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Original Article

Changes in physical function and ambulatory state after Achilles tendon lengthening for diabetic foot ulcers

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Abstract. [Purpose] The recurrence rate of diabetic foot ulcers is high and is related to kinematic factors. Achilles tendon lengthening has been shown to reduce the recurrence rate of foot ulcers by increasing the range of motion in the ankle joint and decreasing the plantar load. However, there are few reports on the effects of Achilles tendon lengthening in Japanese patients, but the results are yet to be clarified. This study aims to investigate the effects of Achilles tendon lengthening on physical function and ambulatory state in patients with diabetic foot ulcers. [Participants and Methods] This study initially included 10 patients with diabetic ulcers who had undergone Achilles tendon lengthening between April 2013 and March 2020. We retrospectively evaluated the factors available from the medical records. [Results] The dorsiflexion range of motion in the ankle joint increased by 10.5 degrees on average after surgery, while the plantar load decreased by 19.1 percent, while gait speed and stride length remained unchanged. [Conclusion] Achilles tendon lengthening for diabetic foot ulcers increased the range of motion in the ankle joint and decreased the plantar load without changing the ambulatory state.

Key words: Achilles tendon lengthening, Diabetic foot ulcer, Wound recurrence

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INTRODUCTION

The number of diabetic patients was estimated to be 463 million in 2019, according to the International Diabetes Federation[1)]. A diabetic foot ulcer (DFU) is the most common diabetes-related complication, and severe cases necessitate amputation of the lower limb[2)]. The recurrence rate of DFUs is high, and the importance of preventing recurrence has been highlighted[3)]. It has become clear that external factors, such as plantar pressure during walking, and functional characteristics of soft tissues, such as skin and foot deformities, are both involved in recurrence[4)].

In diabetic patients, persistent hyperglycemia leads to excessive accumulation of terminal glycation products. This process is characterized by the formation of cross-linked bonds in the collagen tissues of joint capsules and ligaments with low glucose metabolism[5)]. In particular, increased tissue synthesis at the Achilles tendon reduces the range of motion of the ankle joint. This results in increased plantar pressure in the forefoot, which is thought to be related to the occurrence of DFUs[6)].

Surgical prophylaxis has been indicated to address this problem, mainly in Europe and the United States. In particular, Achilles tendon lengthening (ATL) is the most frequently used prophylactic surgery. The 2015 International Working Group Guidelines for Diabetic Foot Lesions recommends using ATL for DFUs[7)], which recur with decreased range of motion in the ankle joint.

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In Japan, however, there are few reports on the prevention of DFUs with ATL, unlike for its other indications, such as joint correction for apex foot deformity caused by cerebral palsy. Therefore, this study aimed to investigate the effect of ATL on physical function and ambulatory state in DFU patients in Japan.

PARTICIPANTS AND METHODS

This study initially included 10 patients with diabetic ulcers who had undergone ATL between April 2013 and March 2020. This study was a single-center retrospective study conducted in the Wound Care Center of Oita Oka Hospital. Measured items included age, gender, body mass index (BMI), hospitalization, physical therapy period, off-loading the foot period, duration of diabetes mellitus (DM), preoperative laboratory parameters (serum albumin [Alb], C-reactive protein [CRP], white blood cells), and lower limb blood flow data (skin perfusion pressure [SPP] and ankle-brachial pressure index [ABI]). Physical function was determined before and after surgery, including knee joint extensor strength, range of motion (ROM) in the ankle joint (dorsiflexion and plantar flexion), ambulation status, ambulation speed, stride length, and plantar load. Knee joint extensor muscle strength was measured using a hand-held dynamometer (μTas F1; ANIMA, Chofu, Japan). For knee extensor strength measurements, patients were asked to sit on a chair with the knee flexed at 90 degrees and to push against the dynamometer pad as much as possible for 5 seconds. Isokinetic knee extensor strength was measured 2 times on each side and the highest value for the right and left legs was used as the knee extensor muscle strength.

A physical therapist was also present during the surgery to check the ROM in the ankle joint (Fig. 1). The ROM in the ankle joint was measured in dorsiflexion and plantar flexion on the ATL side. The ROM was calculated using a goniometer to determine the angle of the maximum range of activity, within the limits of pain onset. Ambulation status was evaluated using the Functional Independence Measure (FIM) movement items. Ambulation speed, stride length, and plantar load were measured using the Walk Way MW-1000 (Anima, Inc.), a sheet-type foot pressure footprint-measuring device. The ambulation condition was measured three times, and the average of each measurement was used as representative value.

