Original Article

How to classify plantar plate injuries: parameters from history and physical examination ☆

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ABSTRACT

Objective: To find the best clinical parameters for defining and classifying the degree of plantar plate injuries.

Method: Sixty-eight patients (100 metatarsophalangeal joints) were classified in accordance with the Arthroscopic Anatomical Classification for plantar plate injuries and were divided into five groups (0 to IV). Their medical files were reviewed and the incidence of each parameter for the respective group was correlated. These parameters were: use of high heels, sports, acute pain, local edema, Mulder's sign, widening of the interdigital space, pain in the head of the corresponding metatarsal, touching the ground, "drawer test", toe grip and toe deformities (in the sagittal, coronal and transversal planes).

Results: There were no statistically significant associations between the degree of injury and use of high-heel shoes, sports trauma, pain at the head of the metatarsal, Mulder's sign, deformity in pronation or displacement in the transversal and sagittal planes (although their combination, i.e. "cross toe", showed a statistically significant correlation). Positive correlations with the severity of the injuries were found in relation to initial acute pain, progressive widening of the interdigital space, loss of "touching the ground", positive results from the "drawer test" on the metatarsophalangeal joint, diminished grip strength and toe deformity in supination.

Conclusions: The "drawer test" was seen to be the more reliable and precise tool for classifying the degree of plantar plate injury, followed by "touching the ground" and rotational deformities. It is possible to improve the precision of the diagnosis and the predictions of the anatomical classification for plantar plate injuries through combining the clinical history and data from the physical examination.

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Como classificar as lesões da placa plantar: parâmetros de história e exame físico

R E S U M O

Palavras-chave:
Síndrome do dedo do pé em martelo
Deformidades adquiridas do pé
Articulação metatarsofalângica

Objetivo: Encontrar os melhores parâmetros clínicos para definir e classificar o grau das lesões da placa plantar.

Método: Foram classificados 68 pacientes (100 articulações metatarsofalângicas [MTF]) de acordo com a classificação anatômica artroscópica para lesão de placa plantar e divididos em cinco grupos (0 a IV). Seus registros médicos foram revisados e se correlacionou a incidência de cada parâmetro no respectivo grupo. Os parâmetros foram: uso de saltos altos, esportes, dor aguda, edema local, sinal de Mulder, alargamento do espaço interdigital, dor na cabeça do metatarso correspondente, toque ao solo, "teste da gaveta", preensão dos dedos e deformidades dos dedos (plano sagital, coronal e transversal).

Resultados: Não houve associação estatisticamente significativa entre o grau de lesão e o uso de sapatos de salto alto, trauma esportivo, dor de cabeça do metatarso, sinal de Mulder, deformidade em pronação, desvio no plano transversal e sagital (embora a sua combinação, o *crossover toe*, tenha mostrado correlação estatisticamente significativa). A correlação positiva com a severidade das lesões foi encontrada em: dor aguda no início, alargamento progressivo do espaço interdigital, perda de "toque ao solo"; positividade do "teste de gaveta" da MTF; diminuição da força de preensão e deformidade em supinação do dedo.

Conclusões: O "teste de gaveta" se apresenta como a ferramenta mais confiável e precisa para classificar o grau da lesão da placa plantar, seguido pelo "toque ao solo" e as deformidades rotacionais. É possível melhorar a precisão do diagnóstico, bem como a previsão da classificação anatômica de lesão da placa plantar, por meio da combinação de história clínica e de dados de exame físico.

Introduction

Instability of the metatarsophalangeal (MTP) joints of the smaller toes is a common clinical entity, but it is often not diagnosed in the consultation office. Several authors have stated that the plantar plate performs the main role in maintaining joint stability in the sagittal plane.[1–4] Insufficiency or tearing of the plantar plate tends to evolve with some degree of deformity, in association with a high possibility of signs and symptoms. The main complaints among these patients are pain in the forefoot and some degree of deformity.[1–5]

DuVries apud Smith and Coughlin[6] observed that the second MTP was the joint that most commonly presented subluxation in the forefoot. The deformity may present multiplanar variance, but more frequently consists of attenuation of the lateral collateral ligament in association with injury to the lateral portion of the plantar plate, thus causing dorsomedial subluxation or a crossover toe.[1,3,7,8]

