear to us. We must consider aspects such as the integrity of the ligament structures, changes in the lower limbs axis, changes resulting from forces in the foot and aspects inherent to the type of gait, such as the force of reaction to the ground, in addition to muscular imbalance.

CONCLUSION

We found no radiographic evidence of a decrease in the longitudinal arch of the foot in the evaluated patients.

Authors' Contribution: Each author made significant individual contributions to this manuscript: TASN (https://orcid.org/0000-0001-7988-6307)* has conceived and planned the activities that led to the study and has approved the final version; BLA (https://orcid.org/0000-0001-7264-3206)* has conceived and planned the activities that led to the study, participated in the review process and has approved the final version; GOG (https://orcid.org/0000-0002-1771-2819)* has participated in the review process, has written the article and has approved the final version; ATOC (https://orcid.org/0000-0002-1643-5629)* has participated in the review process and has approved the final version; IMC (https://orcid.org/0000-0002-7815-6086)* has conceived and planned the activities that led to the study, interpreted the study results, participated in the review process, has approved the final version; LMM (https://orcid.org/0000-0002-6324-1851)* has approved the final version. *ORCID (Open Researcher and Contributor ID).

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