Original article
https://doi.org/10.17816/2311-2905-17712



# Results of the Use of Modified Bipolar Radiofrequency Ablation in Patients with Proximal Plantar Fasciopathy

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**Abstract**
***Background.*** Among the many causes of plantar heel pain, the most common is proximal plantar fasciopathy (PF), second only to ligamentous injuries of the foot. The disease reduces the quality of life and is difficult to treat, as its pathogenesis remains unexplored.
***The aim of the study*** — to conduct a comparative evaluation of treatment outcomes in patients with proximal plantar fasciopathy using extracorporeal shock wave therapy, as well as minimally invasive bipolar radiofrequency ablation, both with and without the described modification.
***Methods.*** We analyzed the treatment outcomes of 36 patients who sought medical care for chronic heel pain caused by proximal PF in the period from 2018 to 2023. Among the patients, there were 14 (38.8%) women and 22 (61.2%) men, with a median age of 55.4 [46.7; 61.7] years. All patients were randomly assigned to three groups of 12 patients each. In Group 1 (control), extracorporeal shock wave therapy (ESWT), which had not been used at previous stages, was used for treatment; in Group 2 (comparison) – minimally invasive bipolar radiofrequency ablation (BRFA); in Group 3 (main) – minimally invasive BRFA using a method modified by the authors. Comparative evaluation of the results was carried out at 1, 3, 6 and 12 months after surgery in Groups 2 and 3 and after the completion of ESWT course in Group 1.
***Results.*** The median plantar fascia thickness of the affected limb did not differ between the groups at 3 months after the completion of treatment. At 6 months, these indicators were significantly different between the control and main groups ($p = 0.001$). In the intergroup analysis of the dynamics of pain syndrome and foot functionality, the treatment results in the main group showed a statistically significant advantage compared with control and comparison groups after 1, 3 and 6 months of follow-up ($p < 0.05$).
***Conclusions.*** The modified minimally invasive radiofrequency ablation method for the treatment of patients with proximal plantar fasciopathy demonstrated superior early clinical outcomes compared to the standard ablation technique and a course of extracorporeal shock wave therapy. The results obtained appear promising and suggest that the modified technique may be considered a preferred treatment option in cases where all types of conservative therapy fail within a six-month period.

**Keywords:** proximal plantar fasciopathy; plantar fascia; plantar heel pain; bipolar radiofrequency ablation; foot function index; functional capacity of the foot and ankle.

**Cite as:** Silantjev V.N., Dzuba G.G., Katina M.M. Results of the Use of Modified Bipolar Radiofrequency Ablation in Patients with Proximal Plantar Fasciopathy. *Traumatology and Orthopedics of Russia*. 2025;31(3):84-95. (In Russian). https://doi.org/10.17816/2311-2905-17712.

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Submitted: 17.04.2025. Accepted: 25.06.2025. Published online: 04.08.2025.

Научная статья
УДК 617.586.2-009.7-08
https://doi.org/10.17816/2311-2905-17712



# Результаты применения модифицированной биполярной радиочастотной абляции у пациентов с проксимальной подошвенной фасциопатией

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**Реферат**

***Актуальность.*** Среди множества причин подошвенной пяточной боли проксимальная подошвенная фасциопатия находится на втором месте, уступая лишь повреждениям связочного аппарата стопы. Заболевание снижает качество жизни и трудно поддается лечению, так как его патогенез остается до конца не изученным.

***Цель исследования*** — сравнительная оценка результатов лечения пациентов с проксимальной подошвенной фасциопатией с применением ударно-волновой терапии, а также мини-инвазивной биполярной радиочастотной абляции с модификацией и без нее.

***Материал и методы.*** Проведен анализ результатов лечения 36 пациентов с проксимальной подошвенной фасциопатией в период с 2018 по 2023 г. Среди пациентов было 14 (38,8%) женщин и 22 (61,2%) мужчины, медиана возраста составила 55,4 года [46,7; 61,7]. Все пациенты случайным образом были распределены на три группы по 12 пациентов в каждой. В 1-й (контрольной) группе для лечения использовалась не применявшаяся на предыдущих этапах ударно-волновая терапия (УВТ), во 2-й группе (сравнения) — мини-инвазивная биполярная радиочастотная абляция, в 3-й (основной) — мини-инвазивная биполярная радиочастотная абляция по модифицированной авторами методике. Сравнительную оценку результатов осуществляли в сроки 1, 3, 6 и 12 мес. со дня оперативного лечения во 2-й и 3-й группах и со дня окончания курса УВТ в 1-й группе.

***Результаты.*** Медианы показателей толщины подошвенного апоневроза стопы с болью через 3 мес. после завершения лечения межгрупповых отличий не имели, через 6 мес. — между контрольной и основной группами эти различия были статистически значимы ($p = 0{,}001$). При межгрупповом анализе динамики болевого синдрома и функциональных возможностей стопы результаты лечения в основной группе показали статистически значимое преимущество по сравнению с группами контроля и сравнения через 1, 3 и 6 мес. ($p < 0{,}05$).

***Заключение.*** Модифицированный мини-инвазивный метод радиочастотной абляции при лечении пациентов с проксимальной подошвенной фасциопатией показал лучшие итоговые результаты в более ранние сроки в сравнении со стандартной методикой абляции и курсом ударно-волновой терапии. Полученные результаты выглядят обнадеживающими, и метод может рассматриваться в качестве приоритетного варианта лечения в тех случаях, когда в течение 6 мес. были исчерпаны все варианты консервативной терапии.

**Ключевые слова:** проксимальная подошвенная фасциопатия; подошвенный апоневроз; подошвенная пяточная боль; биполярная радиочастотная абляция; функциональный индекс стопы; функциональное состояние стопы и голеностопного сустава.

**Для цитирования:** Силантьев В.Н., Дзюба Г.Г., Катина М.М. Результаты применения модифицированной биполярной радиочастотной абляции у пациентов с проксимальной подошвенной фасциопатией. *Травматология и ортопедия России*. 2025;31(3):84-95. https://doi.org/10.17816/2311-2905-17712.

