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ORIGINAL ARTICLE

The effect of extracorporeal shock wave therapy for the treatment of plantar fasciitis in regard to middle-aged patients' activity level and pain localization

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Abstract
In this retrospective cohort study, we compared the efficacy of extracorporeal shock wave therapy (ESWT) for plantar fasciitis in patients with different activity levels and different pain locations. In total, 92 patients (99 feet) who were over 40 years old with chronic plantar fasciitis were treated with ESWT after being categorized as participating in recreational sports (group R) or only activities of daily living (group D). On the other hand, patients were categorized as having pain in the plantar fascia enthesis (group E) or the entire plantar fascia (group W). Pain during activity and general tenderness were evaluated by using the visual analog scale (VAS) before and after ESWT. Although the VAS for pain score during activity significantly improved in both groups R and D after ESWT ($P < 0.001$ in both groups), the degree of improvement in the VAS for pain score in group R was not significantly different from that in group D ($P = 0.061$). The VAS for tenderness score also significantly improved in both groups R and D ($P < 0.001$ in both groups), but there was also no significant difference between the degree of improvement in the VAS for tenderness in group R and that in group D ($P = 0.41$). However, the degree of improvement in the VAS for pain and VAS for tenderness scores was significantly greater in group E than that in group W ($P < 0.001, = 0.042$, respectively). We concluded that ESWT was effective for treating plantar fasciitis in middle-aged patients and ESWT was effective in patients not only playing recreational sports but also having activities of daily living. ESWT was more effective in patients with pain in the plantar fascia enthesis than in patients with pain in the entire plantar fascia.

Keywords Plantar fasciitis · Extracorporeal shock wave therapy · Visual analog scale

1 Introduction

Plantar fascia is the thick aponeurosis which reaches from the tuberosity of the calcaneus tuberosity to the heads of the metatarsals (Fig. 1). Most of plantar fasciitis is enthesopathy which is microrupture or inflammation because of traction by plantar fascia, and the other is degeneration of the whole plantar fascia. Plantar fasciitis is a common disease that often improves with conservative treatments including rest, medication, local injection of anesthetics and steroids, hot pack application, and physiotherapy [1]. However, operative therapy may be performed in patients with prolonged, intractable symptoms [2–4]. Recently, extracorporeal shock wave therapy (ESWT) has been used as a treatment for musculoskeletal diseases. Formerly, ESWT was primarily used in Europe and the USA to treat prolonged and nonunion fractures [5]. When ESWT was found to effectively reduce pain, it began to be used for treating enthesopathy, including chronic Achilles tendinopathy, calcific tendinitis of the shoulder, supraspinatus tendinitis, and lateral epicondylitis [6–10]. In Japan, ESWT treatment for plantar fasciitis was approved in 2008, and, in April 2012, it was covered under national health insurance for patients with refractory plantar fasciitis for whom conservative treatment was ineffective. Since then, there has been a significant amount of Japanese studies describing the efficacy of ESWT for various diseases.

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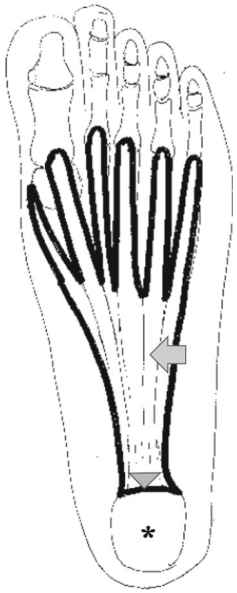

Fig. 1 Anatomy of plantar fascia from the plantar side of the left foot. The arrow shows the plantar fascia, and the downward pointing arrow head represents the enthesis of plantar fascia to calcaneus. Asterisk: calcaneus bone

Although ESWT is available in combination with conservative treatments, few hospitals have ESWT equipment. Several studies concerning the efficacy of ESWT for treating plantar fasciitis have involved only athletes [11,12]. Recently, an increasing number of middle-aged and elderly people are participating in relatively high-activity sports, and we consider that plantar fasciitis is being diagnosed more often in these individuals as well as those involved only in activities of daily living.

