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Magnetic resonance imaging findings of chronic plantar fasciitis before and after extracorporeal shock wave therapy

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ABSTRACT

Introduction: The objective of this study is to examine the relationships between treatment outcome and changes in magnetic resonance (MR) imaging findings after extracorporeal shock wave therapy (ESWT) for chronic plantar fasciitis.

Methods: The subjects were 23 feet of 23 patients of refractory plantar fasciitis. The mean age was 53.7 years. The thickness of the plantar fascia (PF) and findings of a high-signal intensity area (HSIA) inside the PF, edema around the PF, and bone marrow edema (BME) of the calcaneus were investigated on MR images. The Japanese Society for Surgery of the Foot (JSSF) ankle-hindfoot scale and a visual analogue scale (VAS) were used. Correlations between an improvement in symptoms and one in the MRI findings were analyzed.

Results: The mean thickness of the PF was 4.4 ± 1.6 mm before ESWT and 4.6 ± 1.8 mm six months after ESWT. After ESWT, there was a decrease in the numbers of feet showing HSIA inside the PF from 15 to 6, in edema around the PF from 16 to 2, and in BME of the calcaneus from 11 to 4. Clinical outcomes improved with ESWT from 70.3 ± 5.5 to 88.6 ± 9.1 points (JSSF), 74.1 ± 25.3 to 28.5 ± 24.4 points (VAS), respectively. Improvements in symptoms according to the JSSF and VAS scores and improvement in edema around the PF on MR images showed a significant correlation.

Conclusions: Edema around the PF improved significantly in association with an improvement in symptoms after ESWT.

1. Introduction

Plantar fasciitis is a typical disease that causes pain in the plantar calcaneus. Obesity [1], age [2], pes planus [3], pes cavus [4], tension of the Achilles tendon [5], and more have been said to be related to its etiology. Histopathologically, findings such as micro tearing of the plantar fascia (PF), degeneration and necrosis of the collagen fibers, angiofibroblastic hyperplasia, and calcification have reportedly been observed [6].

Plantar fasciitis is mainly treated conservatively. Stretching, bracing, drug therapy, and physical therapy have all been reported [7–12], but many cases have proven refractory. For refractory cases, fasciotomy has been performed. With fasciotomy, it has been reported that 80–85% of cases improve, but it has disadvantages, including postoperative scarring, nerve damage, a reduction of the longitudinal arch of the foot, and a long recovery period [13–15]. For about 20 years, extracorporeal shock wave therapy (ESWT) has been used for refractory plantar fasciitis. ESWT has the significant advantages of being less invasive and requiring a shorter recovery time than fasciotomy, and in many reports it has been stated as having a favorable outcome [16–20]. The mechanism of action of ESWT has been reported to be pain relief through stimulation of soft tissue healing by removal of inflammatory debris and promotion of neovascularization, reduction of calcification, and inhibition of pain receptors or denervation [21,22], but how ESWT exerts its pain-relieving effects on plantar fasciitis is unknown.

Various studies have been reported for imaging of plantar fasciitis [3,23]. Magnetic resonance images (MR images) in particular offers superior visualization of soft tissue and is optimal for assessing the condition of the tendons and ligaments [24]. MR images of plantar fasciitis have also been reported in the past, but the resulting findings are regarded as non-specific, and MR images were often performed for the purpose of differential diagnosis from another disease [25].

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However, thickening of the PF, T2 high signal intensity area in the fascia, edema around the PF, BME of the calcaneus, and more have been noted on MR images of plantar fasciitis [26–30] and it has been reported that associations with symptoms were observed. There is no prior report on the imaging findings of plantar fasciitis over time after ESWT, and the changes after ESWT are unknown. We therefore thought that and understanding of the changes in MRI findings from before to after ESWT may be useful for elucidating the mechanism of action of ESWT. The purpose of this study was to compare treatment outcomes and changes in MRI findings after ESWT for refractory plantar fasciitis, and examine the origins of the pain relief effects of ESWT.