Many authors over the last two decades have reported that insufficiency of the plantar plate is the primary pathological findings that lead to instability,[9–12] but it was only recently suggested that this structure should be the main focus in surgical treatment.[1,13,14] Coughlin et al.[10] described a study on cadavers affected by a crossed-over second toe. Dissection demonstrated anatomical alterations in the MTP joint and the presence of plantar plate injuries that formed a pattern. They reported that in this case series, all the 16 cadavers had a transversal lesion adjacent to the insertion of the

plantar plate, at the base of the proximal phalanx, which varied in length from 33% to 100% along the insertion area. Intrasubstantial lesions, lesions of the collateral ligaments and complete tears of the plantar plate were found in cases of deformities of greater severity. It was concluded that the plantar plate was the main element in deformities of the smaller toes. Since these authors were studying samples presenting crossover toe, which is known to be the advanced stage of the deformity, they did not mention the anatomy or other findings relating to the mild and moderate stages.

The clinical symptoms and physical findings among patients with plantar plate injuries to the MTP joints, along with the activities and habits associated with this condition, have been described by different authors, but controversy still surrounds the importance and significance of each of these factors. Thus, this has stimulated many researchers to study the physiopathology of this deformity, in an attempt to classify the lesions. Thompson and Hamilton[15] proposed a classification system based on the level of subluxation of the proximal phalanx during the "drawer test" (Fig. 1). This test was also used as one of the parameters in the clinical staging system for joint instability that was proposed by Coughlin et al.[1] (Table 1). This classification system also takes into consideration the parameters of pain in the MTP, alignment, toe grip and feelings of swelling in the forefoot.

The anatomical classification system for plantar plate injuries that was proposed previously grades lesions according to their location and severity.[1] It has been suggested by some authors that this classification has a correlation with clinical
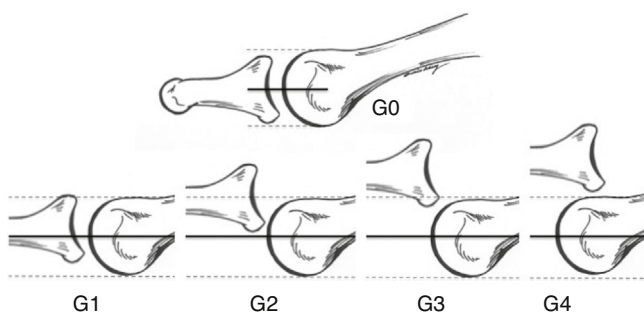
Fig. 1 – Hamilton–Thompson metatarsophalangeal "drawer test": G0, stable joint; G1, mild instability (subluxation < 50%); G2, moderate instability (subluxation > 50%); G3, severe instability (capacity for joint dislocation); G4, dislocated joint.

Table 2 – Clinical parameters used in this study.

Type	Parameter
History	Acute pain at outset of condition
	Sports-related trauma
	Use of high heels
	Feeling of local edema
Physical examination	Increase in space between toes
	Touching the ground
	Pain on plantar palpation of the corresponding metatarsal head
	Positive "drawer test"[a]
	Negative plantar grip[b]
	Mulder's sign
	Displacement of toe[c]

[a] Grading of Hamilton–Thompson test: G0 = stable joint; G1 = mild instability (subluxation < 50%); G2 = moderate instability (subluxation > 50%); G3 = severe instability (capacity for joint dislocation); G4 = dislocated joint.
[b] Bouche's plantar grip test: 0 = absent; 1 = diminished; 2 = normal.
[c] Displacement of toe according to the planes: axial (varus/valgus); frontal (supination/pronation); sagittal (dorsal/plantar); combined–crossover toe.

parameters. However, so far, no analytical statistical studies defining the relationship between each type of lesion and a specific clinical finding have been conducted.

The objective of this study was to determine clinical parameters of greater reliability for defining and grading plantar plate injuries. We hope that through a more accurate diagnosis, an algorithm encompassing treatment options for all the different degrees of plantar plate injuries to the MTP joints of the smaller toes can be established.