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Рукопись получена: 17.04.2025. Рукопись одобрена: 25.06.2025. Статья опубликована онлайн: 04.08.2025.

## INTRODUCTION

Proximal plantar fasciopathy (PF) is the most common cause of heel pain and ranks second in prevalence among all causes of foot pain, second only to pain syndrome resulting from ligamentous injuries of the ankle joint [1, 2]. The term "plantar fasciopathy" most accurately reflects the true nature of the condition, commonly referred to as "heel spur", "plantar fasciitis", or "fasciosis", since the degenerative and inflammatory changes of the plantar fascia that occur at various stages of the pathological process and gradually progress are difficult to detect and differentiate [3]. Chronic pain syndrome associated with proximal PF proves resistant to standard conservative treatment options in 10-20% of cases, and patients with proximal PF increasingly demand not only more efficient treatment modalities and shorter recovery time, but also more satisfactory outcomes [4].

To date, no consensus has been reached among foot and ankle surgeons regarding the type and extent of surgical intervention for long-standing proximal PF. In clinical practice, a significant variety of surgical techniques for proximal PF are used, ranging from different approaches to minimally invasive exostectomy to open or endoscopic release of the plantar fascia [5]. These procedures align with the current surgical trend focused on the development and widespread adoption of minimally invasive techniques aimed at preserving the integrity of the soft tissues of the foot as much as possible [6].

In light of emerging data indicating that the underlying pathogenesis of proximal PF is predominantly degenerative and non-inflammatory, a new surgical approach has been introduced — bipolar radiofrequency ablation (BRFA) of the proximal portion of the plantar fascia. This method, originally developed for transmyocardial and percutaneous myocardial revascularization, aims to stimulate collagen regeneration and improve vascularization [7]. A specially designed bipolar needle electrode was used to deliver radiofrequency energy to the fascia. Following BRFA, elevated levels of fibroblast growth factor and vascular endothelial growth factor have been observed at the pathological site, resulting in an increased number of endothelial cells migrating through the vascular wall and promoting revascularization and tissue regeneration [8]. This etiopathogenetic approach provides an optimal foundation for further research into the condition, as it not only reduces tension in the plantar fascia but also facilitates the resolution of reversible, heteromorphic, and heterochronic changes in its connective tissue structures, thus restoring their morphological integrity. The previously proposed BRFA technique for the proximal plantar fascia using a bipolar needle electrode involves performing a series of microperforations [9]. However, in our opinion, this procedure leads to insufficient elongation of the plantar fascia. The modification of the method consists in supplementing the microperforation series with several marginal microtenotomies, which allow for more substantial elongation and, consequently, a greater reduction in fascia tension. Combined with the regenerative stimulation effect, this modification represents a new stage in the evolution of surgical techniques for treating proximal PF.

*The aim of the study* — to conduct a comparative evaluation of treatment outcomes in patients with proximal plantar fasciopathy using extracorporeal shock wave therapy, as well as minimally invasive bipolar radiofrequency ablation, both with and without the described modification.

## METHODS

### Study design

Type of study: randomized prospective open-label comparative cohort study.

Between 2018 and 2023, a study was conducted at the Department of Traumatology and Orthopedics of RZD-Medicine Clinical Hospital (Omsk), involving 36 patients who sought medical care for chronic heel pain caused by proximal PF.

### Patients

Among the patients included in the study, there were 14 (38.8%) women and 22 (61.2%) men. The median age at disease onset was 55.4 [46.7; 61.7] years.

*Inclusion criteria:* diagnosis of proximal PF lasting 6 months or longer and ineffectiveness of prior conservative treatment.

Patients with BMI > 35, significant biomechanical abnormalities of the foot (posterior hindfoot pronation > 5 mm; medial longitudinal arch angle < 125° or > 140°), hypermobile first ray (sagittal mobility > 10 mm), contracture of the gastrocnemius-soleus complex, autoimmune or other systemic diseases were not included in the study.

Patients were randomly assigned into three equal groups of 12 participants each. The groups were comparable in terms of inclusion criteria, gender, and age. Group 1 (control group) included 12 patients (7 men and 5 women), with a median age of 49 [38; 56] years, who underwent a course of extracorporeal shock wave therapy (ESWT). Group 2 (comparison group) included 12 patients (7 men and 5 women), mean age 50 [38; 62] years, who received a single session of minimally invasive BRFA of the proximal plantar fascia using the standard technique. Group 3 (main group) included 12 patients (8 men and 4 women), mean age 54 [48; 68] years, who underwent minimally invasive BRFA of the proximal plantar fascia using a modified technique developed by the authors (patent RU 2702867).

The main difference between the proposed and standard technique lies in the addition of 4 to 6 marginal microtenotomies, each no longer than 2 mm, performed along the medial edge of the proximal fascia, in addition to the standard series of 18-24 microperforations made with the same bipolar needle electrode. This modification resulted in greater elongation of the plantar fascia and, consequently, more effective reduction in tensile stress.

All patients underwent a comprehensive evaluation of complaints and medical history, including a detailed account of previous treatment for proximal PF, functional status, as well as assessment of occupational and recreational activities. A thorough physical examination of the foot and ankle was performed, which included inspection, palpation, percussion, assessment of range of motion and muscle strength. The scope of laboratory and instrumental examination was determined in accordance with current medical diagnostic standards.

All surgical interventions in Groups 2 and 3 were performed using a minimally invasive approach, under regional (ankle block) anesthesia and tourniquet-induced ischemia.

Postoperative management was standardized across all groups. During the first two days, patients were advised to limit foot movements and avoid weight-bearing. From day 7, passive and active range-of-motion exercises were initiated, and protected ambulation in an offloading boot was recommended. A gradual return to normal activities at home and at work was permitted within the first two months, provided that sports and physically demanding work were completely avoided. In the third postoperative month, intensive training and prolonged axial loading were restricted for professional athletes and individuals engaged in heavy physical labor.

