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ORIGINAL ARTICLE

# Ten-year follow-up of functional and biomechanical outcomes after open double-Tajima repair for acute Achilles tendon rupture in non-competitive adults

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## ABSTRACT

**Objectives:** This study aims to evaluate the clinical and objective biomechanical outcomes at a minimum 10-year follow-up following open double-Tajima repair combined with a structured functional loading protocol.

**Patients and methods:** Between January 2011 and December 2014, a total of 47 consecutive non-competitive adults (Tegner Activity Scale ≤ 4) with acute unilateral Achilles tendon rupture treated with open double-Tajima repair and an eight-week functional loading protocol were included in this retrospective cohort study. The primary outcome was the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score. Secondary outcomes included isokinetic dynamometry (peak torque at 30°/s and total work at 120°/s for plantar flexion and dorsiflexion), joint position sense, and ankle/calf circumference. Between-limb comparisons were performed.

**Results:** Of the patients, 35 were male and 12 were female with a mean age at the time of surgery of 36.7 ± 6.6 (range, 22 to 55) years. The mean follow-up was 132.4 ± 13.5 (range, 120 to 168) months. The rupture involved the dominant limb in 29 patients (61.7%) and the non-dominant limb in 18 patients (38.3%). The primary outcome (AOFAS score) showed no statistically significant between-limb difference: the median score was 91.0 (IQR, 91.0 to 93.0) on the operated limb versus 93.0 (IQR, 91.0 to 93.0) on the contralateral limb (median difference: 0.00 points; 95% confidence interval [CI]: −1.00 to 1.00; $p = 0.92$). No statistically significant between-limb differences were detected across the secondary outcomes, including peak torque at 30°/s, total work at 120°/s, joint position sense, and ankle/calf circumference ($p \geq 0.09$ for all). The complication rate was 4.3% (2/47): one partial rerupture managed conservatively and one superficial wound infection treated with oral antibiotics. No complete reruptures were observed.

**Conclusion:** Open double-Tajima repair combined with a structured functional loading protocol seems to be associated with clinically acceptable long-term outcomes in this cohort of non-competitive adults. However, given the retrospective, single-cohort design without an independent comparison group or formal equivalence framework, these findings should be interpreted as descriptive long-term observations.

***Keywords:*** Achilles tendon, biomechanical phenomenon, muscle strength, rehabilitation, tendon injuries, treatment outcome.

Acute Achilles tendon rupture (ATR) is an increasingly prevalent injury, with the largest rise reported among middle-aged adults.[1] While modern treatments effectively restore tendon continuity, the primary therapeutic goal has shifted from preventing rerupture to minimizing long-term functional deficits. Common sequelae include persistent tendon elongation, calf muscle atrophy, and plantar flexion weakness, with between-limb performance differences reaching 10 to 30% even years after the injury.[2-4]

The optimal management strategy for mitigating these deficits remains debated. Non-operative functional treatment avoids surgical complications;

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however, persistent tendon elongation and heel-rise impairment may occur during recovery.[2,3] Conversely, open surgical repair allows for precise tendon approximation under direct visualization but carries risks of wound compromise and deep infection.[5,6] Minimally invasive techniques reduce soft-tissue disruption, but pose a risk of sural nerve injury and may compromise repair accuracy owing to limited visualization.[7]

A recent randomized study has evaluated an individualized treatment algorithm alongside operative and non-operative pathways.[8] For non-competitive adults, the treatment priority is long-term functional recovery to support their daily and recreational activities. This requires a combination of mechanically robust repair and structured loading protocols. In our practice, this rationale led us to use an open double-Tajima repair technique based on a double-locking-loop configuration. Cadaveric biomechanical studies comparing commonly used suture patterns report variable findings in ultimate load and construct stability across techniques.[9,10]

On the other hand, long-term objective outcomes after standardized surgical repair remain heterogeneous, and reviews with a minimum five-year follow-up document inconsistent reporting of objective biomechanical measures.[11] Furthermore, while patient-reported outcomes dominate the literature, objective measures, such as isokinetic dynamometry and proprioceptive assessment, which are critical for detecting subtle deficits and guiding clinical decision-making, remain underreported.[4,12,13]

To date, no published study has examined decade-long, construct-specific objective biomechanical outcomes, including isokinetic strength, endurance, and proprioception, following open double-Tajima repair in non-competitive adults. In the present study, we, therefore, aimed to evaluate the long-term clinical and objective biomechanical outcomes of acute ATR managed with open double-Tajima repair and a structured functional loading protocol, addressing the limited availability of decade-long construct-specific objective follow-up data.

## PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at the Department of Orthopedics and Traumatology, University of Health Sciences, Gaziosmanpaşa Training and Research Hospital. Medical records of patients who underwent surgical repair for acute spontaneous ATR between January 2011 and December 2014 were analyzed. Inclusion criteria were as follows: acute unilateral midsubstance ATR as confirmed by clinical examination and magnetic resonance imaging (MRI); surgical repair performed within seven days of injury using the open double-Tajima technique; non-competitive activity level (Tegner Activity Scale ≤ 4);[14] minimum 10-year follow-up; and availability of the uninjured contralateral limb for comparison. Exclusion criteria were as follows: chronic or insertional ruptures; previous Achilles tendon injury or surgery on either limb; bilateral ruptures; concomitant lower-extremity fractures or neurological disorders affecting gait; and inability to complete the functional testing. Limb dominance was recorded based on the preferred kicking leg. Of a total of 51 consecutive patients deemed eligible for the study, four were excluded from the final analysis (n = 2 could not be contacted, n = 1 declined to participate, and n = 1 underwent contralateral lower-extremity surgery during the follow-up period). Finally, a total of 47 patients who met the inclusion criteria were recruited. The study flowchart is shown in Figure 1. A written informed consent was obtained from each patient. The study protocol was approved by the Gaziosmanpaşa Training and Research Hospital Clinical Research Ethics Committee (Date: 02.03.2022, No. 34). The study was conducted in accordance with the principles of the Declaration of Helsinki. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

### Surgical technique

All procedures were performed by a single experienced surgeon under spinal or general anesthesia with the patient in the prone position, and no pneumatic tourniquet was applied to the thigh. A posteromedial longitudinal incision was made to expose the rupture site while preserving the paratenon. The tendon ends were not debrided.

Two No. 2 non-absorbable braided sutures (Ethibond Excel; Ethicon, Raritan, NJ, USA) were placed in the proximal stump in a locking fashion to create a four-strand core repair. The strands were passed through the distal stump using a straight needle and tied with the ankle held in approximately 25° to 30° of plantar flexion to achieve stable tendon coaptation without visible gaps (Figure 2).

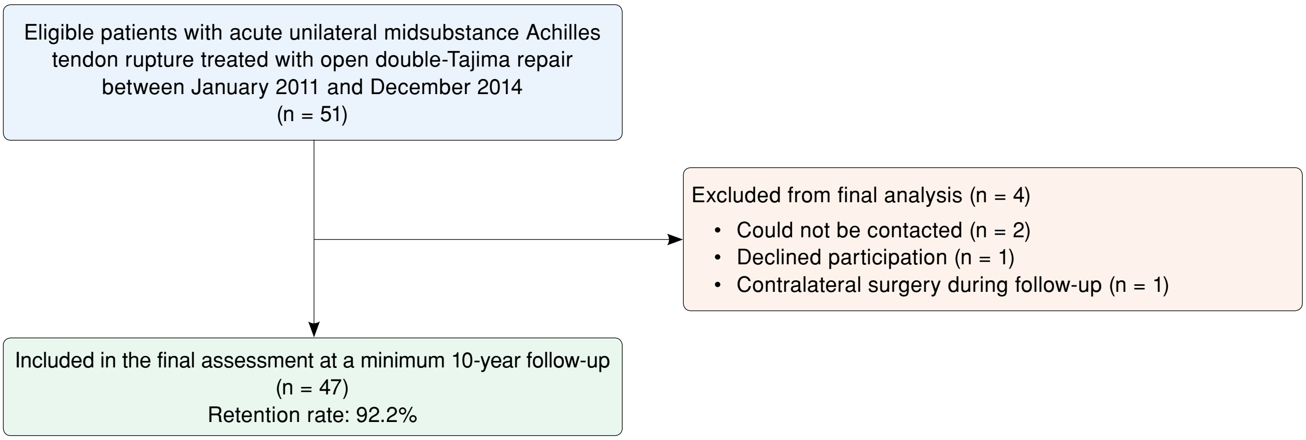


**FIGURE 1.** Study flow chart.

In contrast to single-strand configurations, this reinforced double-Tajima construct was selected to enhance biomechanical stability during the early healing phase.

The repair was circumferentially augmented with a continuous running 3-0 absorbable epitendinous suture (Vicryl; Ethicon Inc., NJ, USA) followed by meticulous paratenon repair with the same suture material (Figure 3). The subcutaneous tissue and skin were, then, closed in layers.

### Postoperative immobilization and rehabilitation

Immediately after surgery, a short-leg plaster cast maintaining approximately 25° to 30° of plantar flexion was applied. After Day 7, the cast was replaced with a range-of-motion walker boot (Vacoped; OPED GmbH, Valley/Oberlaindern, Germany). The skin sutures were removed on postoperative Day 14. Rehabilitation was supervised by the same physical therapy team