First, to our knowledge, there are few studies on the relationship between the level of sports activity and the efficacy of ESWT in middle-aged and elderly patients with plantar fasciitis. We hypothesized the efficacy of ESWT was associated with a patient's activity level, and in this study we retrospectively assessed the effect of ESWT on plantar fasciitis in this population and examined the relationship between the patient's activity levels and elimination of pain by ESWT. Second, there has been no study on the relationship between pain location and the efficacy of ESWT. We also hypothesized the efficacy of ESWT was associated with pain location, and we examined the relationship between pain location and elimination of pain by ESWT.

2 Patients and methods

Patients who received more than three months of conservative treatment other than ESWT for chronic plantar fasciitis were candidates for inclusion in the current study, and we retrospectively researched their medical records. We based our diagnosis on clinical symptoms and ultrasonography images. The criteria used to diagnose plantar fasciitis included the presence of pain while walking or playing sports with the location of maximum tenderness around the plantar fascia enthesis [1,13]. In addition, although we had MRI (magnetic resonance imaging) data of a few patients, an ultrasonography test was done for most patients. Inclusion criteria included use of conservative treatment such as oral nonsteroidal anti-inflammatory drugs, fomentation, physiotherapy, and foot braces for more than three months and age above 40 years. Then, initially 138 patients (150 feet) underwent ESWT between November 2011 and March 2016. Patients were excluded from this study if their pain was due to trauma, previous surgery, inflammation disease, or rheumatoid arthritis. In addition, patients were excluded who did not have data such as visual analog scale (VAS) for pain VAS for tenderness, and location of pain. A total of 92 patients (99 feet), with an average age of 59.9 (range 40–85) years, were ultimately included in this study. We evaluated pain in activity or walking and tenderness in plantar fascia by using a visual analog scale (VAS): On a straight line of 100 mm where the left end point was defined as "no pain" and the right end point as "severest pain until now," the patients drew a line indicating the degree of their pain.

The patients were initially divided into two groups by activity levels. Group R was comprised of 40 feet that had routinely recreational sports, more often than one day every week or every other week. Group D was comprised of 59 feet that participated only in activities of daily living. We evaluated activity-related pain that developed in the soles of the feet while walking (group D) and while participating in sports (group R) and general tenderness (groups R and D). VAS rating of pain or tenderness was used prior to and after ESWT treatment. We analyzed VAS data in each foot, not in patients. Individual pre- and post-ESWT VAS scores were obtained, and the change in VAS scores between pre- and post-ESWT was compared in each group. The degree of improvement in the VAS score was also compared between two groups.

On the other hand, we divided the patients into two groups by location of pain. Group E consisted of 84 feet with pain at the plantar fascia enthesis of the calcaneus while walking, and group W consisted of 15 feet with pain in the entire plantar fascia. The pre- and post-ESWT VAS scores were compared between these groups.

2.1 ESWT procedure

ESWT was performed by two clinicians at one hospital using an Epos Ultra (Dornier Med Tech, Wessling, Germany). The Epos Ultra has 7.3–39.5 MPa as the maximum pressure and 0.03–0.36 mJ/mm^2 as the consistency of the energy of the shock wave. The focal range of the pressure distribution of shock wave is 4.9 mm × 26.0 mm. The focal location was confirmed in the plantar fascia at the point of severest tenderness by using ultrasonography (Fig. 2). ESWT began at Level 1 (0.03 mJ/mm^2, 50 shots) and increased to a maximum output of Level 7 (0.36 mJ/mm^2, 3500 shots), step by step. Finally, we aimed for 1300 mJ/mm^2 as the total energy expo-

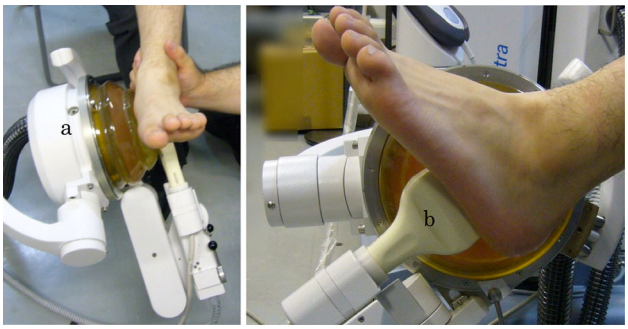

Fig. 2 Shock wave generator and position of patients' foot during ESWT. **a** Shock wave generator, **b** ultrasonography probe

sure. None of the patients was anesthetized. Patients who experienced improvement after a single ESWT session did not undergo a second session. The need for a second session was determined by patient self-assessment of residual pain during activity or general tenderness. When a second ESWT treatment was indicated, it was performed three weeks after the first. ESWT was performed until the patient was satisfied with the reduction in pain but was limited to five applications overall. All patients were re-examined for four months. During the follow-up, the patients were monitored for potential side effects including skin redness, exacerbation of the pain to the point that it was unbearable, and rupture of the plantar fascia.

