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Objectification of indications for surgical restoration of the plantar plate in the treatment of multiplanar static foot deformities accompanied by hammertoe deformity of the lesser toes using ultrasound

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Introduction Progressive multiplanar static deformity of the forefoot can result in hallux valgus, metatarsus primus varus, transverse flat foot and associated overload of the metatarsophalangeal joints (MTPJ) with plantar plate degeneration and rupture of MPT joints of the lesser toes leading to hammertoe deformity. Diagnostic ultrasound in the identification of plantar plate tears is easy to use at any medical center of the Russian Federation with orthopaedic services and provide a relatively inexpensive option compared with other advanced imaging modalities. **The goal** was to present ultrasound technology for accurate evaluation of the severity of plantar plate injury which may provide guidance for surgical treatment of hammertoe deformity of the lesser toes in patients with multiplanar static forefoot deformity. **Material and methods** The study recruited 88 participants with multiplanar static deformity of the forefoot, who underwent ultrasound evaluation according to the original method (RF Patent No. 2699383 "Method for determining the type of degenerative rupture of the plantar plate of the metatarsophalangeal joint due to overload metatarsalgia") to objectify the results of a physical examination with the Hamilton-Thompson test performed for identifying the degree of instability of the MTPJ, and nonparametric analysis was produced with Pearson's Chi-square test. **Results** Evaluation of the severity of plantar plate injury in the study group of patients (n = 88) with the Hamilton-Thompson test and ultrasound imaging showed diagnostic error in 22.8 % of cases with the use of clinical methods that allowed reasonable reduction of surgical intervention in 2.3 % and substantial correction of the treatment approaches in 20.5 % preventing a complete plantar plate tear. **Discussion** The ultrasound scanning introduced in the algorithm for diagnosing the degree of plantar plate rupture facilitated an objective approach to the choice of the most appropriate treatment strategy for complicated multiplanar forefoot deformities accompanied by a non-rigid hammertoe deformity of lesser toes. **Conclusion** Preoperative ultrasound imaging of the plantar surface of the foot for detecting the severity of plantar plate injury should be included in the diagnostic algorithm for patients with complicated multiplanar forefoot deformities accompanied by a non-rigid hammertoe deformity of lesser toes.

Keywords: hallux valgus, non-rigid hammertoe deformity of lesser toes, plantar plate, Hamilton-Thompson test, ultrasonography

Progressive multiplanar static deformity of the forefoot can result in hallux valgus, metatarsus primus varus, transverse flat foot and associated overload of the metatarsophalangeal joints (MTPJ) [1–6] with plantar plate degeneration and rupture of MPTJs of the lesser (the second, third or fourth) toes leading to hammertoe deformity with subluxed and/or dislocated toe, dislocation of the flexor tendons, maltraction of the vermiform muscles, hyperextended toe) [7]. Distal scarf [1, 8–11], chevron [9, 12–14], MICA [15–17] osteotomies of the first metatarsal bone have been commonly used since the second half of the XXth and the beginning of the XXIst century to correct hallux valgus and metatarsus primus varus with the osteotomy produced at the apex of the deformity reducing the first-second metatarsal angle with less complication and recurrence rates. The extent of the plantar plate injury and other MPTJ stabilizers can often be disregarded with the approaches developed to address non-rigid hammertoe deformity of lesser toes which leads to the use of unreasoned surgical interventions including the plantar plate plasty [3, 7, 18–20]. The recurrence of hammertoe deformity of the lesser toes, the floating toe syndrome, rigid hammertoe deformity are reported to occur in 20–54 % of cases [6, 12, 21–24]. Failures in the surgical treatment of hammertoe deformity can be caused by subjective/inaccurate methods of diagnosing a plantar plate injury [2]. The degree of instability of the MTPJ was described and graded by Thompson and Hamilton. The Hamilton-Thompson metatarsophalangeal "drawer" test can identify stability of the MPTJ joint in 93 % and assess pain in 94 % of cases and fails to accurately diagnose a plantar plate tear [2, 12, 21]. Magnetic resonance imaging (MRI) [25, 26] of the forefoot as a well-recognized and accepted diagnostic tool may also be useful to identify a plantar plate tear but the imaging technique is expensive and can be unavailable in most medical institutions in Russia, and interpreting an MRI scan can be technically demanding. The ultrasonic imaging as relatively inexpensive and widely available method may also be useful to identify plantar plate tear. Ultrasound is an efficient choice in the identification of plantar plate tears. The use of diagnostic ultrasound in the detection of plantar plate tears is important for surgical criteria as the reference test.

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The goal was to present ultrasound technology for accurate evaluation of the severity of plantar plate tears which may provide guidance for surgical treatment of hammertoe deformity of the lesser toes in patients with multiplanar static forefoot deformity.