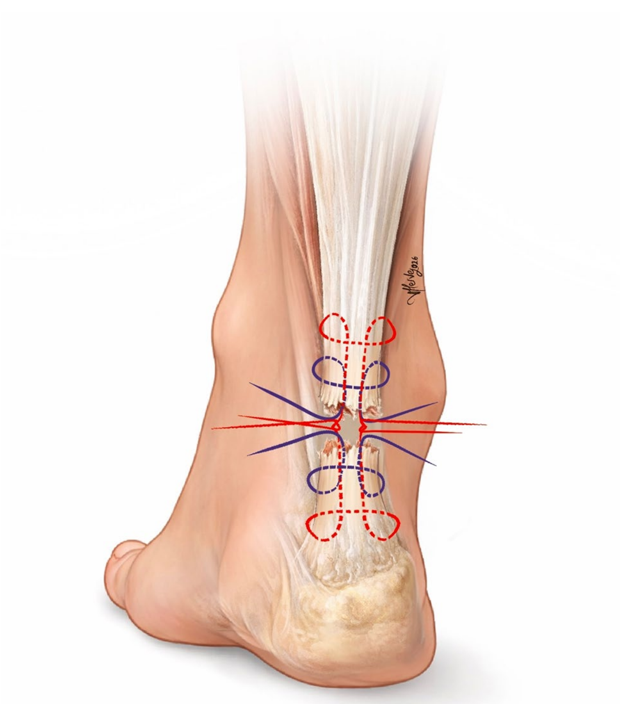

**FIGURE 2.** Schematic illustration of the open double-Tajima core suture technique.

**FIGURE 3.** Illustration of the epitendinous suture technique.

using an eight-week structured functional loading protocol (Table I), culminating in full weight bearing by Week 8. After 12 weeks of progressive rehabilitation, the patients were cleared for unrestricted activities of daily living. Return to recreational sports was permitted at approximately six months, contingent upon satisfactory single-leg heel-rise performance (minimum, 25 reps) and the surgeon's approval.

### Outcome measures

*Clinical assessment:* The primary clinical outcome was the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score.[15] The ankle range of motion (ROM) was assessed clinically using a goniometer to confirm the absence of motion restriction; however, the ROM was not included as a formal bilateral outcome variable, as all patients achieved full, unrestricted motion by the time of final assessment. Calf circumference was measured 15 cm distal to the tibial tuberosity, and ankle circumference was measured at the level of the malleoli.

*Proprioceptive testing:* Joint position sense (JPS) was evaluated using an active angle-reproduction task at 15° dorsiflexion and 20° plantar flexion with vision occluded. For each target, the reproduced ankle angle (degrees) was recorded (reproduced position rather than absolute angular error).

*Isokinetic dynamometry:* Muscle performance was assessed using an isokinetic dynamometer (Cybex Humac Norm; CSMI, Stoughton, MA, USA). After a standardized warm-up, the patients performed concentric plantar flexion and dorsiflexion tests at two angular velocities: 30°/s (five reps) to assess peak torque (strength), and 120°/s (15 reps) to assess total work (endurance). Both the operated and contralateral limbs were tested.

### Statistical analysis

Statistical analysis was performed using the IBM SPSS version 30.0 software (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test. Continuous variables were summarized as mean ± standard deviation (SD) or median (interquartile range), as appropriate, and categorical variables as counts and percentages. No formal *a priori* sample size calculation was performed; consequently, the study was not powered to demonstrate formal equivalence, and the absence of a statistically significant difference should not be interpreted as evidence of true biomechanical equivalence. The primary outcome (AOFAS score) showed non-normal distribution and was therefore analyzed using the Wilcoxon signed-rank test, with the Hodges-Lehmann median difference and its 95% confidence interval (CI) reported. Parametric paired comparisons were analyzed using the paired-samples t-test; non-parametric paired comparisons were analyzed using the Wilcoxon signed-rank test. For JPS outcomes, despite evidence of non-normality on Shapiro-Wilk testing, paired t-tests were used given the moderate sample size and robustness of the t-test to departures from normality in paired comparisons; results were confirmed using Wilcoxon signed-rank tests, which yielded consistent findings. Effect sizes are presented as Cohen's dz for parametric paired comparisons and r for Wilcoxon signed-rank tests. As eight secondary outcomes were evaluated, Bonferroni

**TABLE I**
Postoperative structured functional loading protocol (first 8 weeks)

| Week | Ankle position | Loading | Exercises |
|---|---|---|---|
| 1st | 25-30° plantar flexion | Non-weight bearing | None |
| 2nd | 25-30° plantar flexion | Partial loading | None |
| 3rd | 15-20° plantar flexion | Partial loading | None |
| 4th | 5-10° plantar flexion | Partial loading | Active plantar flexion (no resistance) |
| 5th | 5° plantar flexion | Partial loading | Active plantar flexion and dorsiflexion ROM |
| 6th | Neutral (0°) | Partial loading | Active range-of-motion exercises |
| 7th | Neutral (0°) | Partial loading | Stretching[a]; isometric strengthening[b]; proprioceptive exercises[c] |
| 8th | Neutral (0°) | Full weight bearing | Stretching[a]; progressive isometric strengthening[b]; advanced proprioceptive exercises[c] |

[a] Stretching: repeated gentle calf stretching within a pain-free range.
[b] Isometric strengthening: plantar flexion against resistance without ankle joint movement.
[c] Proprioceptive exercises: balance training progressing from stable to unstable surfaces and from double-leg to single-leg stance.

