Genij Ortopedii. 2022. Vol. 28, no. 3. P. 361-366.

Original article

https://doi.org/10.18019/1028-4427-2022-28-3-361-366

Comparative analysis of outcomes of multiplanar static forefoot deformity accompanied by flexible second mallet toe deformity treated with various techniques

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Abstract

Introduction Complicated multiplanar static forefoot deformities can occur at any age ranging 72 % to 80 % in older patients significantly reducing the quality of life. The results of treatment of flexible mallet toe deformity of "smaller" toes cannot be considered satisfactory with floating toe syndrome reported in 20–54 % of cases. **The objective** of the study was to evaluate the effectiveness of the original technology offered for the treatment of complicated multiplanar static forefoot deformities which differs from traditional methods by the way the plantar plate of "smaller" toes is restored. **Material and methods** The study included 43 patients who were divided into two groups depending on the type of reconstruction performed. Long-term outcomes were evaluated at 12 months of surgery using AOFAS questionnaire, radiology, VAS and the Hamilton-Thompson metatarsophalangeal "drawer test". **Results** Conventional surgical technology applied for patients of group A and group B allowed reduction of the M1-M2 angle by 7.2 ± 1.1 degrees and visual elimination of the the second mallet toe deformity in all cases. There was no floating toe noted among patients of group B, and the deformity was defected in 5 (27.8 %) patients of group A; contracture of the second metatarsophalangeal joint diagnosed in 1 (4.0 %) patient of group B and in 8 (44.4 %) cases of group A. **Conclusion** The flexible mallet toe deformity of the second toe treated with the technique we developed allowed us to avoid the development of floating toe syndrome, contracture of the second metatarsophalangeal joint and improve the quality of life by 28.7 ± 2.4 AOFAS score.

Keywords: hallux valgus, flexible mallet toe deformity, "smaller" toes, plantar plate, Hamilton-Thompson metatarsophalangeal "drawer" test

For citation: Cherevtsov V.N., Blazhenko A.N., Bogdanov S.B., Kireev V.S., Gorokhov A.V. Comparative analysis of outcomes of multiplanar static forefoot deformity accompanied by flexible second mallet toe deformity treated with various techniques. *Genij Ortopedii*, 2022, vol. 28, no 3, pp. 361-366. https://doi.org/10.18019/1028-4427-2022-28-3-361-366

BACKGROUND

Complicated multiplanar static forefoot deformities can occur at any age ranging 72 % to 80 % in older patients [1]. The condition significantly reduces the quality of life due to pain (metatarsalgia), painful plantar hyperkeratosis, difficulties in footwear and aesthetic problems [2]. Multiplanar static deformity of the forefoot leads to hallux valgus, varus alignment of the first metatarsal (metatarsus primus varus), transverse flattening of the forefoot developing in stages with resultant overloading of the metatarsophalangeal joints [3] and degenerative thinning followed by rupture of the plantar plates of the metatarsophalangeal joints of the lesser toes (second, third, less often the fourth), a hammertoe (subluxation and / or dislocation of the toe, dislocation of the flexor tendons, changes in the traction axis of the lumbrical muscles, digital hyperextension) [3]. Impaired position and function of the toes, unstable fixation of the lesser toes and lesser metatarsophalangeal joints during the gait cycle due to muscles imbalance in the foot and injury to the static articular limiters or joint stabilizers (plantar plate, collateral ligaments, tendons) gradually interfere with the gait [4]. Surgical restoration of the forefoot biomechanics by reconstructing the optimal parabola of Lelivier is one of the ways to eliminate metatarsalgia [3]. Lelivier's parabola can be restored using corrective osteotomies aimed at eliminating hallux valgus and varus of the 1st metatarsal, unloading corrective osteotomies of the IInd, IIId, the fourth (less often) metatarsals with the purpose to achieve ratios between the metatarsal heads of the bones matching the "Roman foot" [4]. Distal metatarsal SCARF, Chevron, MICA, Slide down osteotomies with less relapse and complication rates [5] have become the standard surgical treatment for the correction of hallux valgus in the second half of the 20th and early 21st centuries and allowed reduction of the angle between the first and second metatarsals, thereby partially solving the problem.

Despite a variety of surgical correction techniques (corrective metatarsal and phalangeal osteotomy, soft tissue releases and combined interventions) described in the special medical literature [6, 7] outcomes with non-rigid hammertoe deformity of the lesser toes cannot be considered satisfactory. Recurrence of hammertoes,

floating toe, contractures of the metatarsophalangeal joint are reported to develop in 20–54 % of cases [8, 9], and the development of methods for the treatment of non-rigid hammertoe deformity of the 2nd, sometimes 3rd, 4th toes is essenatial. The objective of the study was to evaluate the effectiveness of the original technology offered for the treatment of complicated multiplanar static forefoot deformities which differs from traditional methods by the way the plantar plate of lesser toes is restored.