Material and method

Between January 2009 and January 2012, 82 patients presenting pain and some type of deformity and/or instability of the MTP joints were observed prospectively. In accordance with the inclusion and exclusion criteria, 14 patients were rejected for this study and 68 patients (100 MTP joints of the smaller toes) were included and treated. Of these, 49 (72%) were women and 19 were men (28%). Their mean age at the start of symptoms was 61 years (range: 40–78). The second MTP was the one most commonly affected, in 63 cases (63%), followed by the third in 34 cases (34%) and the fourth in three cases (3%).

The inclusion criteria used comprised pain in the adult forefoot, with or without deformities of the hallux or smaller toes, and with or without callosities. The exclusion criteria comprised presence of systemic comorbidities (especially diabetes mellitus and rheumatoid arthritis); previous surgical treatment on the foot or ankle; infectious or vascular diseases; and any other pathological condition of the foot or ankle that might cause misalignment or painful conditions in the forefoot.

The project for this study was sent to the local research ethics committee and was approved. All the patients involved gave their agreement to the free and informed consent statement of this study.

Before the surgical treatment, all the patients underwent assessment of their clinical history and complete physical examinations. Based on previous reports of common symptoms and the main differential diagnoses for plantar plate injuries, some parameters were selected for analysis (Table 2). These were the parameters that were most popular and had been most frequently mentioned by authors in the literature on this topic.[1,4–6,8,10,16]

Data on the following parameters were gathered:

Plantar grip: The patient's toe grip was evaluated in a test using a strip of paper, described as a "paper withdrawal test".[9,11] With the patient standing, a narrow strip of paper of 1 cm in width by 8 cm in length was placed under the toe that was to be tested, and the patient was then asked to grip the

Table 1 – Clinical staging system for instability of the MTP joints.

Grade 0 – MTP aligned; prodromic stage with pain, but no deformity	Joint pain in MTP; thickening or edema of the MTP joint; diminished plantar grip; negative drawer test
Grade I – mild MTP joint displacement; widening of space between toes, medial displacement	Pain in the MTP joints; joint swelling; diminished plantar grip; mildly positive "drawer test" (subluxation < 50%)
Grade II – moderate displacement; medial, lateral, dorsal or dorsomedial deformity; hyperextension of toe	Joint pain; not much edema; negative plantar grip; moderately positive "drawer test" (subluxation > 50%)
Grade III – severe displacement; dorsal or dorsomedial deformity; second toe may overlap on hallux; flexible toe clawing may be present	Pain in joints and feet; not much swelling; negative plantar grip; very positive drawer (MTP joints dislocated); flexible toe clawing
Grade IV – dorsomedial or dorsal displacement; severe deformity with dislocation; fixed toe clawing	Pain in joints and feet; little or no swelling; negative plantar grip; MTP joint dislocated; fixed toe clawing

paper strip on the ground and try to stop the examiner from pulling it away. When the patient was able to keep the paper strip under his toe, the test was considered positive. When the patient only partially resisted this force, the grip was considered to be diminished. When no grip force was applied and the paper was easily withdrawn, the test was considered to be negative. In the present study, all the "diminished" and "negative" results were grouped as "negative plantar grip".

Joint stability: The stability of the MTP joints was determined by means of the "drawer test". With the MTP under evaluation extended at 25°, a vertical force movement was applied. The results were classified in accordance with the clinical staging system, using a scale from 0 to 4: 0 = stable joint; 1 = mild instability (subluxation < 50% of the joint surface); 2 = moderate instability (subluxation > 50% of the joint surface); 3 = severe instability (joint with capacity for dislocation); 4 = dislocated joint.[9]

"Touching the ground" test: With the patient in an upright standing position, the situation in which the toe touched the ground in a normal manner (i.e. causing a rounded toeprint through contact between the tip of the toe and the ground) was considered to be positive.

After all the positive physical findings had been documented, imaging studies were performed on all the patients, including radiography and magnetic resonance imaging. In this manner, it was possible to determine the degree of deformity and infer the type of injury to the plantar plate in the MTP joints.