**TABLE II**
Demographic, perioperative, and follow-up characteristics of the patients (n = 47)

| Variables | n | % | Mean±SD | Range |
|---|---|---|---|---|
| Age (year) | | | 36.7 ± 6.6 | 22-55 |
| Sex | | | | |
| Male | 35 | 74.5 | | |
| Female | 12 | 25.5 | | |
| Operated side | | | | |
| Left | 24 | 51.1 | | |
| Right | 23 | 48.9 | | |
| Anesthesia type | | | | |
| Spinal anesthesia | 33 | 70.2 | | |
| General anesthesia | 14 | 29.8 | | |
| Dominant limb involved | | | | |
| Yes | 29 | 61.7 | | |
| No | 18 | 38.3 | | |
| Tourniquet use | | | | |
| No | 47 | 100 | | |
| Body mass index (kg/m²) | | | 30.9 ± 2.1 | 26-36 |
| Follow-up time (months) | | | 132.4 ± 13.5 | 120-168 |

SD, standard deviation.

correction was applied for multiplicity (adjusted $\alpha = 0.006$ for secondary endpoints). All $p$ values were two-tailed. Statistical significance was set at $p < 0.05$ for the primary outcome and at the Bonferroni-adjusted threshold of $p < 0.006$ for the secondary outcomes.

## RESULTS

Of a total of 47 patients included in the study, 35 were male and 12 were female with a mean age at the time of surgery of 36.7 ± 6.6 (range, 22 to 55) years. The mean body mass index (BMI) was 30.9 ± 2.1 (range, 26 to 36) kg/m². The mean follow-up was 132.4 ± 13.5 (range, 120 to 168) months. The rupture involved the dominant limb in 29 patients (61.7%) and the non-dominant limb in 18 patients (38.3%). Demographic, perioperative, and follow-up characteristics are summarized in Table II.

The primary outcome (AOFAS score) showed no statistically significant between-limb difference: the median score was 91.0 (IQR, 91.0 to 93.0) on the operated limb versus 93.0 (IQR, 91.0 to 93.0) on the contralateral limb (median difference: 0.00 points; 95% CI: −1.00 to 1.00; $p = 0.92$).

Anthropometric measurements showed no statistically significant between-limb differences in calf circumference (median, 37.0 [IQR, 36.0 to 38.0] cm *vs.* 37.0 [IQR, 36.0 to 38.0] cm; $p = 0.37$) or ankle circumference (median, 27.9 [IQR, 27.6 to 28.2] cm *vs.* 27.9 [IQR, 27.4 to 28.2] cm; $p = 0.33$). Proprioceptive testing revealed no statistically significant between-limb differences in JPS for either dorsiflexion (operated, 16.78° ± 0.70° *vs.* contralateral, 16.83° ± 0.68°; $p = 0.64$) or plantar flexion (operated, 19.18° ± 0.77° *vs.* contralateral, 19.29° ± 0.84°; $p = 0.23$).

Isokinetic evaluation revealed no statistically significant between-limb differences across all secondary outcomes. Plantar flexion endurance (total work at 120°/s) showed a median difference of 0.00 J (95% CI: −2.00 to 3.00; $p = 0.88$), and dorsiflexion endurance showed a median difference of −2.00 J (95% CI: −4.00 to 0.00; $p = 0.09$). Similarly, peak torque at 30°/s showed no statistically significant between-limb differences for plantar flexion (median difference: 0.00 N·m; 95% CI: −1.00 to 1.00; $p = 0.98$) or dorsiflexion (median difference: 0.00 N·m; 95% CI: 0.00 to 0.00; $p = 0.97$). None of the secondary comparisons reached the Bonferroni-adjusted significance threshold ($\alpha = 0.006$), indicating no statistically significant between-limb differences. Detailed bilateral comparisons are presented in Table III.

**TABLE III**

Long-term bilateral outcomes (operated versus contralateral limb)