2. Materials and methods

2.1. Patient population and treatment

A total of 23 feet in 23 patients (10 males, 13 females) of refractory plantar fasciitis that underwent ESWT in 2013 were studied. The patients' mean age was 55.3 years (range 16–81 years). Mean disease duration was 26.9 months (4–300 months), and the follow-up period was six months in all cases. The study was approved by the local university ethical committee. Written informed consent was obtained from all participants.

In terms of treatment strategy, conservative treatment, such as stretching of the PF and Achilles tendon, oral NSAIDs, bracing, and steroid injections, was performed first. Then, ESWT was performed if improvement was not seen after at least three months.

The extracorporeal shock wave pain relief device used was the Epos Ultra (Dornier MedTech, Tokyo, Japan). Treatments were provided by a physician, without anesthesia. Aiming at the PF attachment under ultrasonic guidance from the sole, irradiation with a total energy of 1300 mJ/mm^2 (about 3800 rounds, 1 shock = 0.03–0.36 mJ/mm^2) from the medial calcaneus [11,20,31] was performed. A second treatment was performed if symptoms persisted at three months after the first treatment.

2.2. Evaluation with MR imaging

All cases underwent MRI (Magnetom symphony 1.5-T, Siemens, Tokyo, Japan) of both feet before treatment, in a neutral position of ankle-plantar dorsiflexion. Then, six months after treatment, only the affected feet underwent MRI. On MR images, four items were examined: thickness of the PF, HSIA inside the PF, edema around the PF, and BME of the calcaneus. For the thickness of the PF, the maximum diameter of the PF at the calcaneal attachment was measured on T1-weighted coronal images [32] (Fig. 1a). STIR sagittal images and coronal images were used to investigate the other three items [26,30] (Fig. 1b–d). MRI findings were evaluated by specialists (MM and KI) in ankle surgery who are familiar with MR images.

2.3. Assessment of clinical outcomes

The Japanese Society for Surgery of the Foot ankle-hindfoot scale (JSSF score) [33,34] and a visual analogue scale (VAS) were used as clinical assessments, and they were evaluated before and six months after ESWT. The VAS was assessed by the patients themselves, with 100 mm being the most pain they had ever experienced and 0 mm being no pain [35]. Cases who scored 80 points or higher on the JSSF at six months after implementation were considered the JSSF improvement group [34], and cases whose VAS improved to 50% or lower from before implementation were considered the VAS improvement group [18].

2.4. Statistical analysis

The paired t-test was used to compare JSSF scores and VAS scores before and after ESWT. Spearman's rank correlation coefficient was used for the analysis of correlations in symptom improvement and improvement in the four MRI findings. A significant difference was set as $p < 0.05$.

3. Results

3.1. Clinical outcomes before and after ESWT

The mean VAS was 74.1 ± 25.3 mm before ESWT and 28.5 ± 24.4 mm six months after ESWT, representing a significant improvement ($p < 0.05$). The mean JSSF score was 70.3 ± 0.5 points before ESWT and 88.6 ± 9.1 points sixth months after ESWT, representing a significant improvement ($p < 0.05$). A significant difference between men and women was not observed on the VAS (Table 1, before ESWT: $p = 0.98$, after ESWT: $p = 0.24$) or the JSSF score (Table 1, before ESWT: $p = 0.11$, after ESWT: $p = 0.41$). Symptom improvement on the VAS occurred for 19 feet, and symptom improvement on the JSSF score occurred for 16 feet.

3.2. MRI findings

On MRI findings before ESWT, the mean thickness of the PF was 3.1 ± 1.0 mm for healthy feet and 4.4 ± 1.6 mm for affected feet, with a significant difference between the two groups ($p < 0.01$). HSIA inside the PF was observed in 0 healthy feet and 15 affected feet. Edema around the PF was observed in 0 healthy feet and 16 affected feet. BME of the calcaneus was observed in 0 healthy feet and 11 affected feet (Table 2). On MR images of affected feet after ESWT, thickness of the PF was 4.6 ± 1.0 mm, with no significant difference compared to before ESWT. HSIA inside the PF, edema around the PF, and BME of the calcaneus were observed in six feet, two feet, and four feet, respectively, after ESWT.