## Methods of examination

Ultrasound examination of the plantar fascia structure was performed using an ACUSON X300 PE ultrasound system (Siemens). The following parameters were assessed: thickness, uniformity, echotexture, and echogenicity of the plantar fascia. Among the evaluated parameters, the dorsoplantar thickness of the fascia at its insertion site on the calcaneal tuberosity was considered the most informative and objectively comparable. Therefore, this specific parameter was selected for comparative and statistical analysis at three time points: before treatment, and 3 and 6 months after the completion of therapy.

## Outcome assessment methods

Pain intensity was assessed using the pain subscale of the Foot Function Index (FFI) [10]. This subscale enables the evaluation of foot pain in various situations, such as walking barefoot or in shoes, and provides both total and subscale scores. The Minimal Detectable Change (MDC) was set at 2.42 points, as established by B.R. Martinez et al. for conditions such as plantar fasciopathy, metatarsalgia, and chronic ankle instability [11].

The analysis of function and daily activity in patients with foot and ankle disorders to assess treatment effectiveness was conducted using the Foot and Ankle Ability Measure (FAAM) assessment system [12]. In the clinical study, we used one subscale: Activities of Daily Living (ADL), consisting of 21 items. Each item had five response options and an additional “no answer” option (if the patient was unable to respond). The total score was obtained by summing the item scores and calculating the proportion relative to the maximum possible score, taking into account the number of “no answer” responses. The final score ranged from 0 to

100 points, with higher scores indicating better function, and the MDC threshold was 5.7 points [13]. The FFI questionnaire was administered before treatment, and at 1 month (Timepoint 1), 3 months (Timepoint 2), 6 months (Timepoint 3), and 12 months (Timepoint 4) after treatment. The FAAM (ADL) assessment in all groups was performed before treatment, and at 3 months (Timepoint 1), 6 months (Timepoint 2), and 12 months (Timepoint 3) after treatment.

## Statistical analysis

Statistical processing of the obtained data was performed using MS Excel 2007, Statistica 10, and NCSS 2022 software packages. Descriptive statistics for the study groups were presented as median (Me) and interquartile range [$Q_1$; $Q_3$]. To assess the statistical significance of differences between groups, the Mann-Whitney U test was used for independent samples, and the Wilcoxon signed-rank test was applied to evaluate changes within the same group over time at different study timepoints. A p-value < 0.05 was considered statistically significant. The correlation between study parameters was assessed using Spearman's correlation coefficient with calculation of the exact p-value. To build mathematical models describing the relationship between ultrasound parameters on the affected side at Timepoints 2 and 3 and various predictors, multiple linear regression analysis was performed using NCSS 2022.

The minimum sample size for this study was calculated using Altman's nomogram with the following input parameters: standard deviation (SD), which determines the minimal standardized quantitative difference. In the pilot study, SD = d/s, where d is the absolute value of the minimal clinically significant mean difference, and s is the parameter obtained from the pilot study (the 6-month reduction in plantar fascia thickness in the BRFA group). For the parameter "plantar fascia thickness", SD = 1 mm / 1.1 mm = 0.90. Thus, SD was set at 0.90; the significance level at p < 0.05; and the study power at 80%. According to Altman's nomogram, the minimum required sample size was 12 patients per group, for a total of 36 patients

## RESULTS

Short-term and mid-term treatment outcomes in patients with plantar heel pain caused by proximal PF were analyzed and assessed across all three study groups. The follow-up period in all groups was12 months.

One of the most objective indicators of the reparative processes in the structure of the plantar fascia was its thickness at the calcaneal insertion site as measured by ultrasound. A comparison of ultrasound parameters on the unaffected limbs showed that the median plantar fascia thickness in Group 1 was 3.2 [2.80; 3.33] mm, in Group 2 – 3.25 [3.05; 3.40] mm, and in Group 3 – 3.4 [3.175; 3.800] mm, with no statistically significant differences between Group 1 and Group 2 (p = 0.817), Group 1 and Group 3 (p = 1.000), or Group 2 and Group 3 (p = 0.150). This indicated initial homogeneity of the study groups.

Changes in plantar fascia thickness in patients with plantar heel pain (PHP) during treatment are presented in Table 1.

According to the obtained data, at the first assessment point, the thickness of the plantar fascia in the painful foot was statistically significantly greater than that of the contralateral foot in all study groups (p < 0.001 for all three groups), but there were no statistically significant intergroup differences (p > 0.05).

Within-group dynamics of plantar fascia thickness demonstrated heterogeneous positive trends. In Groups 1 and 2, a significant reduction in fascia thickness was achieved by 6 months. In Group 1: between Timepoints 1 and 2, p = 0.358; between Timepoints 2 and 3,

*Table 1*

**Thickness of changed plantar fascia at the calcaneal insertion site, mm (Me [$Q_1$; $Q_3$])**

| Timepoint | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| 1 (before treatment) | 6.300 [5.675; 6.650] | 6.750 [6.225; 6.925] | 7.050 [6.575; 7.700] |
| 2 (3 months after) | 5.350 [5.175; 6.125] | 5.650 [5.250; 6.000] | 5.400 [4.975; 6.025] |
| 3 (6 months after) | 4.950 [4.425; 5.950] | 4.500 [4.125; 4.750] | 3.800 [3.600; 4.125] |

p = 0.645; between Timepoints 1 and 3, p = 0.035. In Group 2: between Timepoints 1 and 2, p = 0.193; between Timepoints 2 and 3, p = 0.254; between Timepoints 1 and 3, p = 0.012. In Group 3, a statistically significant improvement was observed in 3 months: between Timepoints 1 and 2, p = 0.085; between Timepoints 2 and 3, p = 0.035; between Timepoints 1 and 3, p = 0.002.

