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ANKLE

Clinical comparison of the two-stranded single and four-stranded double Krackow techniques for acute Achilles tendon ruptures

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Abstract
Purpose Several different Krackow stitch configurations have been used for acute Achilles tendon rupture repair. Although several biomechanical studies compared different Krackow stitch configurations, to our knowledge, no previous studies compared the clinical outcome of these different suture methods. Therefore, in this study, we aimed to compare the clinical outcomes and complications of the two-stranded single and four-stranded double Krackow techniques.
Methods Sixty-eight consecutive patients who underwent open repair by using the four-stranded double Krackow (33 patients, group A) or the two-stranded single Krackow (35 patients, group B) techniques between September 2011 and August 2014 were reviewed retrospectively. The isokinetic strength of plantar flexion and dorsiflexion of both ankles was assessed on a Cybex dynamometer 3 and 6 months after surgery. Clinical outcomes were evaluated 3, 6, and 12 months post-operatively.
Results No significant differences were found between the groups regarding patient demographics or activity levels prior to treatment. Significant differences in the Achilles tendon Total Rupture Score, the American Orthopaedic Foot and Ankle Society Ankle–Hindfoot score, or the four-point Boyden scale were not found at any time during follow-up. Rerupture occurred only in one patient from group A. No significant differences were observed between the groups regarding the isokinetic plantar flexion and dorsiflexion strength at any time or any test speed.
Conclusion Equally favourable clinical outcomes and isokinetic muscle strength and a low complication rate were achieved with the two-stranded single Krackow technique as compared with the four-stranded double Krackow technique for acute Achilles tendon rupture repair.
Level of evidence III.

Keywords Achilles tendon rupture · Krackow suture · Treatment outcome · Cybex isokinetic test

Introduction

Acute Achilles tendon rupture is one of the most frequent major tendon injuries, and the incidence of this injury is increasing [1, 14, 21]. Various suture techniques have been used for acute Achilles tendon rupture repair, and the best-known suture techniques for tendon and ligament repair are the Kessler, Bunnell, and Krackow techniques [16].

The Krackow locking loop technique has been favoured for open repair since a biomechanical study using cadaveric Achilles tendons revealed that the initial strength of the Krackow suture was substantially higher than that of the Kessler and Bunnell sutures [6, 20]. In 1986, Krackow et al. [9] described a new locking suture for attaching ligaments, tendons, or capsular components to bone. Although the classic Krackow stitch involves three or more locking loops placed along each side of the tendon, several different configurations of the Krackow stitch have been used for acute Achilles tendon rupture repair. A biomechanical

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study of Krackow stitch configurations demonstrated that the number of locking loops influences the strength of the Krackow suture configuration [6]. However, another biomechanical study reported that increasing the number of sutures is more important than increasing the number of locking loops, and repair with four strands was biomechanically superior to that with two strands [16].

Even though the Krackow stitch configurations biomechanically affect repair strength, to our knowledge, no previous study compared the clinical outcomes of acute Achilles tendon rupture repairs performed using different Krackow stitch configurations. The purpose of this study was to compare the clinical outcomes and post-operative complications between acute Achilles ruptures repaired with the two-stranded single Krackow technique versus the four-stranded double Krackow technique.

Materials and methods

The medical records of 77 consecutive patients (77 ankles) who underwent acute Achilles tendon rupture repair between 2011 and 2015 were retrospectively reviewed. For acute Achilles tendon rupture repair, the four-stranded double Krackow technique (group A) was used in 38 patients in the first half of the study period (up to November 2013) and the two-stranded single Krackow technique (group B) was used in 39 patients during the second half of the study period (after December 2013). All operations were performed by the senior author. The inclusion criteria were acute rupture of the Achilles tendon and age ≥18 years. The exclusion criteria included a previous Achilles tendon rupture on the opposite side, previous tendon surgery, local steroid injection around the Achilles tendon for 6 months before the rupture, and less than 12 months of follow-up. Four patients (10.5 %) in group A and 3 (7.7 %) in group B were followed up for less than 12 months. In total, 33 patients in group A and 35 patients in group B were finally enrolled. Acute Achilles tendon ruptures occurred at the midsubstance (group A, $n = 28$, 84.8 %; group B, $n = 28$, 80 %), at the distal insertion (group A, $n = 3$, 9.1 %; group B, $n = 4$, 11.4 %), and at the myotendinous junction (group A, $n = 2$, 6.1 %; group B, $n = 3$, 8.6 %) (n.s.). Patient demographics, including sex, age, body mass index, time from injury to surgery, and activity level (competitive athlete, recreational athlete, or nonathlete), are shown in Table 1. These variables did not differ significantly between the groups.