3.3. Correlation analysis

In the analysis of correlations between improvement in clinical assessment and one on MRI findings, a significant correlation with an improvement in edema around the PF was observed for both the VAS and JSSF score (Table 3, VAS: $R = 0.63$, $p < 0.01$, JSSF score: $R = 0.57$, $p < 0.01$).

4. Discussion

Four MRI findings have been reported in plantar fasciitis: thickening of the PF, edema around the PF, HSIA inside the PF, and BME of the calcaneus [26,27,29,32]. Thickening of the PF has been reported at a mean of 7.56 mm (10 feet) by Berkowitz et al. [26] and a mean of 6.69 mm (18 feet) by Zhu et al. [30]. The present study found a mean of 4.44 mm (23 feet), which is less than past reports, but the mean thickness was 3.1 mm in healthy feet, which means that the PF was significantly thickened in the affected feet. Conceivable reasons for why there was a difference from other past reports are the fact that in the present cases, the thickness had significant variance, between 2.0 and 8.1 mm, and there was also the possibility of racial differences. Regarding the other MRI findings, Grasel et al. [32] reported that of 56 feet, 76% had edema around the PF, 52% had HSIA inside the PF, and 56% had BME of the calcaneus. Maier et al. [28] reported that of 48 feet, 77% had edema around the PF, 87% had HSIA inside the PF, and 79% had BME of the calcaneus. The present study also found frequencies that were similar to previously reported cases, with 69.6% (16 feet) having edema around the PF, 65.2% (15 feet) having HSIA inside the PF, and 47.8% (11 feet) having BME of the calcaneus. When the healthy feet were also examined in the present study, the result was that none of these MRI findings were found in the healthy feet. It thus follows that these MRI findings are all abnormal findings that are