MATERIAL AND METHODS

A study recruited 88 patients who received treatment at the orthopedic and trauma department of the City Clinical Hospital № 3, Krasnodar, and at the orthopedic department of the multidisciplinary medical center "In Good Hands", Krasnodar, between 2014 and 2019. The inclusion criteria were radiologically verified static multiplanar deformity of the forefoot (hallux valgus, metatarsus primus varus, transverse flat foot) and clinical signs of MTPJ instability in lesser toes including instability of the MTPJ without evident hammertoe deformity of the second or the second and the third toes (n = 4), subluxed and/or dislocated toe, dislocated flexor tendons, hyperextended toe (n = 78), rigid hammertoe/claw deformity (n = 6). To objectify the extent of plantar plate tear, we compared the results of a clinical examination using the Hamilton-Thompson test to measure the degree of instability with ultrasound findings of 88 patients presented with static multiplanar foot deformity using the grading system: G0, stable MTPJ; G1, unstable MTPJ; G2, subluxed MTPJ; G3, completely dislocated MTPJ; G4, rigid hammertoe deformity of lesser toes [1, 22].

The Hamilton-Thompson MTP drawer test was performed with the head and neck of metatasral bone fixed by one hand. The examiner attempted to dislocate the proximal phalanx dorsally with the other hand assessing the severity of the pain and the degree of dorsal displacement in the MTPJ joint (Figure 1).

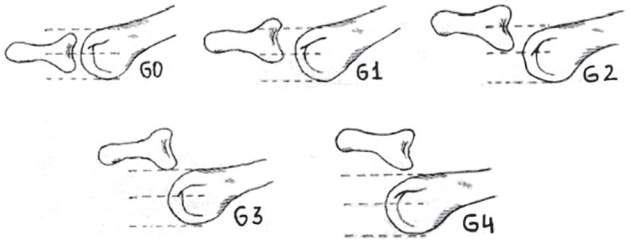

Fig. 1 Degree of displacement of the major phalanx with different plantar plate tears evaluated with the Hamilton-Thompson drawer test

Sonographic scanning was performed according to the original method [27]. With medium viscosity mediagel applied, the transducer was placed over the plantar surface of the metatarsal heads to explore the structural integrity of the plantar plate, orientation of the fibers, edema of the surrounding tissues, changes in the membranes of the flexor digitorum longus muscle, the presence or absence of phalangeal dislocation and dislocation in the MTPJ. The instability was graded as

– the Hamilton-Thompson G0 with sonographic absence of fibrous thinning of the plantar plate, presence of moderate edema and infiltration of the plantar plate, absent edema and infiltration in the membranes of the flexor digitorum longus muscle and dislocation of the major phalanx;

– the Hamilton-Thompson G1 with fibrous thinning of the plantar plate, thin fibers at the metatarsal head, impaired parallel fibrous orientation, moderate edema and infiltration of the membranes of the flexor digitorum longus muscle, absent dislocation of the major phalanx, absent subluxation of the MTPJ;

– the Hamilton-Thompson G2 with impaired fibers of the plantar plate at the metatarsal head of less than 50 %, evident edema and infiltration of the membranes of the flexor digitorum longus muscle, 30 % dislocation of the major phalanx and clinical subluxation of MTPJ;

– the Hamilton-Thompson G3 with more than 50 % impaired fibers of the plantar plate at the metatarsal, edema and infiltration of the plantar plate and the membranes of the flexor digitorum longus muscle, overextended MTPJ with dislocation of the major phalanx by 50 % and over with the possibility of complete reduction of the MTPJ;

– the Hamilton-Thompson G4 with completely (100 %) impaired fibers of the plantar plate at the metatarsal, edema and infiltration of the plantar plate and the membranes of the flexor digitorum longus muscle, dislocation of the MTPJ and dislocation at the base of the toe and complete irreducable dislocation of the MTPJ;

The study was performed in accordance with ethical principles for medical research involving human subjects stated in the Declaration of Helsinki developed by the World Medical Association as revised in 2013 and Order of the Ministry of Health of the RF dtd 19th June 2003 No. 266 on Clinical Practice Guidelines in the Russian Federation. Statistical analysis of clinical results was performed using descriptive statistics with the distribution of values, nonparametric statistics to test the null hypothesis, Pearson's chi-squared test with arbitrary tables to identify differences in variables in unrelated samples [28]. For calculations, a significance level of < 0.05 was adopted. Statistical analysis was performed with computer software: Microsoft Office Excell 2010 and SPSS, version 16.0 for Windows.