2.2 Statistical analysis

In groups R and D as well as in groups E and W, the pre- to post-ESWT change in VAS was examined using the Wilcoxon signed-rank test. To compare the degree of improvement in the VAS from pre- to post-ESWT between groups, we used the Mann–Whitney *U* test. The statistical analysis was performed using the IBM SPSS statistics version 21 (IBM, Armonk, NY, USA). A probability value (*P*) of 0.05 was considered statistically significant.

3 Results

There were 33 feet which underwent one application of ESWT, 35 feet with two applications, 29 feet with three applications, and 2 feet with five applications.

Figure 3 shows the results of the VAS for pain score during activity in groups R and D. In the figure, bars indicate the range of data, not the standard deviation. We use a nonparametric statistical analysis in this study. The differences between the VAS for pain score during activity pre- and post-ESWT were significant in both groups R and D ($P < 0.001$ in both groups). Figure 4 shows the results of the VAS for tenderness score in groups R and D. The VAS for tenderness scores also improved significantly in both groups R and D

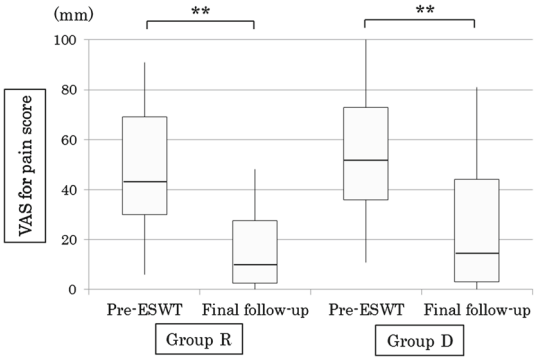

Fig. 3 VAS for pain score during activity in groups R and D. In both groups, a significant difference between the VAS scores of pre- and post-ESWT is obvious: group R pre-ESWT: median; 42.0, Q1; 30.0, Q3; 69.0 mm and post-ESWT: median; 8.0, Q1; 2.5, Q3; 27.5 mm; ($P < 0.001$). Group D pre-ESWT: median; 52.0, Q1; 36.0, Q3; 73.0 mm and post-ESWT: median; 14.0, Q1; 3.0, Q3; 44.0 mm; ($P < 0.001$). $^{**}P < 0.01$

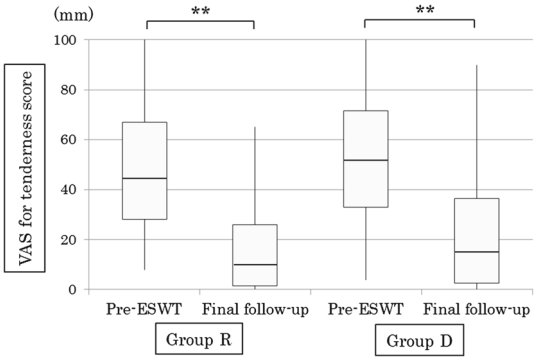

Fig. 4 VAS for tenderness score in groups R and D. In both groups, a significant difference between the VAS scores of pre- and post-ESWT is obvious: group R pre-ESWT: median; 43.0, Q1; 28.0, Q3; 67.0 mm and post-ESWT: median; 9.0, Q1; 1.5, Q3; 26.0 mm; ($P < 0.001$). Group D pre-ESWT: median; 52.0, Q1; 33.0, Q3; 71.5 mm and post-ESWT: median; 16.0, Q1; 2.5, Q3; 36.5 mm; ($P < 0.001$). $^{**}P < 0.01$

($P < 0.001$ in both groups). The degree of improvement in the VAS for pain score in group R (mean 72.5%, range 0.0–100.0) was not significantly different from that in group D (mean 58.8%, range 0.0–100.0) ($P = 0.061$). There was also no significant difference between the degree of improvement in the VAS for tenderness in group R (mean 67.6%, range 35.9–100.0) and that in group D (mean 61.2%, range 2.7–100.0) ($P = 0.42$).

