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Original Research

Soft Tissue Management and Tibialis Posterior Tendon Transfer in Acute Correction for Neglected Drop Foot Deformity

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A R T I C L E   I N F O

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A B S T R A C T

Acute correction of rigid drop foot deformity can be problematic due to the skin defect that may occur in the medial part of the ankle. The purpose of this study is to present an innovative solution for this problem. We hypothesized that acute correction for rigid ankle contractures without arthrosis might be possible if the medial skin defect could be closed. Therefore, we described a surgical technique for acute functional correction of rigid drop foot deformities. The closure of the medial defect was performed by applying a flap and partial-thickness skin graft. We have retrospectively evaluated the results of 18 patients who were treated between 2010 and 2016 with this technique. The mean age of the patients was 37 ± 9.5 (22-56) years. Foot drop etiology was firearm-related nerve injury. Corrections were performed after 14.6 ± 7.9 (8-38) months following the injury. At the end of an average follow-up period of 44.4 ± 6.2 (37-60) months, 14 of 18 patients (78%) recovered without complications, 3 patients experienced partial loss in the medial skin graft region, and 1 patient developed a superficial infection. None of the patients have developed pes planus. We observed that the ankle flexion contracture, which was 34° ± 9.2° (20°-50°) preoperatively, could reach an average of 2.2° ± 2.5° (0°-6°) dorsiflexion after surgery. We suggest that acute correction and tibialis posterior tendon transfer in the treatment of rigid foot drop deformity can be performed with an effective skin closure with low soft tissue complications.

A drop foot occurs when the foot loses its dorsiflexion ability due to peroneal neuropathy or muscle damage in the anterior tibial compartment. Nerve injuries due to gunshot wounds are among the common causes of this pathology, which complicates daily life and causes falls and accidents (1). Since the peroneal part of the sciatic nerve is more prone to injury due to its lateralization and tension, the tibial nerve is frequently preserved in thigh-level injuries (2). Drop foot can be flexible or rigid (3). If proper physical therapy is not established immediately following the injury, equinus deformity becomes more pronounced, fixed, and rigid (4,5).

Before starting the treatment of foot drop, it is essential to investigate the etiology, evaluate agonist and antagonist muscle strengths, and measure active and passive joint movements using convenient tools. The treatment aims to prevent the foot-slap and toe-drag during the gait cycle's swing phase without using an orthosis, ensure that the heel touches the ground instead of the toe first, and obtain a painless joint (3). For this purpose, osteotomy, arthrodesis, and tendon transfers are among treatment modalities (5).

Several reports suggested tendon transfer procedures to correct foot drop, which is not rigid (6-10). Since acute correction strategies were avoided in rigid deformities due to the possible risk of skin and soft tissue defects, numerous studies recommended gradual correction of the deformity or arthrodesis in patients with severe contractures (4,11-14). However, closure with a flap and partial-thickness skin graft may be an option for managing the skin defects following acute contracture releases. Unfortunately, there is no specific method recommended for the treatment of skin and soft tissue defects that may develop during the acute correction phase in the chronic neglected cases of foot drop in the literature and guidelines.

The purpose of this study is to represent an innovative solution for this problem. We hypothesized that acute correction for chronic rigid ankle contractures without arthrosis might be possible if the medial skin defect could be closed. Therefore, we described a surgical technique for acute functional correction of rigid drop foot deformities. The closure of the medial defect was performed by applying a flap and partial-thickness skin graft. We have evaluated the results of 18 patients who were treated with this technique.

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Patients and Methods

The hospital records of the patients who had surgery due to foot drop between 2010 and 2016 were scanned retrospectively after approval from the hospital's institutional review board (No:378). Patients with drop foot due to spinal damage, neurological diseases, central nervous system-related etiologies, and patients with arthrosis in the ankle joint (narrowing or obliteration of the tibiotalar joint surface) were excluded from the study. Patients with tibialis posterior muscle weakness less than 4/5 were also excluded. Four patients with the injury of the sciatic nerve who underwent arthrodesis were excluded from the study. Patients with rigid drop foot due to peroneal nerve lesion, whose ankle joint cannot be passively dorsiflexed to the neutral position, were included in the study.