The arthroscopic procedure on the MTP was done as the first stage of the operation selected for each patient, and never as a separate procedure. The MTP joint was accessed using a 2.7 mm arthroscope inclined at 30°, through two dorsal portals (medial and lateral) above the joint space. With slight traction on the toe, the central and distal portions of the plantar plate could be viewed, inspected and then palpated using a probe. Synovectomy was performed on the joint affected and, following this, the plantar plate injury was graded. The findings from the physical examination and the radiological and magnetic resonance images were then correlated with the arthroscopic findings (which were used as the gold standard), in order to definitively determine the type of plantar plate injury in our patients. Systemic analysis on these arthroscopic discoveries provided us with important information that allowed us to put forward a suggestion for an anatomical classification system (Table 3). The results from treating these patients will be the subject of another article, in which the surgical treatment performed on the different plantar plate injuries will be explained.

For the first time in the literature, positive clinical data from patients' histories and physical examinations were correlated in this study with arthroscopic findings from the MTP joints. Data gathered prospectively were subjected to statistical analysis in order to determine whether there was any significance in correlations between the preoperative findings and the anatomical grades of the plantar plate injuries.

We divided the variables according to the groups studied (grades of the plantar plate injuries), in order to produce descriptive statistics: mean, standard deviation (SD), median, minimum and maximum numerical variables and relative and absolute frequencies (%), for the categorical variables.

Table 3 – Anatomical grading of plantar plate injuries.

Grade	Injury patterns
0	Attenuation and/or capsular discoloration of the plantar plate
1	Distal transverse lesion (adjacent to insertion); proximal phalanx (<50%); medial/lateral/central area and/or intrasubstantial lesion (<50%)
2	Distal transverse lesion (>50%); medial/lateral/central area and/or intrasubstantial lesion (>50%)
3	Transverse lesion and/or extensive longitudinal lesion (may involve collateral ligaments)
4	Extensive lesion in "buttonhole" shape (displacement); combination of transverse and longitudinal plate injuries

To compare pairs of groups independently, the t test and the nonparametric Mann–Whitney U test were applied. To compare three or more independent groups, analysis of variance (ANOVA) was used with a fixed group factor, complemented with Bonferroni multiple-comparison test; and also the nonparametric Kruskal–Wallis test, complemented with the Dunn multiple-comparison test, if statistically significant p values were found. Associations between the groups studied and the categorical variables were analyzed using Pearson's chi-square test or the likelihood ratio chi-square test.

The analyses on all the statistical data were performed using SPSS for Windows, version 18.0. We used the significance level of 5%, and p values below this level were considered to be statistically significant and were identified with an asterisk (*).

Results

More than two thirds of the patients presented a history of acute pain in the MTP joints of the smaller toes (Table 4). There was a statistically significant association between the grade of the plantar plate injury and this symptom ($p = 0.0005$). We found a positive correlation between the grade of the plantar plate injury and the presence of acute pain, with the exception of grade IV, in which the percentage of patients with pain in this joint became drastically reduced.

Trauma associated with sports activity did not seem to play any important role in the genesis of the plantar plate injuries in our sample, and there was no statistically significant difference between the groups studied, in relation to this parameter ($p = 0.4546$). Likewise, a subjective feeling of edema was reported by some patients, without predominance of any group ($p = 0.0927$).

A high percentage of the patients (68%) correlated their plantar plate injuries with use of high-heeled shoes. Although 83% of the individuals with grade I injuries made such reports, there was no statistical significance in relation to the types of plantar plate injury ($p = 0.2910$).

In the physical examination (Table 5), one of the commonest signs of joint instability in the MTP of the smaller toes caused by insufficiency of the plantar plate was progressive widening of the space between the toes ("open toes"). To evaluate this clinical observation, we took into consideration

Table 4 – Clinical history parameters according to injury grades.