MATERIAL AND METHODS

The study included 43 patients who were treated in the orthopaedic and trauma department of Krasnodar State Budgetary Institution of Health No. 3 and the orthopaedic department of the multidisciplinary medical center "In Safe Hands", Krasnodar between 2014 and 2019. The inclusion criteria were: a complex multiplanar static deformity of the forefoot (hallux valgus grade III with non-rigid hammertoe deformity of the 2nd toe); US confirmed rupture of the plantar plate of the IInd toe Hamilton-Thompson grade 2–3 [10]; absence of concomitant pathology that could affect the results of treatment. The exclusion criteria were: US confirmed injury to the plantar plate of the second toe Hamilton-Thompson grade 0 or 1 (incomplete injury – no hammertoe deformity of the 2nd toe), no surgical restoration of the plantar plate performed [11]; US confirmed injury to the plantar plate of the IInd toe Hamilton-Thompson grade 4 (rigid claw-like deformity of the 2nd toe and complete rupture of the plantar plate); severe concomitant somatic pathology that could affect the results of treatment like rheumatoid arthritis, gout, diabetes mellitus. Depending on the treatment strategy applied, the patients involved in the study was divided into 2 groups.

Group A (n = 18) included patients who were treated with conventional surgical technology: SCARF osteotomy [2, 12], Weil osteotomy [1], Hohmann operation [3, 13] followed by transarticular fixation with a Kirschner wire [7, 13]. The patients were allowed to walk after 2 days with gradual weight-bearing using Baruk shoes [14], after 3 weeks for limited distances, the sutures were removed 3 weeks after the operation. Group B (n = 25) included patients who were treated with SCARF osteotomy, Weil osteotomy and the plantar plate was restored using original technique ("Method of surgical restoration of the plantar plate of the lesser metatarsophalangeal joint using direct plantar approach in case of rupture due to overloading metatarsalgia", RF patent for invention No. 2673782 dated November 26, 2018).

The rupture of the plantar plate was treated with SCARF osteotomy of M1 and Weil osteotomy with the plantar approach performed at the subcapital space of the IInd metatarsal head dissecting the skin, subcutaneous fat and exposing the tendon sheath of the long flexor of the 2nd toe. The sheath of the tendon was dissected longitudinally and the tendon was retracted laterally exposing the plantar plate rupture that was sutured and reinforced with transverse stitches by suturing to the long flexor sheath to allow reliable "plantarization" of the toe with the wound sutured in layers [11]. Walking was allowed after 2 days with gradual weight-bearing using Baruk shoes with a rigid sole. The two metatarsophalangeal joints were exercised after 2 postoperative days. Passive exercises of two metatarsophalangeal joints were encouraged for patients. With the pain relieved, the patients could produce active movements with the operated toes after 7 postoperative days. Walking was allowed for limited distances for 3 weeks. The sutures were removed after 3 weeks. Statistical analysis of the comparability of the groups created for retrospective analysis yielded the following results (Table 1).Based on the results of the analysis presented in Table 1 we could identify 2 statistically comparable groups of patients ($p \geq 0.05$) in terms of the severity of hallux valgus, the presence of non-rigid hammertoe deformity of the II toe, sex, age, the degree of injury to the plantar plates of the second toe, the Charlson comorbidity index [16] and the AOFAS scores.

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 (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.

Table 1

Comparative study of patients included in groups A and B to determine the possibility of statistically correct analysis

Parameters	Groups of patients		Mann-Whitney U-test	Significance level Mann-Whitney U-test, p
	Group A	Group B		
Severity of hallux valgus (M1–M2 angle, degrees)	15.3 ± 0.7	15.1 ± 0.9	U = 191.0,	P = 0.348
AOFAS score	20.2 ± 0.8	20.4 ± 0.9	U = 193.0,	P = 0.387
Age, years	60.3 ± 2.1	60.4 ± 2.4	U = 222.5,	P = 0.950
Charlson comorbidity index, score	4.4 ± 1.0	4.4 ± 0.9	U = 221.0,	P = 0.918

Statistical processing and analysis of clinical results were performed using the methods of descriptive statistics for the distribution of numerical values. The values in the groups were far from normal; nonparametric statistics methods including the Mann-Whitney U-test, the χ^2 test for arbitrary tables designed to identify differences in parameters of several unrelated samples and Fisher's exact test were used to prove the comparability of the values [17]. Results were recognized as significant if the level of statistical significance p was less than or equal to 0.05. Microsoft Excel 2010 spreadsheet processor and SPSS-16.0 program for statistical data processing for Windows were used to complete data analysis reports.