Eighteen patients met the inclusion criteria. The foot drop's etiology was a nerve lesion due to gunshot wounds in all 18 patients, and the mean age was 37 ± 9.5 (22-56) years. Patient demographics are listed in Table 1.

Nerve lesions were at thigh-level in 13 (%72.2) patients and lower leg in 5 (%27.8) patients. There were concomitant femoral fractures in 3 patients, proximal tibia fracture in 1 patient, and isolated proximal fibula fracture in 1 patient. The mean duration between injury and tendon transfer surgery was 14.6 ± 7.9 (8-38) months. The average follow-up period was calculated as 44.4 ± 6.2 (37-60) months.

The patients underwent physical therapy for 2 months before surgery to increase the passive range of motion and strengthen the tibialis posterior muscle. In addition, the joint range of motion was measured before the surgery using a goniometer. The surgical procedures were performed by the same senior surgeon (I.B.O.).

Surgical Technique

The patient was positioned supine with a pneumatic tourniquet placed at the thigh level. The first incision was started medially from the medial cuneiform bone level and advanced horizontally toward the Achilles tendon under the medial malleolus. The incision was then curved upward in the midway between the tibia and Achilles tendon and extended proximally approximately 6 cm longitudinally, forming an "L" shape. After the skin incision, the subcutaneous tissue was dissected in the form of a proximal-based flap. This flap has covered the proximal part of the defect at the end of the surgery (Fig. 1). The remaining defect was closed with a skin graft. Therefore, while preparing the flap, a convenient subcutaneous tissue was left in the distal part to obtain an appropriate graft bed (Fig. 2).

The tendon of the tibialis posterior (TP) muscle was dissected and transected from its insertion site (Fig. 3). Then, Z-shaped Achilloplasty, posterior and medial capsular releases were performed through the "L" shaped incision to achieve passive ankle extension (Fig. 4). In cases with claw toes, flexor tenotomies at the metatarsophalangeal level were added to the procedure.

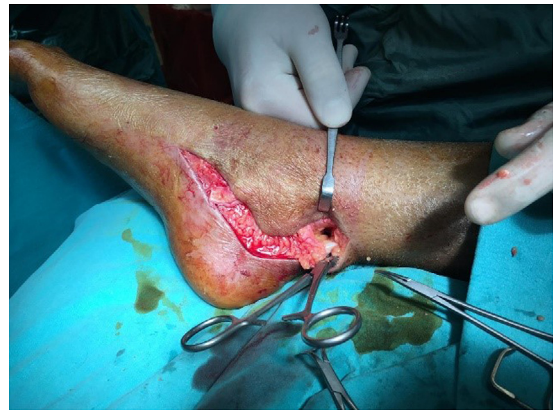

Fig. 1. "L" shape incision, the proximal part is prepared as a proximally based flap.

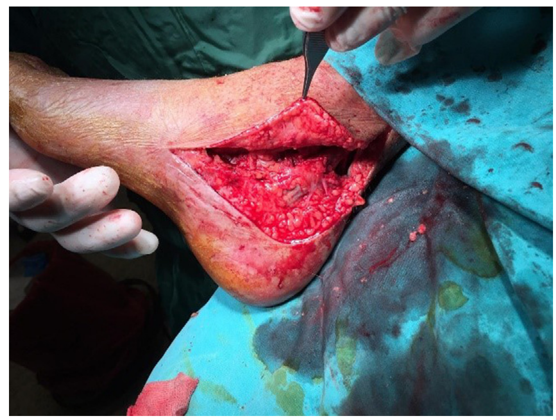

Fig. 2. A convenient subcutaneous tissue must be left in the distal part to be covered by a graft later.