This study was conducted in accordance with the Declaration of Helsinki (as revised in Brazil in 2013), and approval was obtained from the Ethical Committee of the Oita Oka Hospital (approval number: A0052). In place of informed consent from every participant, consent was sought by publishing details of the study on the homepage of the research institute website, as well as on-site posting in the facility. Furthermore, the database used in this study was anonymized in a linkable fashion, and only the researchers could access the identification numbers.

In the statistical analysis, variables before and after ATL were compared using the Wilcoxon rank sum test. Statistical significance was set at $p<0.05$. All analyses were performed using R version 3.2.5 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Ten patients with diabetic foot ulcers indicated for ATL were enrolled, and their patient background is shown in Table 1. The median age was 65 years, male to female ratio was 80%, and BMI was 22.9 kg/m^2. The median length of hospital stay was 31 days; the length of the physical therapy period was 21 days; the duration of unloading was 14 days; and the duration of diabetes was 15 years. The median values of Alb and CRP on admission were 2.7 g/dL and 0.5 mg/dl, respectively. The median values of SPP and ABI on admission were 42 mmHg and 0.6, respectively. The changes in physical function and gait before and after surgery are shown in Table 2. Selected pre- and postoperative measures were as follows: the knee joint extensor strengths were 22.5 kgf and 19.7 kgf (p=0.024), respectively; the ankle joint dorsiflexion ranges of motion were 3.0 degrees and 13.5 degrees (p=0.001); the ankle joint flexion ranges of motion were 15.1 degrees and 12.4 degrees (p=0.074);

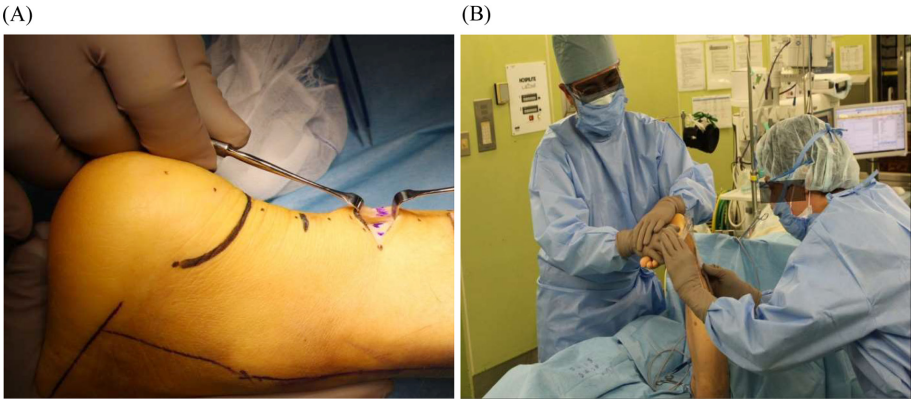

Fig. 1. Achilles tendon lengthening surgery (A) and measurement of ankle joint range of motion (B).

Table 1. Patient clinical characteristics

Age (years)	65 (58–73)
Gender, male, n (%)	8 (80)
BMI (kg/m^2)	22.9 (22.5–28.1)
Hospitalization (days)	31 (25.5–35.7)
Physical therapy period (days)	21 (18–32)
Off-loading the foot period (days)	14 (10–19)
Duration of DM (years)	15 (5–19)
Alb (g/dL)	2.7 (2.4–3.1)
CRP (g/dL)	0.5 (0.3–0.8)
SPP (mmHg)	42 (35–45)
ABI	0.6 (0.4–0.8)

Data expressed as median (interquartile range), n (%). BMI: body mass index; DM: diabetes mellitus; Alb: albumin; CRP: c-reactive protein; SPP: skin perfusion pressure; ABI: ankle brachial pressure index.