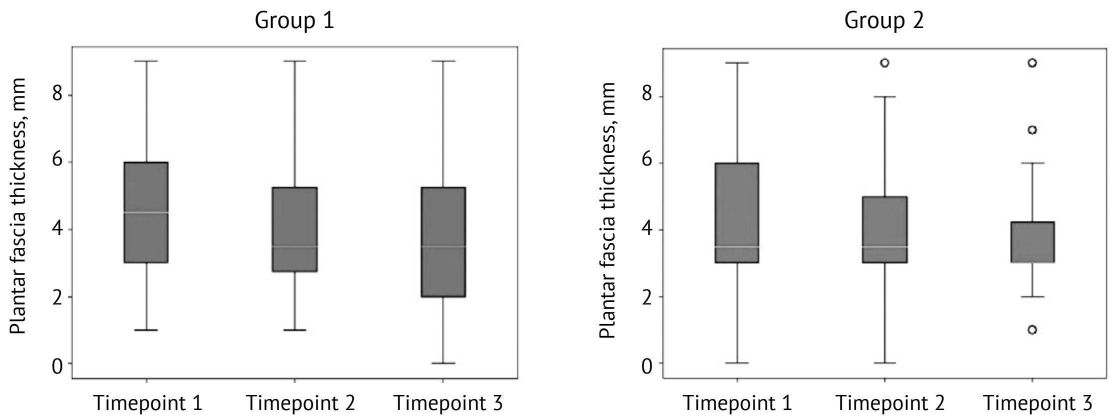
The median plantar fascia thickness in the symptomatic foot before treatment showed no statistically significant difference between Groups 1 and 2 (p = 0.260) or between Groups 2 and 3 (p = 1.000). However, statistically significant difference was found between Groups 1 and 3 (p = 0.010), which was attributed to a longer, more persistent, and treatment-resistant course of the pathological process in the main group. At Timepoint 2, no statistically significant differences were found between Groups 1 and 2 (p = 0.839), 1 and 3 (p = 0.583), or 2 and 3 (p = 0.686). A different picture emerged at Timepoint 3: while there were still no significant differences between Groups 1 and 2 (p = 0.126) or between Groups 2 and 3 (p = 1.000), the difference between Groups 1 and 3 reached statistical significance (p = 0.001).

The lowest final absolute values of plantar fascia thickness were observed in Group 3, despite this group having the highest baseline values of the measured parameter (Figure 1).

To verify the obtained results, two mathematical models were constructed to assess the dependence of ultrasound measurements in the symptomatic foot at Timepoints 2 and 3 on the ultrasound parameters of the contralateral foot, on the previous measurement point of the symptomatic foot, and on the type of treatment.

For this purpose, Spearman's rank correlation coefficient was calculated:

– At Timepoint 2, the ultrasound measurement on the symptomatic foot demonstrated a moderate direct correlation with the ultrasound measurement on the healthy side (T = 0.71; $p < 0.05$), as well as a moderate direct correlation with the baseline value on the symptomatic side (Timepoint 1, before treatment) (T = 0.74; $p < 0.05$).



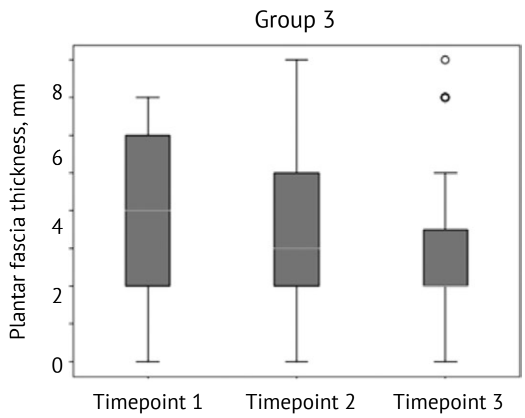




**Figure 1.** Changes in plantar fascia thickness according to the results of ultrasound:
Timepoint 1 – before intervention;
Timepoint 2 – 3 months after intervention;
Timepoint 3 – 6 months after intervention

– At Timepoint 3, the ultrasound measurement showed a weak direct correlation with the ultrasound value of the healthy side (T = 0.38; $p < 0.05$), a weak direct correlation with the baseline value of the symptomatic side (T = 0.31; $p < 0.05$), and a moderate direct correlation with the ultrasound measurement at Timepoint 2 (T = 0.82; $p < 0.05$).

A mathematical model was developed to assess the dependence of the ultrasound measurements on the symptomatic foot at Timepoint 2 on: 1) the ultrasound values of the healthy side; 2) the baseline values of the symptomatic side (Timepoint 1, before treatment); 3) the type of treatment.

The model parameters were calculated using NCSS 2022 software. A linear multiple regression equation was applied.

The equation of the mathematical model at Timepoint 2 was as follows:

$$R = -0.005+0.262B+0.772C+D,$$

where R is the ultrasound measurement at Timepoint 2; B is the ultrasound measurement on the healthy side; C is the ultrasound measurement on the symptomatic side at Timepoint 1; D = 0 for the control group, D = -0.286 for the comparison group, and D = -0.945 for the main group.

A similar equation was developed for Timepoint 3:

$$N = -0.381+0.980E+D,$$

where E is the ultrasound measurement on the symptomatic side at Timepoint 2; D = 0 for the control group, D = -0.652 for the comparison group, and D = -1.090 for the main group.

The equation shows that, all other conditions being equal, at Timepoint 2 the ultrasound measurement in the comparison group is 0.29 mm lower than in the control group, and 0.96 mm lower in the main group. At Timepoint 3, the ultrasound measurement in the comparison group is 0.65 mm lower than in the control group, and 1.1 mm lower in the main group.

Comparative results of pain assessment (FFI), function, and activities of daily living in patients with foot and ankle disorders (FAAM (ADL)), across all groups are presented in Table 2.

When comparing FFI (pain subscale) and FAAM (ADL) scores between groups prior to treatment, no statistically significant differences were observed, which was consistent with the hypothesis of group comparability.

