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Original Research

Comparison of Pedal Soft Tissue Thickness Between Those With and Without Diabetes

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ABSTRACT

Ulceration is a serious consequence of diabetes that can lead to disability in patients with diabetes. One of the risk factors for ulceration is high foot pressure. The thickness of the pedal soft tissue is important because it has a cushioning effect. Soft tissue atrophy causes elevation in the plantar pressure, which, in turn, causes ischemia. Therefore, we investigated the severity of pedal soft tissue atrophy caused by diabetes and aging. From February 2009 to February 2016, we examined the feet of 261 patients treated in our hospital using magnetic resonance imaging. We divided the patients enrolled in the study into 2 groups. The first group included 52 patients with diabetes but without peripheral arterial disease and the second group included 47 patients without diabetes. We measured the vertical distances under all patients' metatarsal heads using T1-weighted magnetic resonance imaging and measured the pedal soft tissue thickness using the PACS workstation (m-view). We compared the soft tissue thicknesses of the 2 groups and performed statistical analyses of the relationships between these data and other parameters using 2-way analysis of variance. The soft tissue under the first to fourth metatarsal heads was thinner in the diabetic patients than in the nondiabetic patients (first metatarsal, 6.4 versus 8.69; second metatarsal, 8.85 versus 10.64; third metatarsal, 8.15 versus 9.21; fourth metatarsal, 7.38 versus 8.54; $p < .05$). Aging had no effect on pedal soft tissue atrophy in either group. In conclusion, our study confirmed that diabetic patients experience more severe plantar soft tissue atrophy than nondiabetic patients. We have developed a standard procedure to enable the prediction of pedal soft tissue atrophy severity in diabetic patients.

Diabetic foot ulceration is a comprehensive diagnosis comprising various morbidities of the foot that are associated with diabetes. The development of diabetic foot ulceration is driven by combinations of the following factors:

1. Diabetic neuropathy
2. Plantar pressure
3. Shoe fit and shoe condition
4. Pedal soft tissue thickness (1,2)

Among these factors, the plantar pressure and pedal soft tissue thickness are particularly important with respect to the development of diabetic foot ulceration, because diabetic foot ulceration caused by excessive pressure can lead to ischemic changes resulting from repeated excessive pressure. Additionally, the soft tissues have a significant effect on the plantar pressure because they act as a cushion (3,4).

Aging and diabetes are the most critical factors affecting the pedal soft tissue thickness in patients with diabetic foot ulceration. Wrinkles form on the human face as a result of aging-induced atrophy of the facial muscles and soft tissues. This phenomenon also occurs on the foot. Hence, atrophy resulting from aging also affects the plantar thickness. Decreases in pedal soft tissue thickness in diabetic patients have been demonstrated by numerous studies using pedobarography and F-scan mat systems (5,6). Researchers have attempted to develop effective methods of treating pedal soft tissue atrophy, such as silicone injections and fat grafting, in previous studies (5,7). For example, in their recent study, Gusenoff et al (8) showed that plantar fat grafting

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resulted in decreased plantar pressure and pain improvements during the first 6 months after surgery. However, standards or guidelines pertaining to pedal soft tissue thickness are required for the effective treatment and prevention of diabetic foot ulceration using therapies such as pedal soft tissue supplementation. A lack of standards defining normal pedal soft tissue thickness values and pedal thickness reduction severities in diabetic patients has made defining the tissue thickness values and characteristics of significant atrophy challenging.

In the present study, the pedal soft tissue thickness was measured below the metatarsal head, and the differences in pedal soft tissue thickness between the diabetic patients and nondiabetic patients were directly quantified using magnetic resonance imaging (MRI). Additionally, the differences in pedal soft tissue thickness caused by aging between the diabetic patients and nondiabetic patients were examined.

We present the standard values for the pedal soft tissue thickness in those with and without diabetes, providing data that could assist clinicians with the treatment and prevention of diabetic foot ulceration.

Patients and Methods

Participants

Our study was a retrospective study. We initially evaluated 261 patients, including 131 diabetic patients who had undergone MRI of the foot at our hospital from February 2009 to February 2016 and 130 nondiabetic patients. The participants were divided into 2 groups. Group I included patients who had had diabetes for >10 years, and group II included patients without diabetes. Sex, age, body mass index (BMI), and diabetes duration were compared between the 2 groups using the patients' medical records.

Inclusion and Exclusion Criteria

Patients aged >50 years, patients who had undergone MRI of the foot, and patients who had an ankle brachial index of ≥0.9 were included in the present study. Patients without a clearly recorded medical history were excluded from the study. To eliminate the variables and diseases other than diabetes that can affect the soft tissue thickness, we also excluded subjects with osteomyelitis, soft tissue infections and swelling, toe deformities, peripheral neuropathy, rheumatoid arthritis, calluses, and a history of diabetic foot ulceration (Table 1). Ultimately, 52 and 47 participants from groups I and II, respectively, were enrolled in the present study.