History	Grade (plantar plate injury)					Total (n = 100)
	0 (n = 23)	I (n = 12)	II (n = 15)	III (n = 33)	IV (n = 17)	
Acute pain – n (%)						
No	10 (43.5%)	4 (33.3%)	3 (20.0%)	3 (9.1%)	11 (64.7%)	31 (31.0%)
Yes	13 (56.5%)	8 (66.7%)	12 (80.0%)	30 (90.9%)	6 (35.3%)	69 (69.0%)
p	0.0005					
Trauma from sports – n (%)						
No	18 (78.3%)	10 (83.3%)	11 (73.3%)	29 (87.9%)	16 (94.1%)	84 (84.0%)
Yes	5 (21.7%)	2 (16.7%)	4 (26.7%)	4 (12.1%)	1 (5.9%)	16 (16.0%)
p	0.4546					
Use of high heels – n (%)						
No	9 (39.1%)	2 (16.7%)	7 (46.7%)	11 (33.3%)	9 (52.9%)	38 (38.0%)
Yes	14 (60.9%)	10 (83.3%)	8 (53.3%)	22 (66.7%)	8 (47.1%)	62 (62.0%)
p	0.2910					
Local edema – n (%)						
No	18 (78.3%)	5 (41.7%)	9 (60.0%)	17 (51.5%)	13 (76.5%)	62 (62.0%)
Yes	5 (21.7%)	7 (58.3%)	6 (40.0%)	16 (48.5%)	4 (23.5%)	38 (38.0%)
p	0.0927					

both the patients' impressions and the physician's objective confirmation that there really was a greater distance between the toes, when the patient was standing. Among the patients of this cohort, 77% presented this characteristic. There was a significant difference in the incidence of this characteristic between the injury grades, such that open toes clearly predominated at the more advanced stages of the injury (p = 0.0127).

Incapacity of the toes to touch the ground in a normal manner when the patient is standing up (touching the ground) is an important physical finding among patients with plantar plate injuries. At the early stages, almost half of

Table 5 – Physical examination parameters according to anatomical grade of plantar plate injuries.

| Physical examination parameters	Grade (Plantar plate injury)					Total (n = 100)
	0 (n = 23)	I (n = 12)	II (n = 15)	III (n = 33)	IV (n = 17)	
Separation of toes						
Absent	8 (34.8%)	5 (41.7%)	3 (20.0%)	7 (22.2%)	0 (0%)	23 (23.0%)
Present	15 (65.2%)	7 (58.3%)	12 (80.0%)	26 (78.8%)	17 (100%)	77 (77.0%)
p			0.0127			
Touching the ground – n (%)						
Negative	9 (39.1%)	6 (50.0%)	14 (93.3%)	32 (97.0%)	16 (94.1%)	77 (77.0%)
Positive	14 (60.9%)	6 (50.0%)	1 (6.7%)	1 (3.0%)	1 (5.9%)	23 (23.0%)
p			<0.0001			
Pain under metatarsal head – n (%)						
Absent	1 (4.3%)	2 (16.7%)	0 (0%)	3 (9.1%)	0 (0%)	6 (6.0%)
Present	22 (95.7%)	10 (83.3%)	15 (100%)	30 (90.9%)	17 (100%)	94 (94.0%)
p			0.1814			
"Drawer test" – n (%)						
I	23 (100%)	11 (71.6%)	49 (60.0%)	15 (35.4%)	0 (0%)	58 (58.0%)
II	0 (0%)	1 (8.3%)	6 (40.0%)	14 (42.4%)	6 (35.3%)	27 (27.0%)
III	0 (0%)	0 (0%)	0 (0%)	4 (12.1%)	5 (29.4%)	9 (9.0%)
IV	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (35.3%)	6 (6.0%)
p			<0.0001			
Plantar grip – n (%)						
Absent	10 (43.5%)	10 (83.3%)	14 (93.3%)	32 (97.0%)	15 (88.2%)	81 (81.0%)
Diminished	11 (47.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	11 (11.0%)
Normal	2 (8.7%)	2 (16.7%)	1 (6.7%)	1 (3.0%)	2 (11.8%)	8 (8.0%)
p			<0.0001			
Mulder's sign – n (%)						
Present	5 (21.7%)	3 (25.0%)	4 (26.7%)	9 (27.3%)	5 (29.4%)	26 (26.0%)
Absent	18 (78.3%)	9 (75.0%)	11 (73.3%)	24 (72.7%)	12 (70.6%)	74 (74.0%)
p			0.9854			
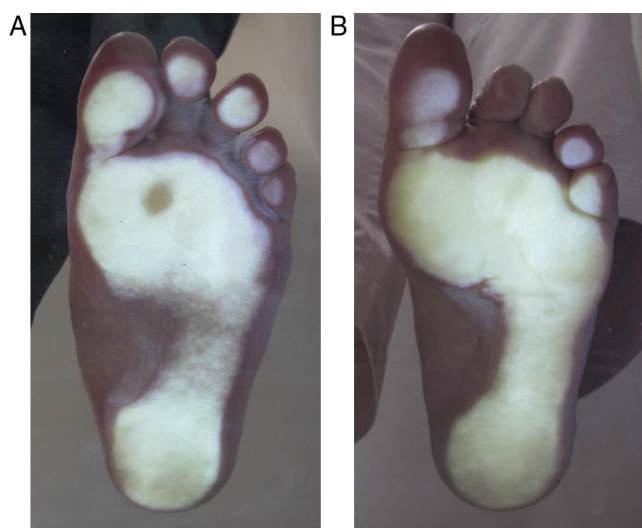
Fig. 2 – Podoscopic views of two patients who were included in our study. A, touching the ground with all the smaller toes; B, second and third toes negative for touching the ground.