In the intergroup analysis of FFI (pain subscale), at Timepoint 1, Group 3 demonstrated a statistically significant advantage compared with Groups 1 and 2. At Timepoint 2 (3 months after treatment initiation), Group 3 again showed a statistically significant advantage over Groups 1 and 2. At Timepoint 3 (6 months after treatment initiation), pain scores in Group 3 continued to demonstrate significantly better results compared with Groups 1 and 2. At Timepoint 4 (12 months after treatment initiation), Groups 2 and 3 showed identical results (p = 1.0) and a statistically significant advantage over Group 1 (p = 0.003 for both Groups 2 and 3).

*Table 2*

**Comparative analysis of the medians of daily activity indicators**

| Parameter | | Group (Me) | | | Mann-Whitney U test (p) | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| FFI | Before treatment | 68.0 | 67.5 | 70.0 | 0.120 | 0.100 | 0.661 |
| | 1month | 31.0 | 19.0 | 17.5 | 0.008 | 0.007 | 0.036 |
| | 3 months | 35.0 | 12.0 | 4.5 | 0.004 | 0.000 | 0.000 |
| | 6 months | 41.0 | 5.0 | 0.0 | 0.002 | 0.000 | 0.000 |
| | 12 months | 60.5 | 0.0 | 0.0 | 0.003 | 0.003 | 1.000 |
| FAAM (ADL) | Before treatment | 49.0 | 46.5 | 47.5 | 0.305 | 0.579 | 0.923 |
| | 3 months | 67.0 | 85.0 | 90.5 | 0.006 | 0.003 | 0.042 |
| | 6 months | 66.0 | 94.5 | 99.5 | 0.055 | < 0.001 | 0.002 |
| | 12 months | 57.0 | 100.0 | 100.0 | 0.003 | 0.003 | 1.000 |

Empirical value of the Mann-Whitney U test and the exact p-value in 1 – comparison of indicators for Groups 1 and 2; 2 – comparison of indicators for Groups 1 and 3; 3 – comparison of indicators for Groups 2 and 3.

In the intergroup analysis of FAAM (ADL) scores, at Timepoint 1 (3 months after treatment initiation), Group 3 demonstrated a statistically significant advantage compared with Groups 1 and 2 (vs. Group 1: p = 0.003; vs. Group 2: p = 0.042). At Timepoint 2 (6 months after treatment initiation), Group 3 also showed a statistically significant advantage over Groups 1 and 2 (vs. Group 1: p = 0.001; vs. Group 2: p = 0.002). At Timepoint 3 (12 months after treatment initiation), Groups 2 and 3 showed identical results (p = 1.0) and a statistically significant advantage over Group 1 (p = 0.002 for both Groups 2 and 3).

## DISCUSSION

Plantar heel pain is a common clinical issue that remains both relevant and, in many respects, controversial. Due to the complex anatomical structure of the heel and foot, the etiology of pain, as well as the associated dysfunction and alterations in foot biomechanics, may be attributed to a variety of factors [14]. Traditionally, three main categories of causes of PHP are distinguished: mechanical – related to pathology of the proximal, middle, or distal portions of the plantar fascia, its ruptures, or stress fractures of the calcaneus; rheumatologic – development of localized pain syndrome in the setting of ankylosing spondylitis, Reiter's syndrome, or other seronegative spondyloarthropathies; neurologic – occurring in cases of L5-S1 radiculopathy or compression of the first branch of the lateral plantar nerve (Baxter's nerve) [15].

The focus of the present study was PHP caused by pathology of the proximal portion of the plantar fascia. According to J. Perry's concept, this condition arises due to the overstress of the plantar fascia during heel lift-off and weight transfer to the forefoot while walking. In his view, because of the fascia's low elasticity, tensile forces are primarily exerted on the calcaneal tuberosity during the push-off phase, and these forces increase with dorsiflexion of the metatarsophalangeal joints. In addition, the gastrocnemius-soleus muscle complex further concentrates stress in the area of the plantar fascia, significantly enhancing the overall loading effect [16]. Morphological changes in the structure of the proximal plantar fascia, resulting from a tendinosis cycle triggered by chronic foot overload, include decreased collagen synthesis or progressive collagen degeneration, tenocyte death, and matrix degradation. These changes, in turn, further increase the fascia's susceptibility to injury [17].

Pain chronification and the ineffectiveness of traditional conservative treatment protocols, which include functional stretching and strengthening of the foot's extensor apparatus, use of orthopedic supports, anti-inflammatory therapy, various local injection and cell-based therapies, as well as physical and radiation modalities, necessitate consideration of more invasive therapeutic approaches. At the same time, ESWT, which has proven highly effective during the acute phase of the condition, remains a relevant treatment option in cases of PHP relapse or when the patient declines surgical intervention.

According to M. Thiel, ESWT is a pathogenetically justified treatment modality as it optimizes reparative processes through microtrauma of avascular or poorly vascularized tissues, which in turn leads to the release of local growth factors, stimulation of revascularization, and ultimately more effective tissue remodeling [18]. Several multicenter studies evaluating the efficacy of low-energy ESWT for chronic heel pain have reported up to 86% favorable outcomes [19, 20]. D.S. Hammer et al. demonstrated similar results – 80% of 49 patients with heel pain experienced complete or near-complete relief after three weekly ESWT sessions [21]. M.I. Ibrahim et al. reported that during a two-year follow-up, all patients noted a 90% reduction in pain compared to baseline [22]. C. Schmitz et al., based on a systematic review, recommended that all patients aged 18 and older with proximal PF undergo a course of ESWT prior to surgical intervention [23]. However, H. Gollwitzer et al. argued that the efficacy of ESWT remains controversial, and the procedure does not guarantee clinical improvement in cases of chronic PHP [24]. Published series of studies have also reported highly heterogeneous results with high-energy ESWT, ranging from 56 to 94% success rates [25].

Conclusions regarding the relatively low efficacy of ESWT in chronic pathological processes were presented in the study by T. Erden et al. [26]. The sonographic and functional results of our study confirmed the reduced effectiveness of ESWT in treating PHP caused by proximal PF.