Table 1 Demographic data

Demographic	Group A ($n = 33$)	Group B ($n = 35$)	*P* value
Mean age (year)[a]	37.8 ± 8.6	36.5 ± 6.4	n.s.
Sex			n.s.
Female	4	5	
Male	29	30	
Affected side			n.s.
Right	18	20	
Left	15	15	
Activity level (*n*)			n.s.
Competitive athlete	3 (9.1 %)	2 (5.7 %)	
Recreational athlete	28 (84.8 %)	30 (85.7 %)	
Nonathlete	2 (6.1 %)	3 (8.6 %)	
Mean body mass index (kg/m^2)[a]	25.4 ± 3.4	24.9 ± 2.7	n.s.
Mean time from injury to surgery (day)[a]	1.3 ± 1.1	1.6 ± 1.1	n.s.

n.s. nonsignificant

[a] Values are expressed as mean ± SD

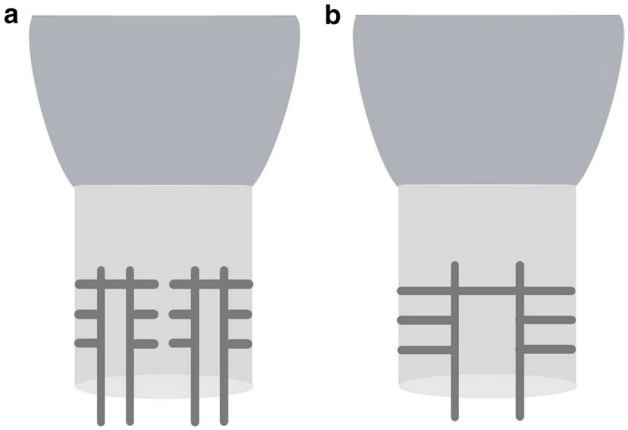

Fig. 1 Two configurations of the Krackow stitch: **a** four-stranded double Krackow technique; **b** two-stranded single Krackow technique

Surgical procedure

The operations were performed by using a pneumatic tourniquet with the patient under general anaesthesia and in the prone position. A 6- to 8-cm longitudinal incision was made 1 cm medial to the Achilles tendon over the rupture site, preserving the lesser saphenous vein and the sural nerve. The paratenon was then carefully dissected. The tendon stumps were carefully approximated in 20°–30° plantar flexion of the ankle. Tendon repair was performed by using the four-stranded double or two-stranded single Krackow techniques with a No. 2 Ethibond suture (Ethicon, Somerville, NJ), and 3 locking loops were placed along the each side of the tendon (Fig. 1). A 1–0 Vicryl (Ethicon, Somerville, NJ) running locking suture was used to reinforce the repair, and the paratenon was closed with a 3–0 Vicryl suture.

The patients followed the same standardized post-operative rehabilitation protocol regardless of suture technique. A non-weight-bearing splint in 20° plantar flexion was applied at surgery and remained in place for 2 weeks. The patients were converted to a tolerable weight-bearing controlled ankle motion (CAM) boot 2 weeks post-operatively that was initially set at 20° plantar flexion and was sequentially increased to neutral at post-operative week 5. From 5 to 7 weeks after surgery, the ankle range of motion exercise was initiated from maximum plantar flexion to neutral. At the end of 7 weeks, the ankle range of motion was increased to 10° dorsiflexion. The patients were weaned off of the CAM boot at post-operative week 9, and the patients were then instructed to perform a home exercise programme for 1 month.