Fig. 3 – Plantar grip of the toes.

the toes examined presented this finding, but this percentage increased with increasing grade of plantar plate injury ($p < 0.0001$). More than two-thirds of the joints included in this study presented this characteristic, which was determined through direct viewing of podoscopic images (Fig. 2).

One of the physical findings most correlated with plantar plate injuries was pain on plantar palpation of the head of the metatarsal affected. No difference was shown between the injury groups ($p = 0.1814$), but 94% of the joints included in this study presented this symptom. The "drawer test" on the MTP joint showed a clear and significant difference between the types of plantar plate injury ($p < 0.0001$).

The scale from 0 to 4 that was used to classify the "drawer test" on the MTP presented a positive correlation with increasing grades of plantar plate injury, which was translated as a progressive increase in the degree of dislocation as the plantar plate injury worsened. All the joints included in our study presented some degree of instability, as measured using this test, and 15% were classified as instability of grade III or IV (capable of dislocation or dislocated, respectively), on the scale of Thompson and Hamilton).

Another important observation in the physical examination was the plantar grip test on the toes, also known as the "paper-pulling test", as described by Bouche and Heit[15] (Fig. 3). We found that there were statistically significant differences between the grades of plantar plate injury, with a clear reduction in toe strength as the lesion worsened ($p < 0.0001$). Among all of our patients, 92% If the joints studied presented this finding. Mulder's sign, which is used in the differential diagnosis for Morton's neuroma, was observed in a small percentage of the cases of our cohort. No statistical difference was found between the different grades of plantar plate injuries and this finding ($p = 0.9854$).

Table 6 presents the results from the statistical analysis on the toe displacements in three different anatomical planes. To evaluate these physical examination parameters, the imaginary long axis of the toes was used in comparison with the imaginary long axis of the metatarsal (by means of an articulated goniometer), using the classical manner of measuring angles within clinical orthopedics, both axially (varus/valgus) and sagittally (dorsal/plantar). To evaluate the displacements in the frontal plane (supination/pronation) the level and inclination of the nail was used, with the patient standing (Fig. 4).

Displacement of the toes in the axial plane was found to be very common (84%), but the relationship with the grade of the plantar plate injury showed low statistical significance ($p = 0.0459$), without clear differentiation between the groups (Table 6).

In the sagittal plane, 93% of the MTP joints studied presented dorsal elevation, but with low statistical correlation ($p = 0.0352$) for the different groups. It was impossible to define any clear difference between them.

The combination of axial and sagittal displacements defined situations of crossover toe. Through using this definition, it was found that 77% of the cases in our cohort had this deformity (Fig. 4). A statistically significant correlation was found between higher grades of plantar plate injury and greater magnitude of deformity ($p = 0.0004$).