Despite the statistical identity of the absolute values of plantar fascia thickness in the affected limb across all groups at baseline, as measured by ultrasound and exceeding the corresponding values of the contralateral limb by 1.7-2.1 times, the plantar fascia thickness in the ESWT group increased by the third month of the study and only decreased by 6.6% by the sixth month after treatment completion. This value remained significantly higher than the thickness of the intact fascia, indirectly indicating a continuing degenerative process.

The recurrent nature of the disease course was also confirmed by the analysis of pain severity using the FFI. Following ESWT, a more than twofold reduction in PHP was observed during the first month after treatment. However, pain intensity increased at 3 and 6 months, and by the 12-month follow-up, the values had nearly returned to baseline, showing only an 11% reduction. Functional assessments of the foot during activities of daily living and various work-related tasks demonstrated a similar pattern: an increase of 25.5 and 29.0% during the first month, stabilization at this level over the next 6 months, followed by a gradual decline between months 6 and 12, ultimately exceeding baseline values by 18.0 and 21.0%, respectively. These findings indicate an almost complete loss of the initial therapeutic effect. Overall, our results suggest a low efficacy of ESWT in treating patients with chronic proximal PF.

Bipolar radiofrequency ablation affects regenerative processes in the plantar fascia differently. Rapid pain relief immediately following treatment is primarily due to denervation, followed by subsequent regenerative processes, including stimulation of angiogenesis in the avascular fibrous fascia through increased secretion of fibroblast growth factors and vascular endothelial growth factor. Radiofrequency treatment does not significantly compromise the mechanical strength of the fascia, does not cause serious complications, and demonstrates favorable early outcomes in the treatment of PHP [27]. F. Yapici et al. unequivocally recommended switching to alternative treatments, with BRFA being the preferred option, in cases where ESWT was ineffective [28].

In a 2023 study, N.P. Tas and O. Kaya compared outcomes of 79 patients treated with BRFA and 80 patients receiving ESWT on the plantar fascia. The authors reported that both procedures significantly reduced pain, disability, and activity limitation. ESWT was particularly effective in early pain reduction, whereas BRFA demonstrated a more pronounced effect on reducing disability and activity limitation [29].

Our study also demonstrated superior treatment outcomes with BRFA compared to ESWT. The analysis of the ultrasound measurements of the dorsal-plantar dimensions of the proximal plantar fascia revealed significant positive changes by the end of the third month post-treatment. By six months, fascia thickness had decreased by one-third compared to baseline, showing statistically significant improvement over the corresponding values observed with ESWT. Unlike the findings reported in the aforementioned study, BRFA in our investigation led to a significant reduction in the FFI as early as the first month of treatment, with a sustained positive effect throughout the follow-up period and marked alleviation of PHP by the sixth month. This contrasted sharply with the outcomes following ESWT. Moreover, during the initial three months of the follow-up, only minor functional limitations of the foot and ankle during walking and various work-related activities persisted, enabling patients to restore mobility and work capacity. From months 6 to 12, functional outcomes approximated those of the healthy limb, fully satisfying all study participants.

Alternative treatment methods to BRFA that lead to pain reduction and improvement of foot biomechanics include surgical procedures based on the concept of plantar fascia lengthening aimed at reducing its tension [30]. Endoscopic plantar fascia release is considered a safe and effective alternative; however, its significant drawback is poor visualization and a high risk of unintentional excessive transection [31]. A.M. Brugh et al. demonstrated that regardless of the surgical technique chosen, transection of more than 50% of the plantar fascia diminishes its supportive function and results in overload pain in the dorsal and lateral aspect of the foot, leading to the development of the so-called “lateral column syndrome” [32].

The short- and long-term outcomes of open release and percutaneous BRFA were reported by Y. Yuan et al. According to their data, both surgical procedures demonstrated equivalent long-term therapeutic effects, with a mean follow-up duration of 58.77 months. However, the authors noted that percutaneous BRFA was superior in terms of reduced operative time and an uncomplicated postoperative course. Additionally, patients undergoing percutaneous BRFA experienced a shorter recovery period for the restoration of normal motor function compared to those treated with open plantar fascia release [33].

In our opinion, it is also important to consider that the therapeutic effect of surgical lengthening may partly result from the enforced period of rest dictated by the postoperative protocol. At the same time, mere reduction of plantar fascia tension without stimulation of collagen regeneration is likely to create conditions for a more prolonged disease course and patient socialization. Taking this into account, the concept of combining microperforations with marginal microtenotomies performed using a bipolar needle radiofrequency electrode allows: first, to achieve a faster analgesic effect through denervation of pathological nerve endings; second, to achieve greater lengthening of the plantar fascia, thereby further reducing its tension; and third, to potentiate regeneration, consequently ensuring a more complete and earlier restoration of limb function.

Ultrasound imaging with analysis of plantar fascia thickness, echotexture, and echogenicity is widely recognized by most authors as an accessible method for diagnosing and objectively assessing treatment outcomes in patients with proximal PF [34]. The results of our study confirmed this assumption. Sonographic measurements of fascia thickness in the main group, which initially showed high baseline values, demonstrated superior dynamics with complete normalization of fascia dimensions by the sixth month of treatment. Moreover, only in the main group did the plantar fascia thickness of the affected limb become not only closest to that of the intact limb but also statistically indistinguishable from it ($p = 1.0$). Meanwhile, among the wide range of subjective methods for monitoring treatment efficacy, assessment of pain reduction and restoration of foot and ankle function remains the most informative [35]. According to the pain subscale of the FFI, by the third month, only patients in the main group had scores that exceeded MDC by less than two times, in contrast to the comparison group (almost eightfold MDC exceedance) and the control group (MDC exceedance by 12.8 times). Complete pain relief was achieved within the first six months of follow-up, earlier than in patients of the other groups. In our opinion, sufficient recovery of foot function and daily activity had already been achieved by the 3-month follow-up (a clinically insignificant exceedance of MDC in the FAAM (ADL) by 1.54 times).