The results of comparison between group E and group W with respect to the location of pain in activity or tenderness are shown in Figs. 5 and 6. The differences between the VAS for pain score during activity pre- and post-ESWT were significant in both groups E and W ($P < 0.001$ in both groups) (Fig. 5). The VAS for tenderness scores also improved significantly in both groups E and W ($P < 0.001$, $P = 0.0043$, respectively) (Fig. 6). The degree of improvement in the VAS for pain score during activity was signifi-

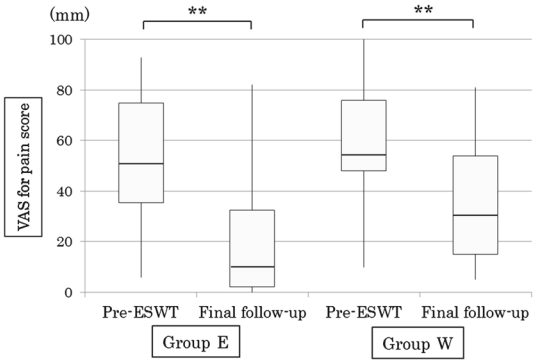

Fig. 5 VAS for pain score during activity in groups E and W. In both groups, a significant difference between the VAS scores of pre- and post-ESWT is obvious: group E pre-ESWT: median; 52.0, Q1; 35.5, Q3; 75.0 mm and post-ESWT: median; 10.0, Q1; 2.0, Q3; 32.5 mm; ($P < 0.001$). Group W pre-ESWT: median; 54.0, Q1; 48.0, Q3; 76.0 mm and post-ESWT: median; 32.0, Q1; 15.0, Q3; 54.0 mm; ($P < 0.001$). $^{**}P < 0.01$

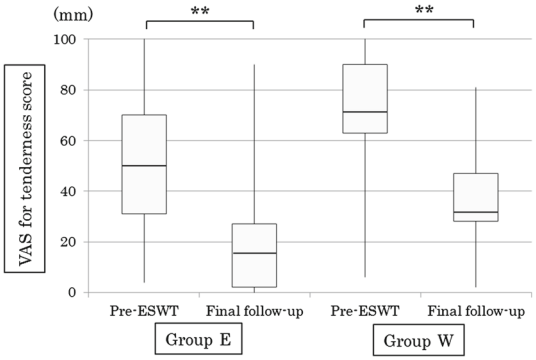

Fig. 6 VAS for tenderness score in groups E and W. In both groups, a significant difference between the VAS scores of pre- and post-ESWT is obvious: group E pre-ESWT: median; 49.5, Q1; 31.0, Q3; 70.0 mm and post-ESWT: median; 15.5, Q1; 2.0, Q3; 27.0 mm; ($P < 0.001$). Group W pre-ESWT: median; 69.0, Q1; 63.0, Q3; 90.0 mm and post-ESWT: median; 32.0, Q1; 28.0, Q3; 47.0 mm; ($P < 0.001$). $^{**}P < 0.01$

cantly greater in group E (mean 66.9%, range 0.0–100.0) than in group W (mean 42.9%, range 0.0–80.9) ($P = 0.0076$). Furthermore, the degree of improvement in the VAS for tenderness score during activity was significantly greater in group E (mean 64.3%, range 0.0–100.0) than in group W (mean 44.3%, range 0.0–84.0) ($P = 0.042$).

We defined a therapy failure as "worse pain after ESWT" or "occurrence of side-effects," for example skin redness. However, none of the patients experienced side effects from the ESWT treatment. Although the VAS score after a single ESWT session worsened slightly for a few patients, at the final follow-up after multiple ESWT treatments most patients had better scores post-ESWT than pre-ESWT.