The second 4 cm longitudinal incision was made in the midline on the dorsal surface of the ankle. Extensor hallucis longus (EHL), extensor digitorum longus (EDL), and tibialis anterior (TA) tendons were explored. Peroneus Tertius (PT) tendon was revealed with the third incision starting from the lateral part of the ankle. With the help of the

Table 1
Patient demographics (N = 18 feet in 18 patients)

No.	Age- Years	Sex	Side	Concomitant Fracture	Duration Between Injury and Drop-foot Correction (Months)	Duration of Follow-Up (Months)	Pre-op Rigid Position of the Ankle as Plantar Flexion Degree
1	24	M	R		10	40	20
2	39	M	R	Tibia	28	41	30
3	36	M	R	Femur	25	42	20
4	22	M	L		16	39	40
5	45	M	R		14	60	30
6	56	M	L		12	48	40
7	34	M	L		8	37	30
8	29	M	L		9	55	50
9	45	M	R		14	40	30
10	48	M	L	Fibula	11	46	40
11	36	M	R		16	50	30
12	28	M	R	Femur	11	39	20
13	34	M	R		9	43	30
14	32	M	L		10	48	40
15	46	M	R		8	40	40
16	26	M	L		38	47	50
17	49	M	L		13	46	40
18	37	M	L	Femur	11	38	40

Abbreviations: M, male; L, left; R, right.

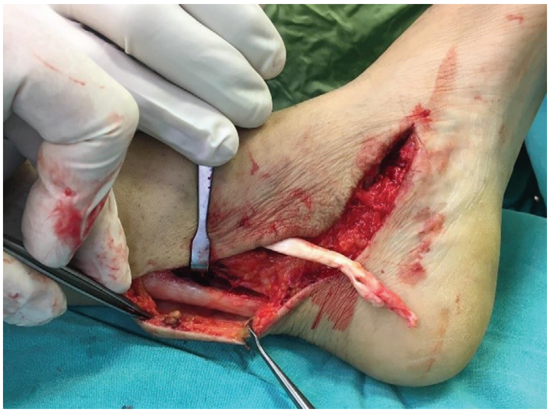

Fig. 3. Tibialis posterior tendon is dissected and transected from its insertion site.

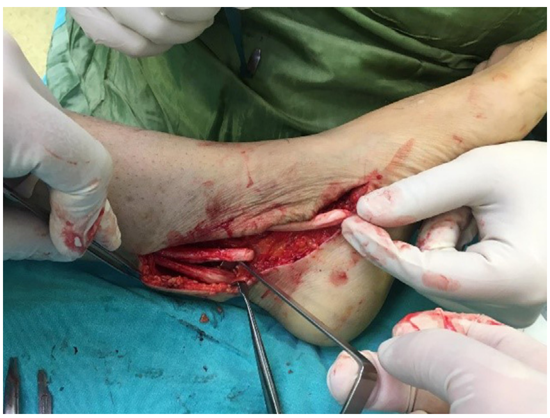

Fig. 4. Z-shaped Achilloplasty is performed.

tendon carrier placed through the second incision, the TP tendon was passed under the skin, not through the interosseous membrane, and delivered to the anterior side of the ankle. At this part, after the tendon was divided into 2, one part was transferred to the TA tendon in an appropriate tension while holding the knee in flexion and the ankle in 20 degrees of dorsiflexion (Fig. 5). The remaining part was inserted into the EHL and EDL, and then the tip was transferred to the PT tendon through the third incision. When the limb was released, it was observed that the ankle was standing in a neutral position due to the tenodesis effect, thus enabling the evaluation of the tendon tension.

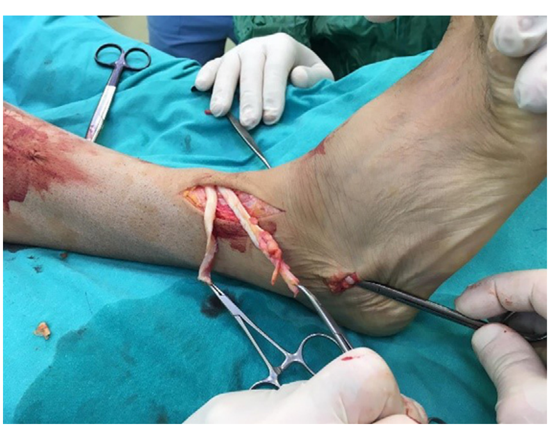

Fig. 5. The tibialis posterior tendon is divided into 2 parts after the subcutaneous transfer.