## Study limitations

The limitation of our study is the relatively small sample size, which is attributable to the strict inclusion and non-inclusion criteria, as well as the limited follow-up period of 12 months. Further research is needed to evaluate the long-term outcomes of the proposed treatment method over a five-year period.

## CONCLUSIONS

The modified minimally invasive bipolar radiofrequency ablation technique proposed in this study for the treatment of refractory proximal plantar fasciopathy demonstrated superior clinical outcomes, including complete resolution of plantar heel pain and earlier restoration of foot function, when compared to both standard bipolar radiofrequency ablation and a course of extracorporeal shock wave therapy. The use of modified bipolar radiofrequency ablation helped to interrupt the degenerative cycle of tendinopathy by applying an etiopathogenetic approach, which successfully combined reduction of plantar fascia tension with partial denervation and activation of collagen regeneration. These findings appear promising and suggest that the modified technique may be considered a preferred treatment option in cases where all types of conservative therapy fail within a six-month period.

## DISCLAIMERS

### *Author contribution*

*Silantjev V.N.* — study concept and design, data acquisition, literature search and review, drafting the manuscript.

*Dzuba G.G.* — scientific guidance, drafting and editing the manuscript.

*Katina M.M.* — data acquisition, analysis and interpretation, statistical data processing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

***Funding source.*** This study was not supported by any external sources of funding.

***Disclosure competing interests.*** The authors declare that they have no competing interests.

***Ethics approval.*** The study was approved by the local ethics committee of Omsk State Medical University, protocol No 9, 13.09.2024.

***Consent for publication.*** The authors obtained written consent from patients to participate in the study and publish the results.

## REFERENCES

1. Brody D.M. Running injuries. Prevention and management. *Clin Symp.* 1987;39(3):1-36.
2. Rasenberg N., Bierma-Zeinstra S.M., Bindels P.J., van der Lei J., van Middelkoop M. Incidence, prevalence, and management of plantar heel pain: a retrospective cohort study in Dutch primary care. *Br J Gen Pract.* 2019;69(688):e801-e808. https://doi.org/10.3399/bjgp19X706061.
3. Monteagudo M., de Albornoz P.M., Gutierrez B., Tabuenca J., Álvarez I. Plantar fasciopathy: A current concepts review. *EFORT Open Rev.* 2018;3(8):485-493. https://doi.org/10.1302/2058-5241.3.170080.
4. Buchanan B.K., Sina R.E., Kushner D. Plantar Fasciitis. [Updated 2024 Jan 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. Available from: https://www.ncbi.nlm.nih.gov/books/NBK431073/.
5. Nayar S.K., Alcock H., Vemulapalli K. Surgical treatment options for plantar fasciitis and their effectiveness: a systematic review and network meta-analysis. *Arch Orthop Trauma Surg.* 2023;143(8):4641-4651. https://doi.org/10.1007/s00402-022-04739-0.
6. Hasegawa M., Urits I., Orhurhu V., Orhurhu M.S., Brinkman J., Giacomazzi S. et al. Current Concepts of Minimally Invasive Treatment Options for Plantar Fasciitis: a Comprehensive Review. *Curr Pain Headache Rep.* 2020;24(9):55. https://doi.org/10.1007/s11916-020-00883-7.
7. Kantor B., McKenna C.J., Caccitolo J.A., Miyauchi K., Reeder G.S., Mullany C.J. et al. Transmyocardial and percutaneous myocardial revascularization: current and future role in the treatment of coronary artery disease. *Mayo Clin Proc.* 1999;74(6):585-592. https://doi.org/10.4065/74.6.585.
8. Gunes T., Bilgic E., Erdem M., Bostan B., Koseoglu R.D., Sahin S.A. et al. Effect of radiofrequency microtenotomy on degeneration of tendons: an experimental study on rabbits. *Foot Ankle Surg.* 2014;20(1):61-66. https://doi.org/10.1016/j.fas.2013.11.003.
9. Domingo-Marques S., Nieto-García E., Fernández-Erhling N., Ramírez-Andrés L., Vicente-Mampel J., Ferrer-Torregrosa J. Efficacy of Radiofrequency by the Topaz Technique for Chronic Plantar Fasciopathy: Systematic Review and Meta-Analysis. *J Clin Med.* 2025; 14(8):2843. https://doi.org/10.3390/jcm14082843.
10. Orlova E.V., Surnov A.V., Karateev D.E., Amirdzhanova V.N. Validation of a Russian-language version of the Foot Functional Index (FFI) questionnaire. *Modern Rheumatology Journal.* 2016;10(3):47-51. (In Russian). https://doi.org/10.14412/1996-7012-2016-3-47-51.
11. Martinez B.R., Staboli I.M., Kamonseki D.H., Budiman-Mak E., Yi L.C. Validity and reliability of the Foot Function Index (FFI) questionnaire Brazilian-Portuguese version. *Springerplus.* 2016;5(1):1810. https://doi.org/10.1186/s40064-016-3507-4.
12. Lutsenko A.M., Kerimova L.G., Prizov A.P., Ananyin D.A., Lazko F.L. Cross-cultural adaptation and validation of the Russian version of the Foot and Ankle Ability Measures (FAAM-Ru). *Clinical and Experimental Surgery. Petrovsky Journal.* 2024;12(1):135-140. (In Russian). https://doi.org/10.33029/2308-1198-2024-12-1-135-140.
13. Martin R.L., Irrgang J.J., Burdett R.G., Conti S.F., Van Swearingen J.M. Evidence of validity for the Foot and Ankle Ability Measure (FAAM). *Foot Ankle Int.* 2005;26(11): 968-983. https://doi.org/10.1177/107110070502601113.
14. Allam A.E., Chang K.V. Plantar Heel Pain. [Updated 2024 Jan 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. Available from: https://www.ncbi.nlm.nih.gov/books/NBK499868/.
15. Choudhary Sh., Sathe A., Kumar D.V. Baxter's Nerve Entrapment: The Missing Nerve. *Arch Med Health Sci.* 2024;12(2):284-285. https://doi.org/10.4103/amhs.amhs_273_23.
16. Perry J. Anatomy and biomechanics of the hindfoot. *Clin Orthop Relat Res*. 1983;(177):9-15.
17. Khan K.M., Cook J.L., Taunton J.E., Bonar F. Overuse tendinosis, not tendinitis part 1: a new paradigm for a difficult clinical problem. *Phys Sportsmed.* 2000;28(5):38-48. https://doi: 10.3810/psm.2000.05.890.
18. Thiel M. Application of shock waves in medicine. *Clin Orthop Relat Res.* 2001;(387):18-21. https://doi.org/10.1097/00003086-200106000-00004.
19. Helbig K., Herbert C., Schostok T., Brown M., Thiele R. Correlations between the duration of pain and the success of shock wave therapy. *Clin Orthop Relat Res.* 2001;(387):68-71. https://doi.org/10.1097/00003086-200106000-00009.