RESULTS

Comparative analysis of patients with G0 and G4 instability showed no significant statistical difference in physical examination and ultrasound findings (Table 1) with the results of physical examination being consistent with ultrasound findings in 100 % of G0 patients who had no injury to the plantar plate (Fig. 2).

Patients with instability graded G1 (n = 17) (Fig. 3, 4) with clinical testing showed plantar plate tear graded G2 (n = 6; 35.3 %) (Fig. 5 and 6) with ultrasound which allowed timely amendments in surgical intervention with suturing the plantar plate (Table 1).

Sonographic scan of patients with plantar plate tear graded G2 (n = 27) with clinical test (Fig. 7) showed plantar plate tear sonographically graded G3 (n = 7) (Fig. 8) and indicated an emergency surgical intervention to avoid transition to grade G4. Plantar plate tear graded G2 (n = 2) with clinical test was sonographically assessed as G1 and allowed reduction in the volume of surgical procedure. Overall, errors occurred in 22.8 % of plantar plate tears graded clinically (Table 1).

Table 1

Comparative analysis of plantar plate injury graded with the Hamilton-Thompson test and ultrasound findings

Types of injury to plantar plate as graded with the Hamilton-Thompson test	Distribution of patients with plantar plate tears graded with clinical test and ultrasound				
	Clinical test of plantar plate tear	False results of clinical testing the plantar plate tear		Extent of plantar plate tear evaluated with ultrasound	significance
	abs.	abs.	%	abs.	
G0	4	0	0	4	–
G1	17	G2–6	35.3	13	$\chi^2 = 5.3$, p = 0.021
G2	27	G1–2 G3–7	33.3	29	$\chi^2 = 10.3$, p = 0.002
G3	35	G2–5	14.2	37	$\chi^2 = 5.6$, p = 0.018
G4	5	0	0	5	–
Total	88	20	22.7	88	–

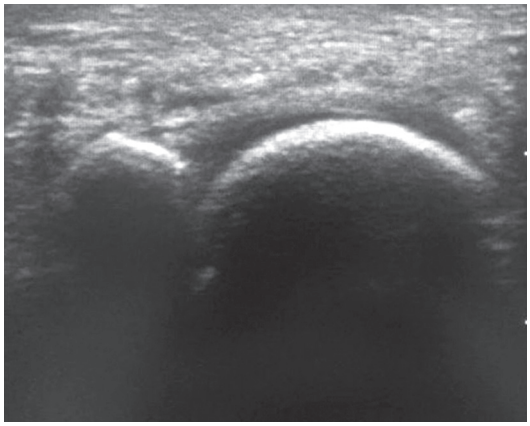

Fig. 2 Sonographic scan showing absent plantar plate tear graded G0

Fig. 3 Displacement of the major phalanx with plantar plate tear graded G1 with the Hamilton-Thompson test

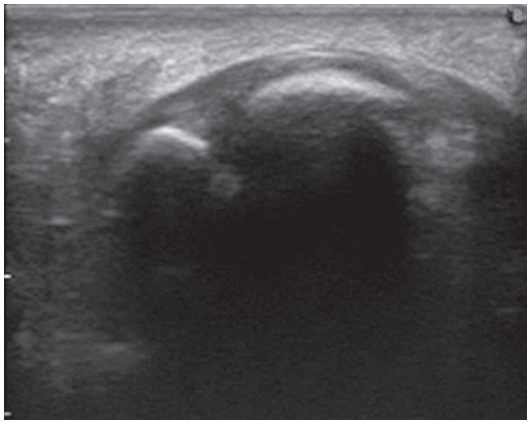

Fig. 4 Sonographic scan showing plantar plate tear graded G1 with the Hamilton-Thompson test

Fig. 5 Displacement of the major phalanx with plantar plate tear graded G2 with the Hamilton-Thompson test

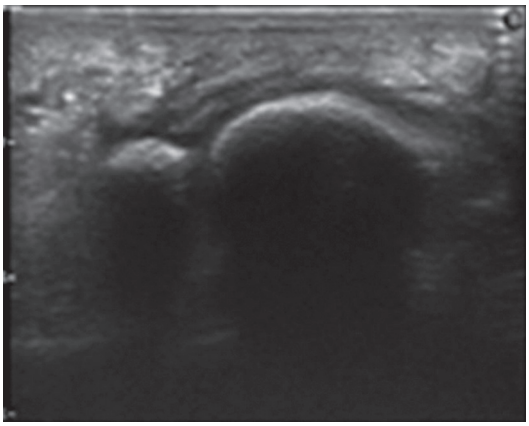

Fig. 6 Sonographic scan showing plantar plate tear graded G2 with the Hamilton-Thompson test

Fig. 7 Displacement of the major phalanx with plantar plate tear graded G3 with the Hamilton-Thompson test