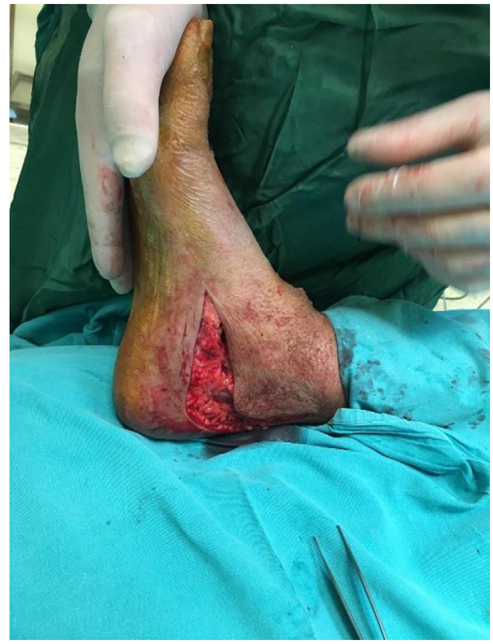

Fig. 6. Medial skin defect occurs after the acute correction.

The tourniquet was released, and bleeding and circulation control was achieved.

After the closure of the anterior incision, a medial skin defect was revealed in all patients (Fig. 6). The previously prepared flap was placed over the skin defect, and the remaining defect was closed with a partial thickness skin graft obtained from the thigh area (Fig. 7).

A short leg plaster cast was applied by molding the ankle in the neutral position. The patients were allowed to walk with 2 crutches without full weightbearing 2 days after the surgery. The splint was removed at the end of the postoperative sixth week, and physical therapy was initiated without any special shoe wear, and weightbearing was allowed as tolerated. Patients were able to walk unaided at postoperative eighth week.

Functional Evaluation

Results were evaluated according to the American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score (Table 2) and Stanmore scales (Table 3) (15-17). According to the AOFAS ankle scale, 90 to 100 points were considered “excellent”; 80 to 89 points, “good”; 60 to 79 points,

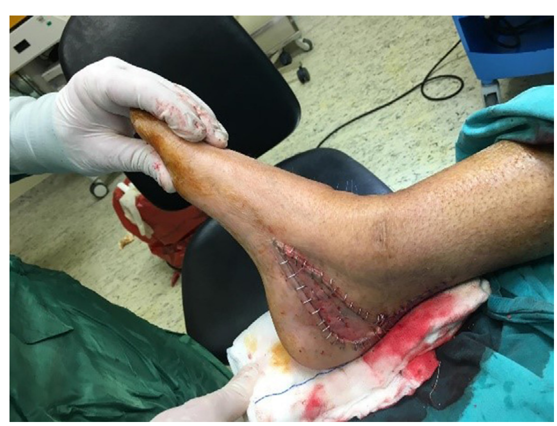

Fig. 7. Closure of the defect with the pre-prepared proximal-based flap. The remaining defect is closed with a partial thickness skin graft.

Table 2
AOFAS ankle-hindfoot scale (100 points total)

Pain (40 points)	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
Function (50 points)	
Activity limitations, support requirement	
No limitations, no support	10
No limitation of daily activities, limitation of recreational activities, no support	7
Limited daily and recreational activities, cane	4
Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
Maximum walking distance, blocks	
Greater than 6	5
4-6	4
1-3	2
Less than 1	0
Walking surfaces	
No difficulty on any surface	5
Some difficulty on uneven terrain, stairs, inclines, ladders	3
Severe difficulty on uneven terrain, stairs, inclines, ladders	0
Gait abnormality	
None, slight	8
Obvious	4
Marked	0
Sagittal motion (flexion plus extension)	
Normal or mild restriction (30° or more)	8
Moderate restriction (15°-29°)	4
Severe restriction (less than 150)	0
Hindfoot motion (inversion plus eversion)	
Normal or mild restriction (75%-100% normal)	6
Moderate restriction (25%-74% normal)	3
Marked restriction (less than 25% normal)	0
Ankle-hindfoot stability (anteroposterior, varus-valgus)	
Stable	8
Definitely unstable	0
Alignment (10 points)	
Good, plantigrade foot, midfoot well aligned	10
Fair, plantigrade foot, some degree of midfoot malalignment observed, no symptoms	5
Poor, nonplantigrade foot, severe malalignment, symptoms	0