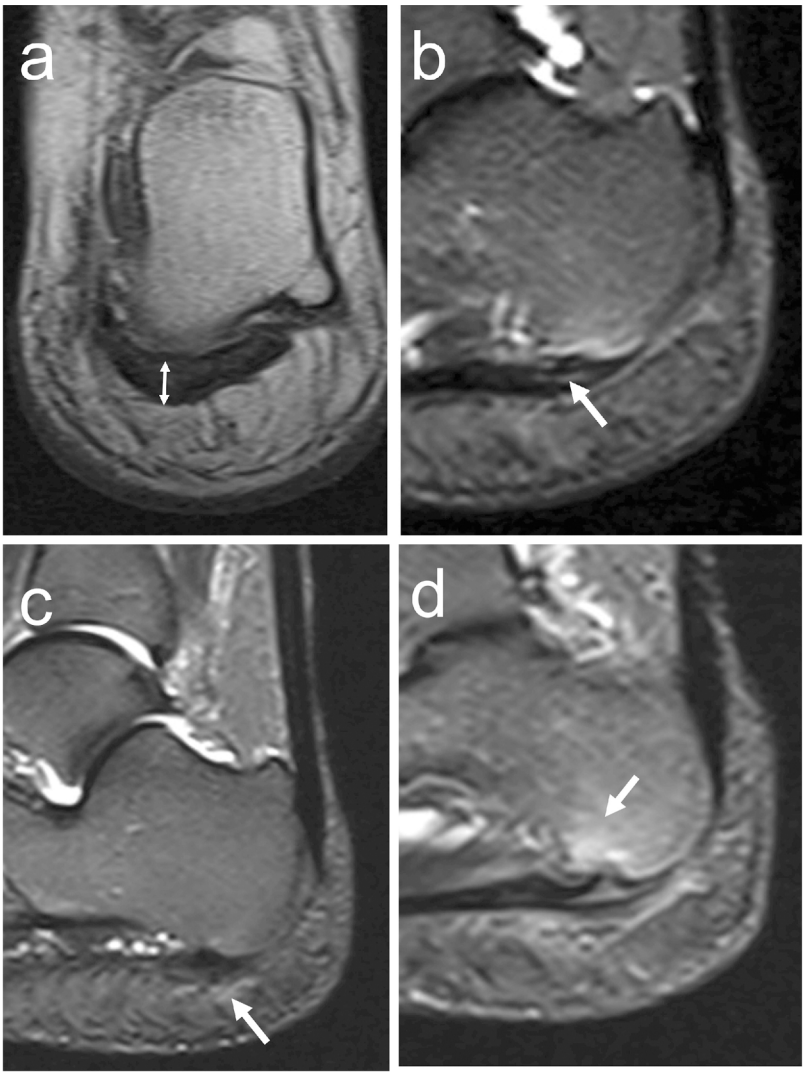

Fig. 1. (a) Thickness of the plantar fascia (PF) is measured on T1-weighted coronal images. (b) High-signal intensity area (HSIA; white arrow) inside the PF is studied using STIR images. (c) Edema (white arrow) around the PF is studied using STIR images. (d) Bone marrow edema (BME; white arrow) of the calcaneus is studied using STIR images.

Table 1
VAS and JSSF scores for all patients by sex.

	VAS before ESWT (mean ± SD)	VAS after ESWT (mean ± SD)	Improved group	Non-improved group
Female	74.2 ± 23.1	22.4 ± 25.2	10 feet	3 feet
Male	74.0 ± 29.1	34.5 ± 21.9	6 feet	4 feet
All	74.1 ± 25.3	28.5 ± 24.4	16 feet	7 feet
	JSSF before ESWT (mean ± SD)	JSSF after ESWT (mean ± SD)	Improved group	Non-improved group
Female	71.9 ± 0.3	90.2 ± 8.8	11 feet	2 feet
Male	68.2 ± 8.1	87.0 ± 9.2	8 feet	2 feet
All	70.3 ± 0.5	88.6 ± 9.1	19 feet	4 feet

VAS: visual analogue scale, JSSF score: Japanese Society for Surgery of the Foot ankle-hindfoot score, ESWT: extracorporeal shockwave therapy, SD: standard deviation.

Table 2
Magnetic resonance imaging findings prior to ESWT for symptomatic and asymptomatic feet.

	Symptomatic side	Asymptomatic side
Thickness of the PF	4.4 ± 1.6 mm	3.1 ± 1.0 mm
HSIA in the PF	15 feet	0 feet
Edema in the vicinity of PF	16 feet	0 feet
BME of the calcaneus	11 feet	0 feet

ESWT: extracorporeal shock wave therapy, PF: plantar fascia, HSIA: high signal intensity area, BME: bone marrow edema.

characteristic of plantar fasciitis.

There is a study that examined the relationship between pre-ESWT MRI findings and post-treatment outcomes. Maier et al. examined 48 feet and 43 cases and reported that bone marrow edema was a significant predictor of post-ESWT symptom improvement [28]. In a past study we conducted, 60 feet in 51 cases were examined, and HSIA inside the PF was reported to be a significant predictor of symptom improvement [36]. However, there has been no reported study on post-ESWT MRI findings.

The present report is the first to have evaluated relationships between symptoms and post-ESWT MRI findings. There was a correlation

Table 3
The correlations between improvement of clinical evaluations and magnetic resonance imaging findings before and 6 months after ESWT.

	Improvement of HSIA of PF	Improvement of edema in the vicinity of PF	Improvement of BME of the calcaneus
Improvement of VAS	R = 0.37 P = 0.06	R = 0.63 P < 0.01	R = 0.23 P = 0.29
Improvement of JSSF score	R = 0.40 P = 0.06	R = 0.57 P < 0.01	R = 0.30 P = 0.16

ESWT: extracorporeal shock wave therapy, VAS: visual analogue scale, JSSF score: Japanese Society for Surgery of the Foot ankle-hindfoot score, HSIA: high signal intensity area, PF: plantar fascia, BME: bone marrow edema.

between clinical assessment done by VAS and the JSSF score after ESWT and changes in edema around the PF. Edema around the PF has shown inflammation in the same area [26]. This leads us to believe that the fact that inflammation surrounding the PF is improved by the action of stimulation of soft tissue healing by removal of inflammatory debris and promotion of neovascularization in ESWT [21,22] may have contributed most to the improvement in clinical symptoms.