RESULTS

Outcomes were evaluated at 12 months (Table 2) using the following criteria:

– severity of Hallux valgus with measurement of the M1–M2 angle;

– presence or absence of a hammertoe deformity of the second toe during physical examination;

– presence or absence of a floating toe at palpation at the site of the 2nd metatarsophalangeal joint;

– presence or absence of contracture of the 2nd metatarsophalangeal joint grade 2, 3 during physical examination;

– objective criterion for improving or worsening the quality of life of patients measured with the AOFAS scale.

A comparative analysis of the results of treatment was performed at 12 months (Table 2) and allowed us to conclude that:

– the traditional technology of surgical treatment used in patients of group A and the technology of surgical treatment we improved and used in patients of group B allowed to:

– reduce the M1-M2 angle by 7.2 ± 1.1 degrees;

– eliminate visual manifestations of hammertoe deformity of the second toe in all patients of the study groups.

There were no such consequences of surgical treatment as floating toe among patients of group B and the condition was diagnosed in 5 (27.8 %) patients of group A; contracture of the second metatarsophalangeal joint grade 2, 3 was noted in 1 (4.0 %) case of group B and in 8 (44.4 %) patients of group A, being greater by 40.4 %. The AOFAS quality of life score was 58.7 ± 3.5 in patients of group A and 87.4 ± 9.5 in group B at 12 months.

Patients of group B could improve the quality of life by 28.7 ± 2.4 points compared to that in patients of group A due to the use of the technology of surgical treatment we developed. Based on the analysis of outcomes presented in Table 2 we can conclude that the improvement in the quality of life of patients on the AOFAS scale by 28.7 ± 2.4 with comparison of groups A and B was associated with the absence of such consequences of surgical treatment as floating toe and contracture of the metatarsophalangeal joint. The absence of such consequences of surgical treatment was due to the recovery of the function and stability of the metatarsophalangeal joint that was achieved by restoring the integrity of the plantar plate with resultant restoration of the balance of the ligaments and tendons of the metatarsophalangeal joint and the normalization of the rolling function in the gait cycle.

Table 2

Comparative analysis of the results of the treatment in groups A and B

Parameters	Period of observation	Groups of patients		Comparison criterion	Significance level, p
		Group A	Group B		
Severity of hallux valgus (M1-M2 angle)	Pre-op	15.3 ± 0.7	15.1 ± 0.9	Mann-Whitney U-test U = 191.0	P = 0.348
	at 12 months	8.1 ± 1.1	8.3 ± 1.2	Mann-Whitney U-test U = 208.5	P = 0.647
Presence of hammertoe deformity of the second toe during physical examination (abs. number / %)	Pre-op	18 (100.0 %)	25 (100.0 %)	Fisher's exact test F = 1	P > 0.05
	at 12 months	0 (0.0 %)	0 (0.0 %)		
Presence of floating toe	Pre-op	0	0	Fisher's exact test F = 0.02,	P < 0.001
	at 12 months	5 (27.8 %)	0		
Contracture of the second metatarsophalangeal joint grade 2, 3	Pre-op	0	0	Fisher's exact test F = 0.01,	P < 0.001
	at 12 months	8 (44.4 %)	1 (4.0 %)		
AOFAS score	Pre-op	20.2 ± 0.8	20.4 ± 0.9	Mann-Whitney U-test U = 193.0,	P = 0.387
	at 12 months	58.1 ± 9.3	86.3 ± 3.9	Mann-Whitney U-test U = 3.0,	P < 0.001

Metatarsalgia was arrested in all patients of group B at 12 months; there were no problems with the selection of shoes either. Instability of the metatarsophalangeal joint determined by the Hamilton-Thompson test and its correlation with the degree of damage to the plantar plate could be objectified by ultrasound [1]. In order to confirm our conclusion we performed an ultrasound of the plantar plates of the 2nd metatarsophalangeal joint and assessed the severity of the Hamilton-Thompson test (G 0, 1, 2, 3) in patients of groups A and B preoperatively and at 12 months (Table 3).