| Outcome | Operated limb | | | Contralateral limb | | | Difference (operated-contralateral) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean ± SD | Median | IQR | Mean ± SD | Median | IQR | Estimate | 95% CI | *p* | Effect size |
| Parametric data | | | | | | | | | | |
| JPS 15° DF (°) | 16.78 ± 0.70 | | | 16.83 ± 0.68 | | | –0.06 | –0.29 to 0.18 | 0.64[a] | dz = –0.07 |
| JPS 20° PF (°) | 19.18 ± 0.77 | | | 19.29 ± 0.84 | | | –0.11 | –0.30 to 0.08 | 0.23[a] | dz = –0.18 |
| Non-parametric data | | | | | | | | | | |
| AOFAS score (0-100) | | 91.0 | 91.0-93.0 | | 93.0 | 91.0-93.0 | 0.00 | –1.00 to 1.00 | 0.92[b] | r = –0.02 |
| PF endurance 120°/s (J) | | 170.0 | 163.0-205.0 | | 170.0 | 166.0-210.0 | 0.00 | –2.00 to 3.00 | 0.88[b] | r = –0.02 |
| DF endurance 120°/s (J) | | 123.0 | 119.0-131.0 | | 126.0 | 120.0-130.0 | –2.00 | –4.00 to 0.00 | 0.09[b] | r = –0.25 |
| PF strength 30°/s (N·m) | | 62.0 | 54.0-68.0 | | 64.0 | 50.0-68.0 | 0.00 | –1.00 to 1.00 | 0.98[b] | r = 0.00 |
| DF strength 30°/s (N·m) | | 36.0 | 33.6-38.0 | | 36.2 | 33.6-38.8 | 0.00 | 0.00 to 0.00[c] | 0.97[b] | r = –0.01 |
| Ankle circumference (cm) | | 27.9 | 27.6-28.2 | | 27.9 | 27.4-28.2 | –0.05 | –0.15 to 0.05 | 0.33[b] | r = –0.14 |
| Calf circumference (cm) | | 37.0 | 36.0-38.0 | | 37.0 | 36.0-38.0 | 0.00 | –0.50 to 0.00 | 0.37[b] | r = –0.13 |

SD, standard deviation; IQR, interquartile range; CI, confidence interval; JPS, joint position sense; DF, dorsiflexion; PF, plantar flexion; AOFAS, American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score. Differences were calculated as operated minus contralateral limb. For parametric outcomes, the estimate represents the mean paired difference with its 95% CI; for non-parametric outcomes, the estimate represents the Hodges-Lehmann median paired difference with its 95% CI. [a], Paired-samples t-test; [b], Wilcoxon signed-rank test; [c], the 95% CI of (0.00 to 0.00) for dorsiflexion strength reflects precision truncation at the two-decimal reporting threshold; the majority of paired differences were zero at the dynamometer's measurement resolution. Strength, peak torque at 30°/s; Endurance, total work at 120°/s. Effect sizes for Wilcoxon signed-rank tests are reported as $r = Z/\sqrt{N}$, where N = 47. The ±10% reference band displayed in Figures 4 and 5 is provided for descriptive visualization only and does not represent a formal equivalence margin. The absence of statistically significant differences should not be interpreted as proof of clinical equivalence.

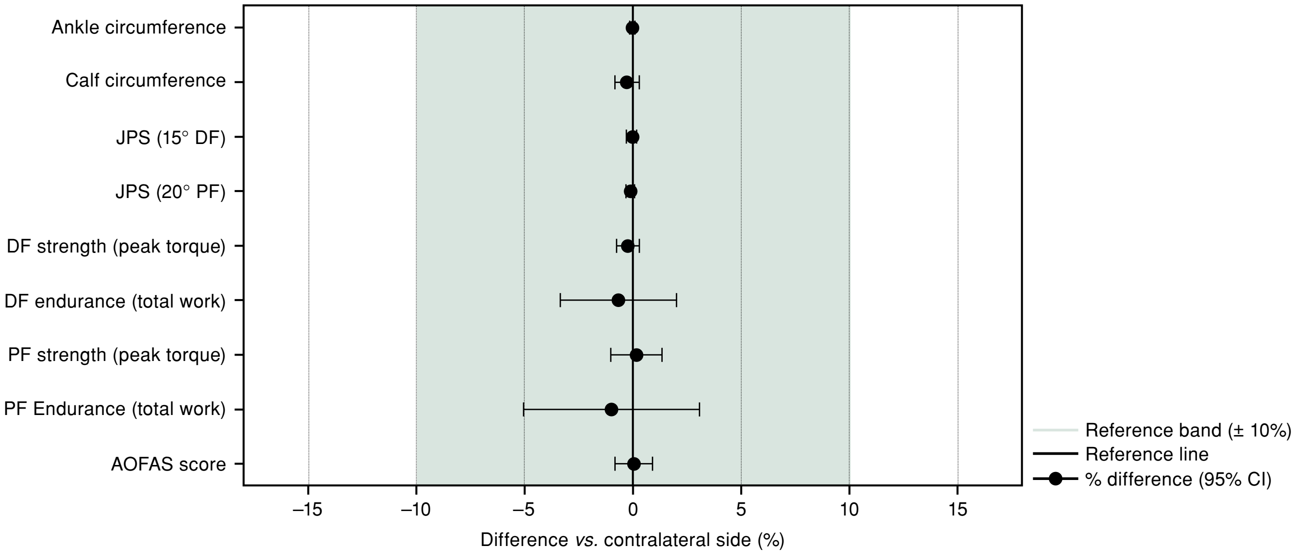


**FIGURE 4.** Forest plot illustrating between-limb differences across all outcomes. Data points represent the percentage difference of the operated limb relative to the contralateral limb, with error bars denoting 95% confidence intervals. The shaded region indicates the ± 10% reference band for descriptive visualization only and does not represent a formal equivalence margin.
JPS, joint position sense; DF, dorsiflexion; PF, plantar flexion; AOFAS, American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score; CI, confidence interval.