Table 2. Changes in physical function before and after Achilles tendon lengthening (ATL)

Variables	Preoperative	Postoperative	p-value
Knee extension muscle strength (kgf)	22.5 (18.2–25.0)	19.7 (15.4–22.5)	0.024
Ankle dorsiflexion angle (°)	3.0 (0–5)	13.5 (5–29)	0.001
Ankle plantar flexion angle (°)	15.1 (10–25)	12.4 (10–15)	0.074
Gait FIM score	6 (5–7)	6 (5–7)	0.951
Walking Speeds (cm/sec)	33.9 (25.4–39.4)	28.1 (22.4–29.7)	0.061
Stride Lengths (cm)	21.2 (15.0–25.6)	19.6 (10.4–22.5)	0.776
Plantar Loads (kgf)	11.5 (10.5–19.5)	9.3 (3.1–12.5)	0.031

FIM: Functional Independence Measure.

gait FIMs were 6 points and 6 points (p=0.951); walking speeds were 33.9 cm/sec and 28.1 cm/sec (p=0.061); stride lengths were 21.2 cm and 19.6 cm (p=0.776); and plantar loads were 11.5 kgf and 9.3 kgf (p=0.031), respectively. Significant differences were found in knee extension muscle strength, ankle dorsiflexion angle, and plantar loads compared to pre-and post-operatively.

DISCUSSION

The results of this study identify statistically significant differences in the ankle dorsiflexion ROM and plantar load after ATL surgery. It has been suggested that ATL increases the ankle joint's postoperative dorsiflexion ROM and reduces the plantar load.

Mueller et al. reported that ATL increased the dorsiflexion angle in DFU cases by an average of 11.4 degrees[8]. These findings were similar to those of the present study, in which the dorsiflexion angle was improved by an average of 10.5 degrees.

Regarding the relationship between the ankle joint ROM in dorsiflexion and the amount of plantar loading in DFU patients, Lavery et al. reported that plantar pressure increased when the dorsiflexion ROM was <0 degrees during automatic exercise[9]. Holstein et al. also reported an increased recurrence rate of ulcers due to increased plantar pressure when the ankle joint ROM in dorsiflexion was <10 degrees after ATL[10].

The participants in this study all had ankle dorsiflexion angles of <5 degrees preoperatively and were at high risk for ulcer formation due to increased plantar pressure. Therefore, we believe that ATL had the same effect in our study as that shown in previous studies. However, the postoperative maximum dorsiflexion ROM was less than that reported in one previous study[12]. This may be because most of the previous studies[8, 12, 13] started walking practice early after surgery using a dedicated walker or total contact cast. In contrast, in the present study, the time until the removal of the bed sheet was approximately two weeks, and rehabilitation was performed by exercise therapy using crutches and other unloading methods. We consider this difference in postoperative rehabilitation programs to be a contributing factor to worse postoperative physical function. We therefore believe it necessary to develop a postoperative rehabilitation program that considers the timing of intervention to maintain joint ROM after ATL.

Hastings et al. found that the amount of plantar loading after ATL was reduced by about 14% compared to the preoperative level[11, 14]. In the present study, we observed a 19.1% reduction after surgery, confirming a similar compaction. There was no significant difference in gait parameters before and after surgery, and no change in ambulatory state was observed.

The risks of partial Achilles tendon rupture and heel ulceration have been reported as adverse events associated with ATL[15]. No adverse events reported in previous studies were observed among the participants in this study. Regarding adverse events, an excessive intraoperative dorsiflexion ROM of ≥15 degrees is associated with a high risk of Achilles tendon rupture and heel gait. Therefore, for patients at high risk of foot ulcer recurrence due to limited dorsiflexion ROM, setting the intraoperative target angle at 10 degrees may lead to an increase in the ROM at the ankle joint and a reduction in the amount of plantar loading without any adverse events.

This is the first study to examine the effect of ATL on diabetic foot patients in Japan, with respect to physical function and plantar load. However, there were the following limitations. First, the number of participants was small; thus, factors related to prognosis could not be analyzed. Second, the study was conducted at a single institution, which may have biased the background and selection of participants. Third, because this was a retrospective observational study, we could not fully investigate physical functions such as the ROM of the leg joints and lower limb muscle strength after discharge. Therefore, it is difficult to say that the results of this study can be generalized. A prospective study adjusting for these factors should be conducted to elucidate the indications for ATL in DFUs, which will lead to effective rehabilitation.

In this study, for the first time in Japan, the effects of ATL on DFU were examined in relation to physical function and plantar load. The results showed that ATL reduced the ROM at the ankle joint in dorsiflexion by an average of 10.5 degrees and the plantar load by 19.1%. However, the improvement in dorsiflexion ROM was smaller than that reported in previous studies, suggesting that efforts to maintain ROM during rest periods are needed.

Conflict of interest

There are no conflicts of interest.

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