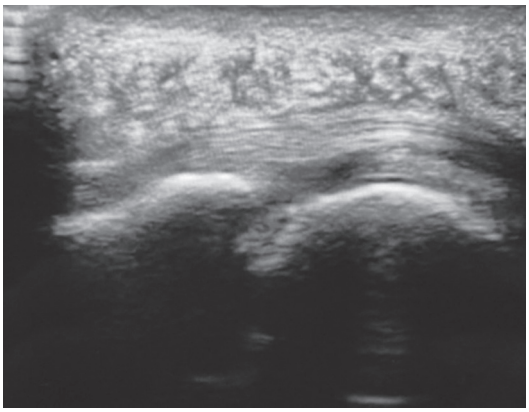

Fig. 8 Sonographic scan showing plantar plate tear graded G2 with the Hamilton-Thompson test

Among 35 plantar plate tears clinically graded G3 five (14.3 %) were sonographically assessed as G2 and indicated an emergency surgical intervention to avoid progression and transition to complete plantar plate tear.

Diagnostic inaccuracies of clinical testing of plantar plate tears occurred in 22.8 % of cases with 2.3 % of patients treated with reasonably reduced volume of surgical intervention, and treatment strategy was significantly adjusted in 20.5 % to avoid a complete plantar plate tear.

DISCUSSION

Acquired forefoot deformity is a common problem with severe restrictions in quality of life and impairment of daily activities. Foot deformities can lead to pain, and change in the walking style, difficulties with footwear and aesthetic concerns. Deformities of lesser toes are more common in the forefoot being a component of a complicated multiplanar deformity associated with hallux valgus [6, 12, 18, 20, 29]. These deformities (hammertoe deformity of the smaller toes) can also occur as an isolated pathology [6, 20, 30, 31]. Evaluation of instability with plantar plate tear using the Hamilton-Thompson test can be subjective and based on the personal findings of the examiner with no objectivity. There are no accurate criteria for evaluation of the plantar plate tear and differentiating between grades G2 and G3 can be difficult. The use of subjective diagnosis and the identity of clinical manifestations can be misleading in grading the G1 and G2 plantar plate tears, and they appear to be combined in one cluster of the anatomical classification [1, 32, 33]. Ultrasound allows assessment of the plantar plate tear under tension with the load and during movements in the MTPJ. Specific foot structures, peripheral edema or excessive soft tissue in obese patients can interefere with the accuracy of the Hamilton-Thompson test.

Preoperative ultrasound examination of the plantar foot is crucial for the diagnosis of complicated static multiplanar deformity of the forefoot accompanied by non-rigid hammertoe deformity of the second and/or second, third toes to identify the extent of plantar plate tear and surgical strategy based on the following:

G0 – stable MTPJ with no anatomical injury to the plantar plate and hammertoe deformity – no surgical treatment indicated;

G1 – unstable MTPJ with no anatomical injury to the plantar plate, with hammertoe deformity to be corrected due to degenerative changes in the stabilizers of the MTPJ – the Weil procedure is indicated with no need for plasty of the plantar plate;

G2 – subluxation of the MTPJ with anatomical injury to the plantar plate and non-rigid hammertoe deformity of lesser toes to be addressed with Weil surgery and plasty of the plantar plate;

G3 – severe injury to the MTPJ with anatomical injury to the plantar plate, complete dislocation in

the joint, non-rigid hammertoe deformity of lesser toes to be addressed with adequate surgical treatment using Weil surgery and plasty of the plantar plate until complete tear occurs;

G4 – severe injury to the MTPJ with anatomical injury to the plantar plate, complete dislocation in the joint, rigid hammertoe deformity of lesser toes, fibrous ankylosis of the interphalangeal joints to be addressed with adequate surgical treatment to correct claw deformity, Hohmann surgery and transarticular fixation of the MTPJ with a wire.

Therefore, sonographic scanning introduced in the algorithm of diagnosis of the extent of the plantar plate tear allows an objective approach to the choice of treatment strategy in complicated static multiplanar deformity of the forefoot accompanied by non-rigid hammertoe deformity of lesser toes.

CONCLUSIONS

1. Preoperative ultrasound imaging of the plantar surface of the foot for detecting the severity of plantar plate injury should be included in the diagnostic algorithm for patients with complicated multiplanar forefoot deformities accompanied by a non-rigid hammertoe deformity of lesser toes.

2. Preoperative ultrasound imaging of the plantar surface of the heads of the second and third metatarsal bones allows reduction in diagnostic errors assessing the extent of the plantar plate tear by 22.8 %.

3. An objective sonographic examination of the plantar plate tear facilitates an objective choice of surgical strategy to avoid an excessive volume of surgical intervention and optimize the timing for the procedure.

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