Table 3
Stanmore system (for assessing results of tibialis posterior tendon transfer)

Categories	Points
Pain (15 points)	
No pain at any time or not worse	15
Mild pain or slightly worse	10
Moderate pain or moderately worse	5
Severe pain or markedly worse	0
Need for orthosis (15 points)	
No	15
Occasional (once a week)	10
Frequently (twice a week)	5
Regularly (greater than twice a week)	0
Normal shoes (5 points)	
Yes	5
Yes, but prefers certain types	3
No	0
Functional outcome (10 points)	
Normal daily activity and normal recreation	10
Normal daily activity and limited recreation	6
Limited daily activity and recreation	3
Severe limitation on daily activity and recreation	0
Muscle power (modified Medical Research Council grading) (25 points)	
Grade 4+ or 5	25
Grade 4	20
Grade 3	10
Grade 2 or less	0
Degree of active dorsiflexion (degrees) (25 points)	
Greater than 6	25
0-5	20
−5 to −1	10
−10 to −6	5
less than −11	0
Foot posture (5 points)	
Plantigrade, balanced, no deformity	5
Plantigrade, mild deformity	3
Obvious deformity or malalignment	0
Total	100

“fair”; and less than 60 points were evaluated as “poor” scores. The results were classified as “excellent” for scores between 85 and 100, “good” between 70 and 84, “fair” between 55 and 69, and “poor” for scores below 55 according to the Stanmore scale.

Statistical Analyses

The normality of the data distribution was analyzed with the Shapiro-Wilk test using SPSS 22.0 (SPSS Inc, IBM, Chicago, IL) software. Paired samples *t* test was used to compare the scores before and after surgery, and Pearson’s correlation coefficient was used to test the correlation between variables. Values with a *p* value of less than .05 were considered statistically significant.

Results

The patients were followed for an average of 44.4 ± 6.2 (37-60) months. The skin grafts and donor site wounds healed without complications in 14 (%78) out of 18 cases. Three patients experienced partial graft loss, and 1 patient developed an infection in the previous wound region on the bottom of the foot. Wound healing was achieved by local wound care in 2 patients since the impaired area was small, whereas 1 patient underwent regrafting. The infection regressed with appropriate antibiotherapy. All patients were able to do their daily work without using orthosis, brace, or any supportive material at the end of the treatment period.

None of the patients developed pes planus or recurrence of the ankle contracture. The ankle flexion contracture, which was 34° ± 9.2° (20°-50°) preoperatively, reached an average of 2.2° ± 2.5° (0°-6°) dorsiflexion.

Two patients scored as excellent, 9 patients as good, and 7 were evaluated as fair scores from the AOFAS ankle scale. According to the Stanmore scale, the results were excellent in 7 patients, good in 5 patients, and fair in 6 patients. In addition, significant improvement was observed in the postoperative AOFAS score and Stanmore scale compared to the preoperative period ($p < .001$; Table 4).

Discussion

Peroneal neuropathy is the most common cause of drop foot deformity, which complicates daily life and causes accidents (1). Rigid equinovarus deformity may develop within a short period in patients with sciatic nerve injury, even if they use a brace (18). It has been shown that the healing capacity of the tibial branch of the sciatic nerve is better than the peroneal branch and that the peroneal nerve is more prone to injury in trauma cases (2). The findings of our study confirm this report as the functions of the muscles innervated by the tibial nerve were well preserved, and functional loss was present in the peroneal muscles in 13 patients (72.2%) injured by a firearm at the thigh level. Nerve exploration was not performed since these patients were not consulted in the acute period of their injuries.