Measurement of Pedal Soft Tissue Thickness

All patients underwent MRI of the foot, which was performed using a 1.5 Tesla MRI scanner (Magnetom Avanto 1.5 Tesla; Siemens, Munich, Germany). Image analyses and measurements were conducted by 1 radiologist (H.C.), and the measurements were repeated twice. Of the images shown on the PACS workstation (m-view; Marotech, Seoul, Korea), the T1-weighted images, which afforded the best view of the soft tissue layer, were selected for the measurements. The sagittal images, which afforded the best measurements of the soft tissue thickness at the metatarsal head, were reconstructed from the T1-weighted images. Of these images, the 5 images with the best view of the first to fifth metatarsal heads were selected. To measure the soft tissue thickness at the metatarsal head, we drew a line along the lowermost boundary of the metatarsal head. This line was parallel to the bottom of the foot (Fig. 1). We drew another line along the lowermost boundary of a region with a hyperintense signal, because the signal was indicative of the presence of soft tissue. This line was also parallel to the bottom of the foot. We then measured the vertical distance between these 2 parallel lines, which we defined as the soft tissue thickness.

Table 1
Inclusion and exclusion criteria

Criteria
Inclusion
MRI of the foot at our hospital between February to February 2016
Ankle brachial index ≥0.9
Exclusion
Age <50 y
Presence of osteomyelitis
Presence of soft tissue infection
Presence of toe deformity
Presence of peripheral neuropathy
Presence of rheumatoid arthritis
Presence of cutaneous callus
History of diabetic foot ulceration
Unclear/incomplete medical records

Abbreviation: MRI, magnetic resonance imaging.

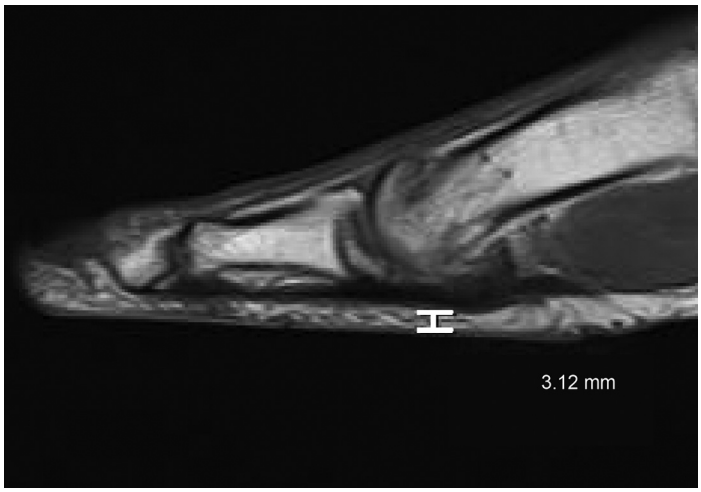

Fig. 1. Measurement of soft tissue thickness below the metatarsal head.

Statistical Analysis

The means, standard deviations, and minimum and maximum values were obtained for each data item pertaining to the patients enrolled in the 2 groups. To determine the significance of the differences between the 2 groups, we performed Pearson's χ^2 test using SPSS, version 19.0 (IBM Corp., Armonk, NY).

The mean value of the 2 repeated measurements was defined as the thickness of the soft tissues below the metatarsal head. By obtaining the intraclass correlation coefficient (ICC) using SPSS, version 19.0 (IBM Corp.), we confirmed the credibility of the 2 measurements. The patients were divided into the 4 indicated 10-year age groups (50 to 60, 60 to 70, 70 to 80, and ≥80 years), and the significance of the differences in pedal soft tissue thickness according to age and the presence of diabetes and age was examined using 2-way analysis of variance. Statistical significance was defined at the 5% ($p \leq .05$) level.

Results

Of the 99 patients, 52 were included in group I (33 males [63.5%] and 19 females [36.5%]) and 47 in group II (24 males [51.1%] and 23 females [48.9%]). The mean age in group I was 65.09 ± 13.26 years, and the mean age in group II was 63.72 ± 9.54 years ($p = .130$). The average BMI in group I was 23.7 ± 2.99 kg/m^2, and the average BMI in group II was 23.01 ± 2.93 kg/m^2 ($p = .143$). All the patients in group I had type 2 diabetes, and the average diabetes' duration was 20.25 ± 8.2 years. The p values pertaining to the differences in sex, age, and BMI between the 2 groups were > .05, indicating that the differences in these parameters between the 2 groups were not statistically significant (Table 2).

To examine the significance of the differences in the measured pedal soft tissue thickness according to age and the presence of diabetes and age, we used 2-way analysis of variance. We noted the following differences in pedal soft tissue thickness between the 2 groups. The thickness of the pedal soft tissue below the first to fourth metatarsal heads was significantly lower in group I than in group II, and thickness of the pedal soft tissue below the first, second, third, and fourth metatarsal heads in groups I and II was 6.4 mm and 8.69 mm ($p = .002$), 8.85 mm and 10.64 mm ($p = .006$), 8.15 mm and 9.21 mm ($p = .021$),