Follow-up evaluation

The American Orthopaedic Foot and Ankle Society (AOFAS) Ankle–Hindfoot score [8], the Achilles tendon Total Rupture Score (ATRS) [17], and the four-point Boyden scale [3] were evaluated at 3, 6, and 12 months after surgery to evaluate clinical outcomes. This evaluation was performed by a blinded clinical observer. The time from surgery to return to work and complications after surgery were assessed. The isokinetic strength of both ankles in plantar flexion and dorsiflexion was assessed 3 and 6 months after surgery. A blinded athletic therapist unaware of the method of repair performed all strength measurements by using an isokinetic dynamometer (CSMI HUMAC Norm, Stoughton, Massachusetts, USA). The patient lay supine on the positioning chair. The patient's foot was securely strapped into the foot attachment by using Velcro straps. All patients were verbally encouraged in a positive manner to achieve a maximal effort during testing. Five isokinetic plantar flexion and dorsiflexion cycles were performed at a speed of 30°/s and 120°/s. The peak torque and average work of the injured as well as uninjured limb were measured. The relative deficit in peak torque and average work was calculated as follows: (unaffected side − affected side)/unaffected side × 100 % [10]. This study (KUGH16008-001) was approved by the Korea University Guro Hospital Institutional Review Board.

Statistical analysis

Statistical analyses were performed by using the software package SPSS for Windows version 16.0.0 (SPSS Inc., Chicago, Illinois). All continuous data assessed with the Kolmogorov–Smirnov test revealed a normal distribution. The Student's *t* test was used to compare continuous variables between the groups. The Chi-squared test or Fisher's exact test was used to compare dichotomous data. The paired *t* test was used to evaluate changes in the isokinetic muscle strength values at 3 and 6 months post-operatively. Repeated-measures analysis of variance (ANOVA) was employed to determine if there were any significant differences between the time points (3, 6, and 12 months after surgery) or between the groups. The *P* values reported as the result of repeated-measures ANOVA are labelled as follows: P_{time}, overall change over time; P_{group}, average difference between the groups; and $P_{time \times group}$, interaction between time and group. A *P* value of <0.05 was considered statistically significant. A power analysis with repeated-measures ANOVA (within-between interaction) was performed to calculate the sample size for each group to achieve 80 % power at a 5 % significance level on the ATRS. A power analysis with repeated-measures ANOVA (within-between interaction) revealed that a minimum sample size of 276 in each group was needed to achieve 80 % power at a 5 % significance level on the ATRS.

Results

Clinical outcomes

No significant time-by-group interaction was observed for the ATRS and AOFAS Ankle–Hindfoot score. The ATRS and AOFAS Ankle–Hindfoot scores significantly improved from 3 to 12 months after surgery ($P < 0.001$ and $P < 0.001$, respectively), with no significant difference between the groups (Figs. 2, 3). The four-point Boyden scale did not differ significantly between the groups at any time point (Table 2). The times to return to work and sports did not differ significantly between the groups (Table 2). The complication rate was low in both groups. In group A,

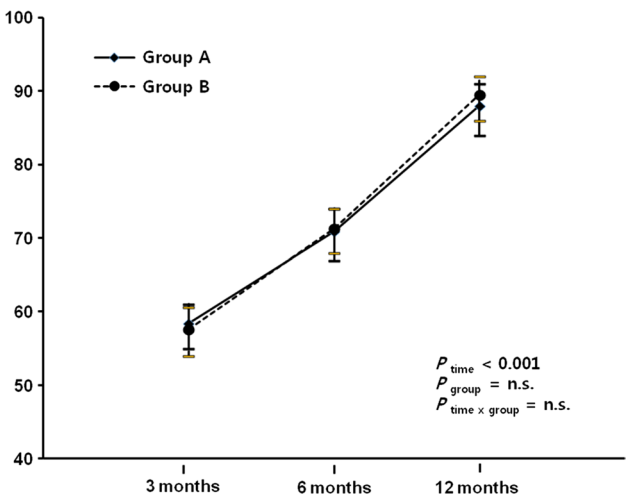

Fig. 2 Achilles tendon Total Rupture Score at follow-up. The means and 95 % confidence intervals (whiskers) are shown