Between-limb percent differences with 95% CIs are visualized in Figure 4, and individual-level operated-versus-contralateral comparisons are shown in Figure 5.

Complications occurred in two patients (4.3%). During postoperative follow-up, one patient developed new-onset symptoms suggestive of partial tendon insufficiency. Physical examination and ultrasonography confirmed a partial rerupture. The patient was managed conservatively with immobilization in a walker boot for six weeks, followed by gradual rehabilitation. At the final follow-up, the patient had an AOFAS score of 89 and was able to perform daily activities without restriction. The second complication was a superficial wound infection diagnosed on postoperative Day 10, which resolved completely with a course of oral antibiotics. No complete reruptures, deep infections, or sural nerve injuries were observed.

## DISCUSSION

In the present study, we evaluated the long-term clinical and objective biomechanical outcomes of acute ATR managed with open double-Tajima repair and a structured functional loading protocol. The primary finding of this study was that non-competitive adults treated with open double-Tajima repair and structured functional loading showed no statistically significant between-limb differences in clinical or objective biomechanical outcomes over a minimum 10-year follow-up. The AOFAS ankle-hindfoot scores and objective measures, including isokinetic strength and endurance, showed no statistically significant between-limb differences in this cohort. However, this single-cohort retrospective study lacked both a formal equivalence framework and an independent control group. Accordingly, these findings should be interpreted as descriptive long-term observations rather than as a basis for comparative conclusions regarding other surgical techniques.

Whether Achilles tendon repair is associated with small long-term between-limb differences or persistent residual deficits remains a matter of debate. While longitudinal studies have identified persistent endurance and muscle performance deficits ranging from 10 to 15% even a decade after injury,[3,16] our cohort did not show statistically significant between-limb deficits in isokinetic performance. Horstmann et al.[16] specifically reported significant plantar flexion total work deficits 10 years after repair; in contrast, corresponding isokinetic measures in our cohort did not differ significantly between limbs. These findings should be interpreted cautiously,