4 Discussion

Recently, Gollwitzer et al. [14] reported a good effect of ESWT on recalcitrant plantar fasciitis, and Lou et al. [15] described the effectiveness of ESWT without local anesthesia by meta-analysis. Our outcome was a little better than that in those references. High-energy ESWT is reported to be more effective than low-energy treatment [16]. Therefore, we performed high-energy ESWT up to the level tolerable to the patient. We evaluated the effect of ESWT with VAS. The disadvantage of using VAS was that it is a subjective tool and therefore lacks objectivity. ESWT resulted in significant improvement in VAS score, confirming the efficacy of ESWT for treating plantar fasciitis in population of this study which was middle-aged or elderly patients. Kumai et al. [17] reported that calcaneal spurs are more similar to osteophytes than to traction spurs in a cadaver study examining the histological relationship between calcaneal spurs and the plantar fascia. They stated that degeneration influenced the clinical condition of plantar fasciitis, leading us to surmise that treatment of plantar fasciitis was age dependent. However, ESWT was an effective treatment for plantar fasciitis in middle-aged and elderly patients in this study and we considered ESWT may be effective for even tendinous degeneration. Although there was no significant difference of the degree of improvement in VAS for pain between group R (mean 72.5%) and group D (mean 58.9%), the effect of ESWT in patients involved in recreational sports might be superior to that in patients not involved in sports. For the patients involved in recreational sports, we believe that the pain was due to actual plantar fasciitis located in the enthesis of the calcaneus, whereas the pain in the individuals not playing sports was the result of degeneration of the plantar fascia.

To our knowledge, the relationship between the location of pain in the plantar fascia and the effect of ESWT has not been described in the literature. Ieong et al. reported that in plantar fasciopathy patients, there were 66% typical insertional diseases, 22% mixed insertional and distal diseases, and 12% pure distal diseases [18]. In this study, 15 feet (15.2%) were not a typical plantar fasciitis because the location of pain was not only at the insertion but also distal side. In the present study, the effect of ESWT in patients with pain throughout the plantar fascia was inferior to the effect in patients with pain at the plantar fascia enthesis of the calcaneus. Thus, we believe that the efficacy of ESWT depends on the location of the pain in the plantar fascia. The extracorporeal shock wave produces a treatment effect by passing through muscle and adipose tissue and releasing energy at the border of the bone due to the difference in impedance. Therefore, ESWT improves the clinical condition of the plantar fascia enthesis of the calcaneus more effectively than it does the entire plantar fascia. Thus, the benefits of ESWT may be fundamentally more difficult to achieve in patients with pain throughout the entire plantar fascia when the ESWT target site is far from the enthesis of the calcaneus. Furthermore, we speculate that the ESWT effect may be insufficient in patients with degeneration of the plantar fascia itself.

Some patients with plantar fasciitis refractory to conservative treatment now undergo endoscopic plantar fasciotomy. Othman et al. reported that endoscopic plantar fasciotomy was more effective than ESWT for reducing pain and provided greater patient satisfaction, six months after treatment [19]. However, because they showed that ESWT does not result in any complications or require immobilization and allows early resumption of full activity after treatment, we recommend attempting ESWT before performing endoscopic plantar fasciotomy.

There were limitations to this study. First, we did not have a control group to determine the placebo effect of ESWT. However, ESWT efficacy has previously been shown in prospective randomized studies and reviews [20–23]. Second, the diagnosis of the plantar fasciitis was made clinically and by using ultrasonography. The patients did not undergo magnetic resonance imaging to confirm the diagnosis. Because there may be several causes of plantar pain including calcaneal fat pad syndrome and plantar nerves, we believe that magnetic resonance image evaluation of plantar fasciitis must be included in future studies. Third, particularly group W had a relatively small number of patients. However, we considered that this study was specifically set up to determine that attention is necessary for those patients whose pain does not confine in the enthesis of plantar fascia to the calcaneus with plantar fasciitis when they receive ESWT treatment.

5 Conclusion

ESWT is an effective treatment for plantar fasciitis. Although the VAS for pain score during activity of patients who play recreational sports might have shown more improvement with ESWT than the score of patients who participate only in activities of daily living, this was not a statistically significant difference. ESWT is more effective in patients who have pain at the plantar fascia enthesis of the calcaneus than in patients who have pain throughout the entire plantar fascia.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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