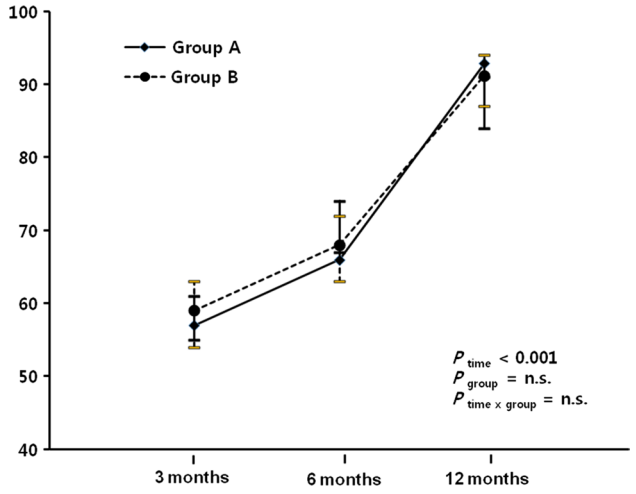

Fig. 3 American Orthopaedic Foot and Ankle Society Ankle–Hindfoot score at follow-up. The means and 95 % confidence intervals (whiskers) are shown

Table 2 Four-point Boyden scale and time to return to work

	Group A ($n = 33$)	Group B ($n = 35$)	*P* value
Boyden scale[a]			
3 months			n.s.
Excellent	0 (0 %)	0 (0 %)	
Good	5 (15.2 %)	4 (11.4 %)	
Fair	16 (48.5 %)	20 (57.1 %)	
Poor	12 (36.4 %)	11 (31.4 %)	
6 months			n.s.
Excellent	3 (9.1 %)	4 (11.4 %)	
Good	10 (30.3 %)	9 (25.7 %)	
Fair	15 (45.5 %)	18 (51.4 %)	
Poor	5 (15.2 %)	4 (11.4 %)	
12 months			n.s.
Excellent	12 (36.4 %)	10 (28.6 %)	
Good	17 (51.5 %)	20 (57.1 %)	
Fair	3 (9.1 %)	4 (11.4 %)	
Poor	1 (3.0 %)	1 (2.9 %)	
Time to return to work (weeks)[b]	7.7 ± 1.9	8.3 ± 2.4	n.s.
Time to return to sports (weeks)[b]	18.7 ± 2.0	17.8 ± 1.9	n.s.

n.s. nonsignificant

[a] Values represent the number and percentage of patients

[b] Values are expressed as mean ± SD

one case (3.0 %) experienced rerupture requiring reoperation and one case (3.0 %) experienced superficial infection requiring oral antibiotics. In group B, one case (2.9 %) of superficial wound dehiscence required local wound care.

Table 3 Dynamometry data

	Group A ($n = 33$)	Group B ($n = 35$)	*P* value
Plantar flexion strength (N m)			
Peak torque			
30°/s angle speed			
3 months	61.7 ± 6.3 (20.2)	59.8 ± 6.0 (19.6)	n.s.
6 months	77.0 ± 6.0 (13.1)	75.5 ± 6.1 (13.4)	n.s.
P value	<0.001	<0.001	
120°/s angle speed			
3 months	36.3 ± 6.8 (15.7)	35.9 ± 6.1 (15.8)	n.s.
6 months	40.5 ± 8.1 (12.1)	41.3 ± 7.7 (11.7)	n.s.
P value	0.005	<0.001	
Mean work			
30°/s angle speed			
3 months	30.5 ± 6.3 (18.1)	30.4 ± 5.7 (17.7)	n.s.
6 months	33.3 ± 3.4 (15.2)	32.9 ± 3.9 (15.4)	n.s.
P value	0.032	0.047	
120°/s angle speed			
3 months	21.3 ± 3.4 (20.8)	21.6 ± 3.3 (20.5)	n.s.
6 months	24.9 ± 3.5 (13.6)	24.7 ± 3.9 (12.8)	n.s.
P value	<0.001	0.001	
Dorsiflexion strength (N m)			
Peak torque			
30°/s angle speed			
3 months	31.8 ± 5.2 (15.1)	31.3 ± 5.8 (14.6)	n.s.
6 months	32.2 ± 5.2 (−6.3)	32.2 ± 6.3 (−6.7)	n.s.
P value	n.s.	n.s.	
120°/s angle speed			
3 months	18.9 ± 4.4 (−1.8)	18.8 ± 4.5 (−2.4)	n.s.
6 months	19.6 ± 4.6 (−9.8)	18.7 ± 4.8 (−10.3)	n.s.
P value	n.s.	n.s.	
Mean work			
30°/s angle speed			
3 months	17.1 ± 3.8 (10.6)	16.8 ± 4.4 (10.8)	n.s.
6 months	18.2 ± 4.8 (−8.5)	16.8 ± 3.8 (−9.0)	n.s.
P value	n.s.	n.s.	
120°/s angle speed			
3 months	13.3 ± 7.1 (0.3)	11.3 ± 7.4 (−0.3)	n.s.
6 months	13.0 ± 3.2 (−11.1)	12.3 ± 3.3 (−10.7)	n.s.
P value	n.s.	n.s.	