Table 4
Outcome (N = 18 feet in 18 patients)

No.	Postoperative Dorsiflexion Degree	Postoperative Plantar Flexion Degree	Preoperative AOFAS Score	Postoperative AOFAS Score	Preoperative Stanmore Score	Postoperative Stanmore Score
1	6	20	51	90	18	86
2	5	30	60	89	44	86
3	6	30	40	83	16	88
4	0	40	35	77	16	79
5	3	40	35	85	16	79
6	0	35	30	73	5	69
7	3	30	37	85	16	90
8	0	35	33	72	10	69
9	3	30	39	87	21	91
10	2	30	37	87	13	81
11	6	30	39	87	16	90
12	6	30	63	95	21	95
13	0	30	37	81	16	71
14	0	30	37	77	13	69
15	0	30	37	78	13	71
16	0	30	33	77	10	69
17	0	35	37	81	5	69
18	0	35	37	77	5	64

Physical therapy remains incompetent after the rigid equinovarus deformity develops. Therefore, while Bridle's tendon transfer procedure is preferred in the surgical management of non-rigid foot drop, it has been reported that the triple arthrodesis procedure as described by Lambrinudi in 1927 or the Ilizarov external fixator was suggested as surgical treatment options for rigid equinovarus foot deformity (4,19,13).

Acute corrections would have skin-related complications like skin necrosis or skin rupture, even if tibiocalcaneal arthrodesis with talectomy were performed to overcome the skin tightness (20-22). Therefore, in this study, an acute correction was performed in the patients with severe equinus deformity, and subsequent skin defects were closed using a medial flap and partial thickness skin graft.

Lengthening the Achilles tendon after removing the TP tendon generally will not be enough in severe equinus deformities. Therefore, posterior capsulotomy and medial capsular release should be performed at this stage in both the tibiotalar and talocalcaneal regions. During the operation, it should be aimed to provide passive dorsiflexion of the ankle up to 20° (23). Toe flexors should also be examined during the dorsiflexion, and if the contracture-related clawing develops, this problem should be solved by flexor tenotomy. Achilles tendon lengthening and capsulotomy procedures were performed as described above, and all patients required flexor tenotomy in our study group.

During the transfer of the TP tendon, either circumtibial or interosseous routes may be used. The interosseous route is more suitable for the transferred tendon's new function, and since there is a shorter path on this axis, a longer functional tendon will be achieved. However, if the interosseous window is not extended wide enough, friction and motion limitation may develop. In addition, the neurovascular structures just beneath the membrane are also at risk. On the circumtibial route, the tendon transferred under the skin follows a longer track and would be more tenacious due to an extended moment arm; however, its excursion decreases. There are publications reporting efficient results with both techniques (3,6,7,9,10,23). In this study, we preferred subcutaneous circumtibial transfer since an additional incision was not necessitated.

Another subject of the discussion is whether the transferred tendon should be fixed onto the tarsal bones or not. Ober reported the fixation of the tendon together with the navicular bone piece to the third metatarsal through the circumtibial route (24). In contrast, Watkins followed an approach through the interosseous membrane for the same fixation technique (25). There are also studies where fixation was performed on the third cuneiform and intermediate cuneiform bones. However, it has been reported that neuropathic arthropathy and varus or valgus deformities arose in the tarsal bones depending on the place of insertion following fixation to these structures (26). Srinivasan et al reported that the division of the transferred tendon into 2 parts and its distribution only to the tendons in the dorsal foot eliminated these possible complications (27). Riordan has suggested that PTT should be anastomosed not only to the tibialis anterior tendon but also to the peroneus longus tendon for pes equinovarus deformities; thus, the "Bridle Procedure" had emerged (8). However, the tendon transferred in this approach does not constitute an anastomosis to the bone. Later, Rodriguez modified the technique by providing the tenodesis of the transferred tendon to the medial cuneiform bone with an interference screw (10). In our study, the transfer of PTT to the tendons at the dorsum of the foot was performed without bone fixation. The end of the tendon was also transferred to the peroneus tertius muscle as described by Hove et al; thus, the lateral part of the foot was involved in dorsiflexion (28).