Deformities of the smaller toes	Grade (Plantar plate injury)					Total (n = 100)
	0 (n = 23)	I (n = 12)	II (n = 15)	III (n = 33)	IV (n = 17)	
Varus/Valgus – n (%)						
Absent	8 (34.8%)	2 (16.7%)	3 (20.0%)	2 (6.1%)	1 (5.9%)	16 (16.0%)
Present	15 (65.2%)	10 (83.3%)	12 (80.0%)	31 (93.9%)	16 (94.1%)	84 (84.0%)
p				0.0459		
Dorsal elevation – n (%)						
Absent	5 (21.7%)	0 (0%)	1 (6.7%)	1 (3.0%)	0 (0%)	7 (7.0%)
Present	18 (78.3%)	12 (100%)	14 (93.3%)	32 (97.0%)	17 (100%)	93 (93.0%)
p				0.0352		
Crossover toe – n (%)						
Absent	13 (56.5%)	2 (16.7%)	4 (26.7%)	3 (9.1%)	1 (5.9%)	23 (23.0%)
Present	10 (43.5%)	10 (83.3%)	11 (73.3%)	30 (90.9%)	16 (94.1%)	77 (77.0%)
p				0.0004		
Pronation – n (%)						
Absent	23 (100%)	12 (100%)	15 (100%)	29 (87.9%)	17 (100%)	96 (96.0%)
Present	0 (0%)	0 (0%)	0 (0%)	4 (12.1%)	0 (0%)	4 (4.0%)
p				0.0560		
Supination – n (%)						
Absent	23 (100%)	12 (100%)	11 (73.3%)	21 (63.6%)	4 (23.5%)	71 (71.0%)
Present	0 (0%)	0 (0%)	4 (26.7%)	12 (36.4%)	13 (76.5%)	29 (29.0%)
p				<0.0001		

Table 6 – Deformities of the smaller toes.

Pronation of the toe was shown to be a rare deformity (4%), without any difference between the classes of plate injury. On the other hand, supination seemed to be an important finding in groups II, III and IV with plantar plate injuries, in accordance with the tendency for worsening of the deformities ($p < 0.0001$).

Discussion

Chronic instability of the smaller MTP joints presents an insidious onset of pain.[6] This instability encompasses a wide spectrum of signs and symptoms, composed of synovitis, toe displacement, subluxation and, subsequently dislocation. In the initial phases, making a diagnosis of insufficiency of the plantar plate may be difficult, because the symptoms mimic

Fig. 4 – Different degrees of deformity of crossover toe.

other common pathological conditions, such as interdigital neuroma or metatarsalgia.[1,11,17]

However, early diagnosis of this injury provides better results. Klein et al.[4] recently reported on the parameters presented in patients' histories and physical examinations that had greatest specificity and sensitivity and compared these parameters with the intraoperative findings.[18]

In the present study, all the patients evaluated presented some type of injury to the plantar plate. However, there have been no reports of patients with lesions of grade 0 or with attenuated plantar plates. Nor have there been any descriptions of the characteristics of plantar plate injuries from observations during intraoperative evaluations.

Coughlin et al.[1] proposed a clinical staging system for instability of the second MTP joint and suggested that there might be a direct correction with the anatomical classification system. Although their suggestion was based only on observations, without statistical analysis, we came a similar conclusion in the present study: patients with injuries of grades II and III were the ones who most commonly presented pain, which indicates that there was a clear worsening of the clinical condition with progression of the plantar plate injury. The number of patients with grade IV injuries who presented conditions of acute pain was substantially smaller than the numbers in the other groups. We interpret this finding as the result of complete tearing of the adjacent soft tissues, including the local sensory nerve fibers, in the final stages of the plantar plate injury.