20. Rompe J.D., Schoellner C., Nafe B. Evaluation of low-energy extracorporeal shock-wave application for treatment of chronic plantar fasciitis. *J Bone Joint Surg Am.* 2002;84(3):335-341. https://doi.org/10.2106/00004623-200203000-00001.
21. Hammer D.S., Rupp S., Kreutz A., Pape D., Kohn D., Seil R. Extracorporeal shockwave therapy (ESWT) in patients with chronic proximal plantar fasciitis. *Foot Ankle Int.* 2002;23(4):309-313. https://doi.org/10.1177/107110070202300403.
22. Ibrahim M.I., Donatelli R.A., Hellman M., Hussein A.Z., Furia J.P., Schmitz C. Long-term results of radial extracorporeal shock wave treatment for chronic plantar fasciopathy: A prospective, randomized, placebo-controlled trial with two years follow-up. *J Orthop Res.* 2017;35(7):1532-1538. https://doi.org/10.1002/jor.23403.
23. Schmitz C., Császár N.B., Rompe J.D., Chaves H., Furia J.P. Treatment of chronic plantar fasciopathy with extracorporeal shock waves (review). *J Orthop Surg Res.* 2013;8:31. https://doi.org/10.1186/1749-799X-8-31.
24. Gollwitzer H., Saxena A., DiDomenico L.A., Galli L., Bouché R.T., Caminear D.S. et al. Clinically relevant effectiveness of focused extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis: a randomized, controlled multicenter study. *J Bone Joint Surg Am.* 2015;97(9):701-708. https://doi.org/10.2106/JBJS.M.01331.
25. Rompe J.D., Furia J., Weil L., Maffulli N. Shock wave therapy for chronic plantar fasciopathy. *Br Med Bull.* 2007;81-82:183-208. https://doi.org/10.1093/bmb/ldm005.
26. Erden T., Toker B., Cengiz O., Ince B., Asci S., Toprak A. Outcome of Corticosteroid Injections, Extracorporeal Shock Wave Therapy, and Radiofrequency Thermal Lesioning for Chronic Plantar Fasciitis. *Foot Ankle Int.* 2021;42(1):69-75. https://doi.org/10.1177/1071100720949469.
27. Sean N.Y., Singh I., Wai C.K. Radiofrequency microtenotomy for the treatment of plantar fasciitis shows good early results. *Foot Ankle Surg.* 2010;16(4): 174-177. https://doi.org/10.1016/j.fas.2009.10.008.
28. Yapici F., Gur V., Sari I.F., Karakose R., Tardus I., Ucpunar H. Which Treatment Method Is Better in the Treatment of Chronic Plantar Fasciitis: Corticosteroid Injection, Extracorporeal Shock Wave Therapy, or Radiofrequency Thermal Lesioning? *J Am Podiatr Med Assoc.* 2023;113(5):21-049. https://doi.org/10.7547/21-049.
29. Tas N.P., Kaya O. Treatment of Plantar Fasciitis in Patients with Calcaneal Spurs: Radiofrequency Thermal Ablation or Extracorporeal Shock Wave Therapy? *J Clin Med.* 2023;12(20):6503. https://doi.org/10.3390/jcm12206503.
30. Sereda A.P., Moysov A.A., Smetanin S.M. Plantar fasciitis: diagnosis and treatment. *Sibirskij Nauchnyj Medicinskij Zhurnal.* 2016;143(4):5-9. (In Russian).
31. Sarrafian S.K. Functional characteristics of the foot and plantar aponeurosis under tibiotalar loading. *Foot Ankle.* 1987;8(1):4-18. https://doi.org/10.1177/107110078700800103.
32. Brugh A.M., Fallat L.M., Savoy-Moore R.T. Lateral column symptomatology following plantar fascial release: a prospective study. *J Foot Ankle Surg.* 2002;41(6):365-371. https://doi.org/10.1016/s1067-2516(02)80082-5.
33. Yuan Y., Qian Y., Lu H., Kou Y., Xu Y., Xu H. Comparison of the therapeutic outcomes between open plantar fascia release and percutaneous radiofrequency ablation in the treatment of intractable plantar fasciitis. *J Orthop Surg Res.* 2020;15(1):55. https://doi.org/10.1186/s13018-020-1582-2.
34. Wang X., Xu L., Hu X., Zhao H., Yin J. Musculoskeletal Ultrasound for the Diagnosis of Plantar Fasciitis: An Accuracy and Diagnostic Yield Study. *Int J Gen Med.* 2023;16:4765-4771. https://doi.org/10.2147/IJGM.S434182.
35. Whittaker G.A., Munteanu S.E., Roddy E., Menz H.B. Measures of Foot Pain, Foot Function, and General Foot Health. *Arthritis Care Res (Hoboken)*. 2020;72 (Suppl 10): 294-320. https://doi.org/10.1002/acr.24208.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