The limitations of this study include the small sample size and, in particular, the small number of cases with no improvement of symptoms. A study with an increased sample size might possibly also find a significant correlation with symptoms for HSIA inside the PF and BME of the calcaneus, as well, and future investigations are needed.

5. Conclusion

Relationships between MRI findings and ESWT treatment effects before and after ESWT for refractory plantar fasciitis were examined, and it was found that edema around the PF improves significantly in association with post-ESWT symptom improvement.

Conflicts of interest

The authors declare that they have no conflicts of interest in the research.

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References

[1] Rano JA, Fallat LM, Savoy-Moore RT. Correlation of heel pain with body mass index and other characteristics of heel pain. J Foot Ankle Surg 2001;40:351–6.
[2] Scher DL, Belmont Jr. PJ, Bear R, Mountcastle SB, Orr JD, Owens BD. The incidence of plantar fasciitis in the United States military. J Bone Joint Surg Am 2009;91:2867–72.
[3] Prichasuk S, Subhadrabandhu T. The relationship of pes planus and calcaneal spur to plantar heel pain. Clin Orthop Relat Res 1994;306:192–6.
[4] Werner RA, Gell N, Hartigan A, Wiggerman N, Keyserling WM. Risk factors for plantar fasciitis among assembly plant workers. PM & R 2010;2:110–6.
[5] Riddle DL, Pulisic M, Pidcoe P, Johnson RE. Risk factors for plantar fasciitis: a matched case-control study. J Bone Joint Surg Am 2003;85:872–7.
[6] Wearing SC, Smeathers JE, Urry SR, Hennig EM, Hills AP. The pathomechanics of plantar fasciitis. Sports Med 2006;36:585–611.
[7] Davis PF, Severud E, Baxter DE. Painful heel syndrome: results of nonoperative treatment. Foot Ankle Int 1994;15:531–5.
[8] Gill L. Plantar fasciitis: diagnosis and conservative management. J Am Acad Orthop Surg 1997;5:109–17.
[9] Goff JD, Crawford R. Diagnosis and treatment of plantar fasciitis. Am Fam Physician 2011;84:676–82.
[10] Guner S, Onder H, Guner SI, Ceylan MF, Gökalp MA, Keskin S. Effectiveness of local tenoxicam versus corticosteroid injection for plantar fasciitis treatment. Orthopedics 2013;36:e1322–6.
[11] Rompe JD. Plantar fasciopathy. Sports Med Arthrosc 2009;17:100–4.
[12] Wolgin M, Cook C, Graham C, Mauldin D. Conservative treatment of plantar heel pain: long-term follow-up. Foot Ankle Int 1994;15:97–102.
[13] Bader L, Park K, Gu Y, O'Malley MJ. Functional outcome of endoscopic plantar fasciotomy. Foot Ankle Int 2012;33:37–43.
[14] Covey CJ, Mulder MD. Plantar fasciitis: how best to treat? J Fam Pract 2013;62:466–71.
[15] Weil LS, Roukis TS, Weil LS, Borrelli AH. Extracorporeal shock wave therapy for the treatment of chronic plantar fasciitis: indications, protocol, intermediate results, and a comparison of results to fasciotomy. J Foot Ankle Surg 2002;41:166–72.
[16] Chuckpaiwong B, Berkson EM, Theodore GH. Extracorporeal shock wave for chronic proximal plantar fasciitis: 225 patients with results and outcome predictors. J Foot Ankle Surg 2009;48:148–55.
[17] Hammer DS, Adam F, Kreutz A, Kohn D, Seil R. Extracorporeal shock wave therapy (ESWT) in patients with chronic proximal plantar fasciitis: a 2-year follow-up. Foot Ankle Int 2003;24:823–8.