To our knowledge, the present study is the first to report a correlation between clinical data and the anatomical findings from plantar plate injuries, taking into consideration the different grades of injury. The data from this study support previous reports from other authors: insufficiency of the plantar plate usually begins with plantar pain in association with deformity and slight instability. With progression of the

Parameter	Incidence %	Grade (Plantar plate injury)					Statistical significance
		0	I	II	III	IV	
"Drawer test"	100	1	1	2	2/3	3/4	High
Pain in metatarsal head	94	–	–	–	–	–	Non-significant
Dorsal elevation of toe	93	√	–	–	–	–	Low
Plantar grip	92	√	–	–	–	–	High
Varus/valgus	84	√	√	√	√	√	Low
Widening of space	77	–	–	√	√	√	Low
Touching the ground	77	–	–	√	√	√	High
Crossover	77	–	–	–	√	√	High
Acute pain	69			√	√		High
High-heeled shoes	62	–	–	–	–	–	Non-significant
Local edema	38	–	–	–	–	–	Non-significant
Supination of toe	29	–	–	√	√	√	High
Mulder's sign	26	–	–	–	–	–	Non-significant
Sports trauma	16	–	–	–	–	–	Non-significant

Table 7 – Summary of the statistically significant results relating to each parameter studied.

anatomical injury, the findings from the physical examination also seem to worsen.[3,14,18,19]

Based on the statistical analysis presented here, we were able to evaluate each parameter studied in accordance with its importance, incidence and statistical significance (Table 7). The physical characteristic of greatest importance in our study was the "drawer test" on the MTP joints. This test was done on all the joints with plantar plate injuries, with a direct correlation between the magnitude of the instability and the grade of the plantar plate injury, which was determined through high statistical significance. This test was the most reliable and precise tool for classifying and grading plantar plate injuries before the surgery.

After the "drawer test", the next commonest finding was "pain below the metatarsal head". This symptom was very common in our sample (94%), but it did not have the capacity to differentiate between the groups.

Deformity consisting of dorsal elevation of the toe affected was an important clinical finding (93%) and it correlated with all grades of plantar plate injury, although it was somewhat less frequent in grade 0 (attenuation). The degree of dorsal elevation of the toe increased with worsening of the plantar plate injury, such that this might even be a way of grading the severity of the injury.

Absence or diminution of the plantar grip capacity of the toe was observed in 92% of our cases. Except for the low percentage decrease in grip strength among the patients with grade 0 injuries (48%), this parameter was not useful for differentiating between other types of plantar plate injury. Nevertheless, it was a valuable tool for verifying the treatment.

Varus/valgus displacement was found in 84% of the toes in our cohort. It was less frequent in the cases of grade 0 deformity and its incidence was seen to increase with increasing severity of the plantar plate injury. This displacement may be useful for differentiating between the grades of plantar plate injury.

Expansion of the space between the toes, toes that would not touch the ground when the patient was standing up and crossover toes (deformity in the sagittal and axial planes) appeared in 77% of the MTP joints in this study, and their incidence increased with progression of the injury. Widening of the space between the toes was seen more frequently in the groups with injuries of grades II, II and IV. Incapacity of toes to touch the ground showed a clear correlation with progression of the plantar plate injuries, and crossover deformities were commonest in grades III and IV. All of these three parameters can be used as tools for differentiating between the grades of plantar plate injuries. Acute pain at the outset of the symptoms appeared in 69% of our population, but was concentrated mainly in grades II and III. Use of high-heeled shoes was reported by 62% of our sample and there was no correlation with the different groups.

Rotational deformity of the toe in supination occurred in only 29% of the toes evaluated in this study, but there was a clear correlation between this observation and worsening of the plantar plate injuries.

Based on the lack of statistical significance and low incidence of local edema (38%), Mulder's sign (26%) and histories of sports trauma (16%) in our sample, we considered these parameters to be of lesser importance for diagnosing and differentiating plantar plate injuries.

Conclusions

It is possible to improve the precision of the diagnosis and the prediction of the anatomical grade of plantar plate injuries, through combining the clinical history and the data from the physical examination.

Based on our results, the precise clinical description of a plantar plate injury to a MTP joint should include a complaint of pain below the head of the metatarsal affected, in association with varying degrees of dorsal elevation and varus displacement of the corresponding toe, also combined with expansion of the space between the toes. More than half of our patients recalled an episode of acute pain at the outset of their symptoms, possible associated with using high-heeled shoes.

The "drawer test" on the MTP joint detected a progressive degree of joint instability that was clearly correlated with the