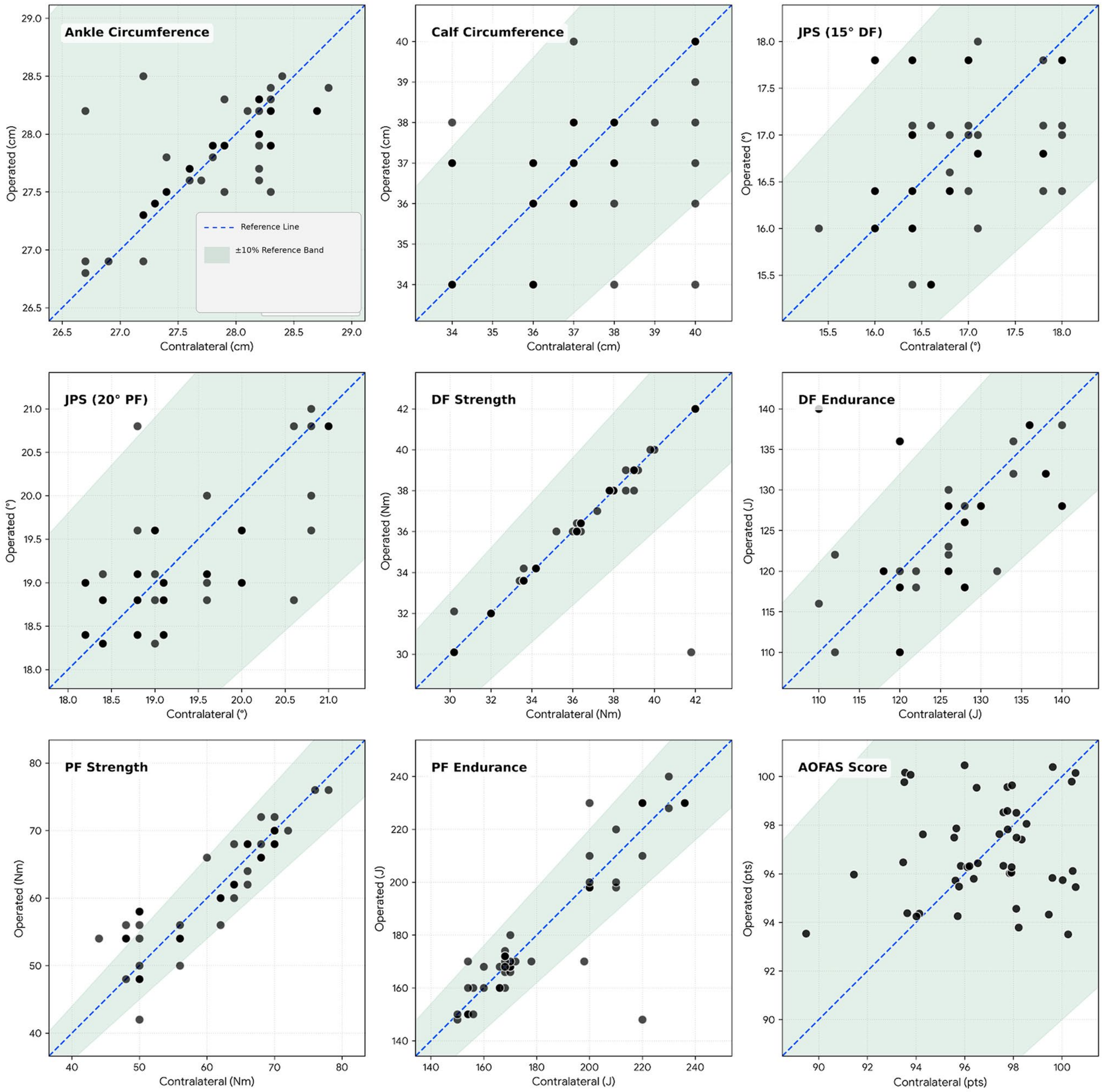


**FIGURE 5.** Multipanel scatter plots showing individual bilateral comparisons for all outcome measures. The x-axis represents the uninjured (contralateral) limb, and the y-axis represents the operated limb. The dashed line indicates the identity line (y = x), and the shaded region represents the ± 10% reference band around the identity line for descriptive visualization only and does not represent a formal equivalence margin.

JPS, joint position sense; DF, dorsiflexion; PF, plantar flexion; AOFAS, American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score.

as the study was not designed to establish formal biomechanical equivalence.

While our findings are broadly consistent with earlier reports of clinically acceptable outcomes, they differ from published reports of persistent isokinetic weakness in longitudinal cohorts. Previous studies have documented plantar flexion strength deficits of 10 to 30% persisting for years after injury,[2-4] including losses reported in mid-to-long-term studies.[17] In contrast, our cohort exhibited no statistically significant between-limb differences; the 95% CIs for peak torque and endurance were relatively narrow and included values close to zero, but these data remain descriptive and do not establish formal equivalence.

The surgical approach and soft tissue handling may have contributed to these divergent results. Čretnik et al.[18] reported similar long-term AOFAS scores after percutaneous repair, but documented sural nerve complications. We observed no sural nerve complications. Although no comparative inference can be made from a single-cohort study, the absence of sural nerve complications in this series may be descriptively noted without implying more favorable outcomes than other techniques. Overall, meticulous tendon repair combined with a structured functional loading protocol may have contributed to the long-term outcomes observed in this cohort.

Randomized evidence indicates that operative and non-operative management can yield comparable patient-reported outcomes after acute ATR.[19] However, patient-reported outcome measures (PROMs) alone may not detect subtle residual performance deficits. Therefore, we complemented the clinical outcome assessment with objective isokinetic dynamometry and proprioceptive testing. At a minimum 10-year follow-up after open double-Tajima repair, these assessments showed no statistically significant between-limb differences in peak torque and endurance for both plantar flexion and dorsiflexion. These long-term findings extend the shorter-term objective data of Arslan et al.,[12] who reported objective assessment of strength, endurance, and proprioception at a mean follow-up of approximately 34 months using a similar Tajima-based open repair technique. The JPS data should be interpreted as exploratory; since proprioception was assessed using a reproduced-position paradigm rather than absolute angular error, these values are not directly comparable to error-based metrics, and the reported between-limb symmetry in JPS cannot be interpreted as evidence of intact proprioceptive function.

Long-term functional outcomes after ATR are highly variable. Systematic review evidence supports an association between tendon elongation and altered biomechanical parameters after rupture.[20] This is compounded by data showing that tendon elastic properties can remain inferior to the contralateral tendon even after a long-term healing phase.[21] Clinically, these factors may contribute to residual plantar flexor weakness, as documented in a randomized trial at 18 months,[22] a randomized trial at 12 months,[23] and longitudinal cohorts.[3,13] In contrast to these reports of chronic deficits, we found no statistically significant between-limb differences in plantar flexion or dorsiflexion at a mean follow-up of 132.4 months post-injury.

On the other hand, the absence of statistically significant between-limb differences observed at long-term follow-up in our non-competitive cohort with a mean BMI of 30.9 $kg/m^2$ may reflect both demographic and technical factors. Although cadaveric biomechanical studies have reported variable findings across multistrand locking-loop constructs,[9,10] the four-strand core configuration of the double-Tajima technique may have contributed to maintaining the tendon length-tension relationship and mitigating the risk of elongation in individuals with higher BMI. Despite obesity being a significant cofactor for perioperative complications,[24] such complications were uncommon (4.3%) in our series, consistent with the feasibility of this approach when combined with meticulous soft tissue handling.