[18] Metzner G, Dohnalek C, Aigner E. High-energy extracorporeal shock-wave therapy (ESWT) for the treatment of chronic plantar fasciitis. Foot Ankle Int 2010;31:790–6.
[19] Ogden JA, Alvarez R, Levitt R, Cross GL, Marlow M. Shock wave therapy for chronic proximal plantar fasciitis. Clin Orthop Relat Res 2001;387:47–59.
[20] Theodore GH, Buch M, Amendola A, Bachmann C, Fleming LL, Zingas C. Extracorporeal shock wave therapy for the treatment of plantar fasciitis. Foot Ankle Int 2004;25:290–7.
[21] Krishnan A, Sharma Y, Singh S. Evaluation of therapeutic effects of extracorporeal shock wave therapy in resistant plantar fasciitis patients in a tertiary care setting. Med J Armed Forces India 2012;68:236–9.
[22] Moretti B, Garofalo R, Patella V, Sisti GL, Corrado M, Mouhsine E. Extracorporeal shock wave therapy in runners with a symptomatic heel spur. Knee Surg Sports Traumatol Arthrosc 2006;14:1029–32.
[23] Mahowald S, Legge BS, Grady JF. The correlation between plantar fascia thickness and symptoms of plantar fasciitis. J Am Podiatr Med Assoc 2011;101:385–9.
[24] Terk MR, Kwong PK. Magnetic resonance imaging of the foot and ankle. Clin Sports Med 1994;13:883–908.
[25] League AC. Current concepts review: plantar fasciitis. Foot Ankle Int 2008;29:358–66.
[26] Berkowitz JF, Kier R, Rudicel S. Plantar fasciitis: MR imaging. Radiology 1991;179:665–7.
[27] Chimutengwende-Gordon M, O'Donnell P, Singh D. Magnetic resonance imaging in plantar heel pain. Foot Ankle Int 2010;31:865–70.
[28] Maier M, Steinborn M, Schmitz C, Stäbler A, Köhler S, Pfahler M, et al. Extracorporeal shock wave application for chronic plantar fasciitis associated with heel spurs: prediction of outcome by magnetic resonance imaging. J Rheumatol 2000;27:2455–62.
[29] Steinborn M, Heuck A, Maier M, Schnarkowski P, Scheidler J, Reiser M. MRI of plantar fasciitis. Rofo 1999;170:41–6.
[30] Zhu F, Johnson JE, Hirose CB, Bae KT. Chronic plantar fasciitis: acute changes in the heel after extracorporeal high-energy shock wave therapy-observations at MR imaging. Radiology 2005;234:206–10.
[31] Rompe JD, Kirkpatrick CJ, Küllmer K, Schwitalle M, Krischek O. Dose-related effects of shock waves on rabbit tendo Achillis. A sonographic and histological study. J Bone Joint Surg Br 1998;80:546–52.
[32] Grasel RP, Schweitzer ME, Kovalovich AM, Karasick D, Wapner K, Hecht P, et al. Original report MR imaging of plantar fasciitis: edema, tears, and occult marrow abnormalities correlated with outcome. Am J Roentgenol 1999;173:699–701.
[33] Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, et al. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders I: development of standard rating system. J Orthop Sci 2005;10:457–65.
[34] Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, et al. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders II: interclinician and intraclinician reliability and validity of the newly established standard rating scales and Japanese Orthopaedic Association rating scale. J Orthop Sci 2005;10:466–74.
[35] Huskisson EC. Measurement of pain. Lancet 1974;2:1127–31.
[36] Maki M, Ikoma K, Imai K, Kido M, Hara Y, Arai Y, et al. Correlation between the outcome of extracorporeal shockwave therapy and pretreatment MRI findings for chronic plantar fasciitis. Mod Rheumatol 2015;25:427–30.