The data presented in Table 3 allowed us to conclude that patients of group B treated with surgical technology offered showed instability of grade G3 completely eliminated in 15 (60.0 %); G2, in 10 (40.0 %) cases that could be transferred to group G1 (n = 3, 12.0 %) and G0 (n = 22, 88.0 %) according to clinical and ultrasound manifestations of metatarsophalangeal joint instability. Patients of group A treated with traditional surgical technology showed reduction in manifestations of G3 instability from 10 (55.6 %) to 5 (27.8 %) cases that were transferred to groups G2 and G1 increasing the G2 group from 8 (44.4 %) to 11 (61.1 %) and the G1 group from 0 to 2 (11.11 %) and no cases of metatarsophalangeal joint stability could be graded as G0 (Table 3). Evidenced by the data presented in Table 3, G2 and Hamilton-Thompson 3 impairments objectified by ultrasound could be indicated for surgical treatment. The objective of surgical treatment was to achieve stability in the metatarsophalangeal joint and restore the plantar plate to grade G0, 1 confirmed by ultrasound that could significantly improve treatment results measured with the AOFAS score (Table 2).

Table 3

Comparative analysis of the results of the treatment in groups A and B

G-Graduate	Groups of patients				Comparison criterion (χ^2 for arbitrary tables)	Significance level, p
	Group A		Group B			
	Pre-op	At 12 months	Pre-op	At 12 months		
G0	0	0	0	22 (88.0 %)	$\chi^2 = 38.1$, df3,	P < 0.001*
G1	0	2 (11.1 %)	0	3 (12.0 %)		
G2	8 (44.4 %)	11 (61.1 %)	10 (40.0 %)	0		
G3	10 (55.6 %)	5 (27.8 %)	15 (60.0 %)	0		

* comparison of treatment results at 12 months of surgical treatment.

DISCUSSION

Some authors [8, 18] suggest that the current surgical treatments of hammertoes either neglect the restoration of plantar plates as major stabilizers of the metatarsophalangeal joint in nonrigid cases or surgical interventions can be traumatic for plantar plate recovery requiring special equipment and consumables with no considerations to the type, nature, extent of toe deformity, degree of rupture of the plantar plate resulting in poor outcomes.

The need to restore the plantar plate of the lesser toes in the presence of hammertoe can be determined subjectively using the G-Graduate with the Hamilton-Thompson test [1] that allows evaluation of the metatarsophalangeal joint stability in 93 % (drawer symptom) and pain in 94 % of cases. The test is used to determine the degree of dislocation in the metatarsophalangeal joint depending on the degree of degenerative changes:

G0 – stable metatarsophalangeal joint;

G1 – unstable metatarsophalangeal joint;

G2 – subluxated metatarsophalangeal joint;

G3 – completely dislocated joint;

G4 – rigid hammertoe deformity of lesser toes.

However, the Hamilton-Thompson test does not allow for an objective differential diagnosis of degenerative lesions of the G1 and G2 plantar plate that can affect the surgical strategy: if G1 is injured restoration of the plantar plate is impractical, and restoration of the plantar plate is needed for G2. MRI allows reliable differential diagnosis but is not always possible due to the relatively high costs and / or unavailability at a medical institution. Ultrasound diagnostic method we used was practical for identifying the extent of injury to the plantar plate (RF Patent No. 2699383 "Method for determining the type of degenerative rupture of the plantar plate of the metatarsophalangeal joint due to overloading metatarsalgia") and the optimal method of surgical intervention avoiding diagnostic errors and inappropriate surgical interventions and facilitating resultant improved outcomes.

The known methods that involve plantar plate restoration (corrective osteotomy of the metatarsal

bones and digital phalanges, soft tissue releases and combined interventions) described in the special medical literature [7] are traumatic requiring special equipment and consumables, with no considerations to the type, nature, degree of toe deformity and the extent of rupture of the plantar plate. We undertook to develop a "Method for surgical restoration of the plantar plate of lesser metatarsophalangeal joint by direct plantar approach in case of traumatic ruptures due to overloading metatarsalgia" (Patent of the Russian Federation No. 2673382), to facilitate hammertoe correction of the second toe. Therefore, the objectification of the extent of injury to the plantar plate with ultrasound ruling out unreasonable surgical interventions, and a relatively simple and minimally invasive method of surgical restoration of the plantar plate provided improvements in the following way: recurrence of hammertoe deformity, floating toe, metatarsophalangeal contractures are reported in special medical literature as high as 20–54 % [8, 9] and our series showed complications developed in 4 % of cases (Table 2).

CONCLUSION

1. Elimination of nonrigid hammertoe deformity of the 2nd toe using the traditional technology of surgical treatment (group A) results in floating toe in 27.8 % of cases or grade 2, 3 contracture of the second metatarsophalangeal joint in 44.4 % of cases.

2. The technique offered to restore the plantar plate of the 2nd toe allowed us to avoid such complications as floating toe and contracture of the second metatarsophalangeal joint and resulted in improvements in the quality of life by 28.7 ± 2.4 AOFAS score.

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The article was submitted 30.06.2020; approved after reviewing 29.07.2020; accepted for publication 28.03.2022.

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