Neuromuscular adaptations may not have been fully captured by our measurements. Horstmann et al.[16] reported persistent isokinetic deficits and altered gastrocnemius electromyographic activity approximately 10 years after Achilles tendon repair, indicating that neuromuscular changes can persist despite favorable clinical outcomes. As electromyography was not performed, subclinical alterations in motor control may have been missed. Nevertheless, the absence of statistically significant differences in isokinetic performance and anthropometric measures suggests that any residual adaptations, if present, may not have translated into clinically or functionally detectable limitations in this non-competitive cohort. An important interpretive consideration is that the contralateral limb cannot be assumed to have remained functionally static over the 10-year observation period. Age-related declines in lower-extremity isokinetic strength and muscular endurance have been reported in adults from the fourth decade onward, and histological changes in Achilles tendon structure, including collagen fibril disorganization and reduced cellularity, have been documented with advancing age in animal models.[25] Consequently, bilateral age-related decline may have reduced the measurable between-limb contrast in our cohort, potentially masking residual deficits that would have been detectable at an earlier time point. This limitation should be considered when interpreting the absence of statistically significant between-limb differences as a long-term outcome.

Our results are consistent with evidence supporting structured functional rehabilitation after ATR repair. Zhao et al.[26] reported greater patient satisfaction and shorter time to return to prior sporting level without increased major complications compared to traditional immobilization. Similarly, Cao et al.[27] reported faster early recovery with shorter immobilization, whereas Irfan et al.[28] found no significant differences in total complications across weight-bearing strategies. Although our protocol (full weight bearing by Week 8) was more conservative than immediate-loading regimens, it was associated with clinically acceptable long-term outcomes in this cohort and a low observed complication rate.

To the best of our knowledge, this study is among the few reports to present decade-long biomechanical outcomes after open double-Tajima repair. Biomechanical outcomes beyond the first postoperative year have been reported for other open repair approaches;[13,22] however, construct-specific data extending beyond a decade still remain limited. In addition, this open construct incorporates tissue-preserving features, including direct visualization and preservation of the paratenon without an additional longitudinal paratenon incision, which may help explain why its long-term evaluation remains clinically relevant despite increasing interest in less invasive strategies. The multistrand nature of the double-Tajima repair may have contributed to these outcomes. Multistrand constructs may provide greater tensile stability and improved load distribution compared to traditional two-strand repair configurations.[9,10] In bench testing, Dündar et al.[29] reported greater load to 2-mm and 5-mm gap formation with the Tsuge technique (a similar locking-loop configuration), supporting the mechanical plausibility of multistrand anchoring. Our long-term findings are compatible with the possibility that the double-Tajima construct functioned as a stable multistrand repair in this cohort; however, comparative trials are still required before drawing conclusions relative to contemporary techniques.

Although data extending beyond a decade are exceptionally rare, our observations are consistent with the 15-year outcomes reported by Atik et al.[30] In their long-term analysis, they showed that excellent functional capacity could be maintained despite patient-reported structural concerns. Similarly, our cohort showed no statistically significant between-limb differences in isokinetic torque at 10 years, although these observations remain descriptive.

Nonetheless, this study has several limitations that should be acknowledged. First, its single-center, retrospective design limits generalizability, and survivorship bias cannot be excluded despite the 92.2% follow-up rate. Second, no formal *a priori* sample size calculation was performed, and the study was not designed within a formal equivalence framework; therefore, the absence of statistically significant differences should not be interpreted as evidence of true biomechanical equivalence. Third, the use of the contralateral limb as an internal control is imperfect, as age-related bilateral decline (including histological tendon changes documented with aging in animal models[25]), possible pre-injury between-limb differences, and limb dominance may have reduced the apparent between-limb contrast. Fourth, the use of the AOFAS ankle-hindfoot score without an Achilles-specific PROM, such as the Achilles Tendon Total Rupture Score (ATRS) or Victorian Institute of Sport Assessment-Achilles (VISA-A), together with the absence of ultrasound or magnetic resonance imaging to assess tendon elongation and the lack of electromyography, may have limited the detection of subtle residual deficits. Finally, proprioception was evaluated using reproduced joint position rather than absolute angular error, which may have reduced the sensitivity and comparability of these findings. Future multi-center, prospective studies incorporating disease-specific instruments, structural imaging, and standardized biomechanical assessment are warranted.

In conclusion, open double-Tajima repair combined with a structured functional loading protocol seems to be associated with clinically acceptable long-term outcomes in this cohort of non-competitive adults. However, given the retrospective, single-cohort design without an independent comparison group or formal equivalence framework, these findings should be interpreted as descriptive long-term observations. Further studies are needed to evaluate comparative effectiveness, validate these findings in larger cohorts, and better define long-term functional and biomechanical outcomes.

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