Values are expressed as mean ± SD (deficit %)

n.s. nonsignificant

Isokinetic muscle strength

No significant differences were found between the groups regarding the isokinetic plantar flexion and dorsiflexion strength (mean peak torque and work per repetition) at any time point (3 and 6 months after surgery) and any test speed (30°/s and 120°/s) (Table 3). The mean peak torque and work for plantar flexion strength at both test speeds improved significantly from 3 to 6 months after surgery in both groups, whereas those for dorsiflexion strength at both test speeds did not change significantly from 3 to 6 months after surgery in either group (Table 3).

Discussion

The most important finding of the present study is that no significant differences in the clinical outcomes and isokinetic muscle strength were detected between the two-stranded single and the four-stranded double Krackow techniques for repairing acute Achilles tendon ruptures. Suture repair of a ruptured tendon should have sufficient initial repair strength because early active motion provides better results for tendon repair [5, 7, 11, 19]. In biomechanical studies, the number of strands crossing the repair site was demonstrated to be more important for the strength of the repair than the number of locking loops [2, 16, 20]. Another biomechanical study, in which the rabbit Achilles tendon and flexor digitorum longus repair were utilized, reported a correlation between better outcome and more strands [18]. Based on the results of biomechanical studies, the double suture has been considered superior to the single suture because the double suture may allow for earlier active rehabilitation with fewer reruptures. However, biomechanical studies cannot represent the physiologic condition of Achilles tendon ruptures in vivo in humans because biomechanical studies using animal or cadaveric models provide a non-physiologic cyclical load and create clean surgical cuts of tendons as opposed to the frayed appearance of most traumatic tears. Therefore, the results of biomechanical studies may not be clinically relevant because they may differ from those of clinical studies. Further, to our knowledge, no previous studies compared the clinical outcomes of acute Achilles tendon rupture repairs by using different Krackow stitch configurations. Therefore, the importance of the present study is that the clinical outcomes and muscle strength were compared between acute Achilles ruptures repaired with the two-stranded single Krackow technique and those repaired with the four-stranded double Krackow technique.

The four-stranded double Krackow technique has been recommended for acute Achilles tendon rupture repair over the two-stranded single Krackow technique because of biomechanical superiority [6, 15, 16]. However, the space is usually insufficient for 4 strands during Achilles tendon repair, and using 4 strands results in the risk of avascularity and fraying of the tendon ends [4, 12, 13, 18]. We found no significant differences between the two-stranded single and four-stranded double Krackow techniques regarding clinical outcomes and isokinetic muscle strength. Even though the same standardized post-operative rehabilitation protocol was applied to both groups, only one patient experienced rerupture, and this patient was in the four-stranded double Krackow group. Therefore, the two-stranded single Krackow technique appears to provide sufficient repair strength for our post-operative rehabilitation protocol; further, compared with the four-stranded single Krackow technique, the two-stranded single Krackow technique may be easier to perform and does not produce inferior results.

The limitations of the present study are the retrospective design and small sample size. The power analysis showed that the sample size was insufficient to demonstrate the absence of significant differences in clinical scores between the two-stranded and four-stranded Krackow techniques. Further prospective studies are required to confirm our findings. However, this is the first study to compare the clinical outcomes of acute Achilles tendon rupture repairs by using different Krackow stitch configurations.

The clinical relevance of the present study is that equally favourable clinical outcomes and isokinetic muscle strength and a low complication rate were achieved with the two-stranded single Krackow technique as compared to the four-stranded double Krackow technique for acute Achilles tendon rupture repair.

Conclusion

The four-stranded double Krackow technique is not superior to the two-stranded single Krackow technique for acute Achilles tendon rupture repair.

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