Another point to be considered while transferring the tendon is the tension of the tendon. If it is sutured in an overstretched state, it loses its motor function and contributes to the foot's dorsiflexion only by acting as an internal splint with its tenodesis effect (29). Since a 20° dorsiflexion loss was expected shortly after the tendon to tendon transfer (23), the transfer was performed while the ankle joint dorsiflexion was established as 20° intraoperatively, and an average of 2.2° $\pm$ 2.5° (0°-6°) active dorsiflexion was observed in all patients at the controls.

Posterior tibial tendon dysfunction is known to be the most common cause of adult acquired flat foot (30), and it has been suggested that pes planus may develop after the harvesting of the posterior tibialis tendon. Flynn et al used a subtalar implant for arthroereisis to prevent this complication. However, they couldn't show the superiority of implant use due to the insufficient number of patients (31). A recent review showed that arthroereisis has a 30% tarsal sinus pain rate when combined with other procedures like tendon transfers (32). Flexor digitorum longus (FDL) transfer is the most common tendon transfer in treating adult flat foot deformity (30). Still, to our knowledge, it has not been added to the tibialis posterior tendon transfer procedure as a flat foot prevention method. Therefore, we did not use any subtalar implant or FDL transfer, and we did not observe pes planus development in our cases as in many other studies (6,10,27,28,33). Compression wounds at the fifth metatarsal bone's plantar surface were present in 4 of our patients and recovered spontaneously after obtaining the plantigrade stance.

Some studies recommended triple arthrodesis if the subtalar joint surfaces are damaged and removal of the talus if necessary while correcting the contracture (13). In foot drop patients with rigid flexion contractures, gradual correction with the Ilizarov external fixator is preferred due to possible skin-related complications that may develop with an acute correction (14). A correction of 1 mm is performed within 4 days with the Ilizarov fixator, and the device is kept for at least 6 more weeks following the correction (4). It is a long-term treatment that requires patient compliance and close follow-up. A second surgery to remove the Ilizarov ring apparatus would also be needed. Therefore, a single-step correction would be more cost-effective and would have a shorter recovery period. Shakirov stated that acute correction and skin grafting might provide satisfactory outcomes in patients with burn-related skin contractures (34). They have evaluated different surgical techniques depending on the localization of the defect, but they have not performed any functional tendon transfer. In our study, an acute correction was performed in rigid contractures due to foot drop, and skin defect was covered with the flap, which was prepared at the beginning of the operation. The remaining defect was closed with a partial-thickness skin graft, while the tibialis posterior tendon was transferred for the foot drop. The whole procedure was completed in a single operative session.

Following acute correction of rigid ankle contractures, vascular problems may also occur (14). Although we did not experience any circulatory problems due to acute correction in our study group, it is essential to deflate the tourniquet and control the circulation after the contracture correction. Therefore, all patients were admitted overnight, received periodic monitoring at the day of surgery, and were discharged 2 days after the surgery.

The limitations of our study are its retrospective nature and the lack of a control group for comparison. In addition, as the patient group consists of young (mean age is 37 ± 9 [22-56] years) and healthy people, we can't suggest the technique for elderly patients. However, given the specific nature of the gunshot wound-related injuries, we suggest that our data might provide beneficial information concerning the use of skin graft for one-step management of rigid foot drop deformities.

In conclusion, the skin defects which may arise after acute correction in the ankles that have been contracted in flexion for a long time can be covered with a well-prepared superomedial tissue as a flap and with a partial thickness skin graft with low complication rates if the patient has a compliant joint surface without arthrosis.

Author Contributions

Erdem Özden: Writing - review & editing, Formal analysis and interpretation of data, Methodology, Investigation

Murat Mert: Writing - review & editing, Data curation, Investigation, Acquisition of data, Project administration

İsmail Bülent Özçelik: Writing - review & editing, Data curation, Investigation, Acquisition of data, Supervision

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study has obtained IRB approval from Yeniyyüzyıl University Gaziosmanpaşa Hospital. Informed consent was obtained from all individual participants included in the study.

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