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Percutaneous versus Open Achilles Tendon Repair: A Case-Control Study

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Abstract

Purpose: We investigated whether percutaneous suturing of Achilles tendon ruptures showed better results and superiority in terms of clinical outcomes when compared to open suturing. Methods: We conducted a case-control study. Between 2009 and 2014, we performed surgical revisions of closed acute Achilles tendon ruptures in our hospital in 146 patients, of which 71 patients (2012-2014) received percutaneous suturing using Dresden instruments, and 75 patients (2009-2012) underwent open suturing. After a minimum period of 1 year post surgery, we performed clinical follow-up in 25 patients of each of the groups using the AOFAS hind foot score and the SF-12 questionnaire. Furthermore, we implemented a clinical questionnaire with a reference population of 200 healthy individuals. Results: Mean age in the total population of 146 patients was 47 years (range 21 to 83 years) at the time of surgery. The duration of the surgical procedure with percutaneous suturing was significantly shorter (24 versus 43 minutes, $p < 0.0001$), the complication rate was significantly lower (2.81% versus 10.7%, $p < 0.0001$), and the time of hospitalisation was significantly shorter (3 versus 4 days, $p < 0.0001$) when compared to open suturing. During follow-up, no significant differences between the two groups were observed in terms of descriptive parameters. Furthermore, ultrasound examinations of both follow-up populations did not show any significant difference. From a clinical perspective, the good to very good results achieved with open suturing (as measured with the AOFAS hind foot score and the SF-12 questionnaire) have not been significantly improved with percutaneous suturing. The additional use of a new clinical score (with the reference population) demonstrated good to very good consistency with the established scores. Conclusion: In our population, percutaneous Achilles tendon suturing showed significantly lower complication rates and significantly shorter procedure times when compared to open suturing. However, percutaneous suturing did not show clinical improvements of the good to very good results that were achieved with open suturing (as measured with the AOFAS back foot score and the SF-12 questionnaire). The implementation of a new and simple score for the clinical evaluation of Achilles tendon injuries resulted in good to very good consis-

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tency with the established questionnaires and, thus, offered a straightforward and rapid alternative when compared to the more elaborate scores.

Keywords

Achilles Tendon Rupture, Open Suture, Percutaneous Repair, Clinical Outcome

1. Introduction

Due to the increasing level of activity in elderly populations, Achilles tendon rupture is a common injury [1] with an incidence of 6 - 21.5/100,000 [1] [2]. However, available evidence is still insufficient (despite numerous studies) with regard to recommending conservative or surgical therapy and a specific surgical procedure [3]-[5]. In this study, we evaluated the difference in clinical outcomes after open Achilles tendon revision [6] compared to the minimally invasive percutaneous technique described by Amlang *et al*. [7]. Evaluation was performed using the SF-12 questionnaire and the AOFAS hind foot score [8] [9]. Furthermore, we implemented a new clinical score for the future assessment of surgical outcome in patients who were not able to return to the hospital for clinical follow-up.

2. Material and Methods

Before starting the clinical case-control study, the study protocol was evaluated and approved by a university ethics committee (Ethics committee notification: 14-101-0246). Then, all patients in the hospital information system were identified who were diagnosed with acute Achilles tendon rupture between 2009 and 2014, and who underwent surgery, either using open revision (first group) following the technique described by Kirchmayer und Kessler (plus additional fibrin sealing) [6] [10] [11] or percutaneous suturing (second group) using Dresden instruments [7]. Surgery was performed in accordance with the criteria defined by Pagenstert *et al*. and Amlang *et al*. [7] [12].

The following exclusion criteria applied: surgical revision more than 7 days post-trauma, bilateral ruptures, and surgical revision following re-rupturing after conservative treatment.

All surgically treated patients underwent a standardised follow-up schedule [13]. The time from surgery to clinical follow-up was at least 1 year.

Identified patients were invited by letter or telephone call to participate in the outpatient procedure. Prior to their participation, the participants were informed about the objectives and risks of the study, and all participants signed an informed consent form. In addition to the descriptive data of the study participants (age, gender, nicotine consumption, BMI, lateral localisation, diabetes mellitus, ASA classification, and mechanism of trauma) the following parameters were recorded: duration of hospital stay, length of time between accident and skin incision, duration of surgical procedure, length of time until work was resumed, complication rate, and all reported complications.

The clinical follow-up included palpatory examinations to detect lymphoedema and tenderness, and the evaluation of the range of motion in the upper and lower ankle using a goniometer. The results were categorised into four groups (range of motion identical on both sides, range reduced by <10˚, range reduced by >10˚, greater range of motion when compared to healthy side). Furthermore, calf circumference was measured in a standardised procedure 10 cm and 20 cm above the Achilles tendon enthesis (as determined per ultrasound) and compared between both sides. Ultrasound examination was also used to determine Achilles tendon morphology (compared between both sides) and cross-sectional and longitudinal diameters at 4 cm above the Achilles tendon enthesis. In order to reduce potential investigator-related bias, all examinations were performed by an independent investigator (B.S.) who had explicitly not been involved in the surgical treatment.

Furthermore, the SF-12 and the AOFAS hind foot scores were assessed [8] [9]. In addition to these two standardised and validated questionnaires, an additional new questionnaire-exclusively focused on clinical perspectives and consisting of 10 questions with four answering options each-was created and used (**Figure 1**). Questions investigate the patient's subjective assessments in the domain of pain, impairment of daily routine functionality, and impairment of weight-bearing functionality. This questionnaire was based on a reference population

Regensburg Achilles tendon score

For the following questions, please check the statement that is most suitable for you (AT = Achilles tendon):

1. Do you have any problems or complaints in the AT region when wearing a normal shoe?

Never	Rarely	Often	Always

2. Do you tend to develop swellings in the AT region over the day?

Never	Rarely	Often	Always

3. Do you have any problems or complaints in the AT region during rest?

Never	Rarely	Often	Always

4. Do you have any problems or complaints in the AT region when walking?

Never	Rarely	Often	Always

5. Do you have any problems or complaints in the AT region when running?

Never	Rarely	Often	Always

6. Do you have any problems or complaints in the AT region when climbing stairs?

Never	Rarely	Often	Always

7. Do you feel "run-in" pain after stating walking (e.g. after sleeping, after sitting for longer periods of time etc.)?

Never	Rarely	Often	Always

8. Can you exercise the same way you did prior to your injury?

Without restrictions	With minor restrictions	With considerable restrictions	Not possible

9. Can you perform toe walking?

Without restrictions	With minor restrictions	With considerable restrictions	Not possible

10. Are you taking pain medication due to pain in the AT region?

Never	Rarely	Often	Always

Figure 1. Regensburg Achilles tendon score.

of 200 healthy individuals, and the results underwent correlation analysis in comparison with the AOFAS hind foot score. Furthermore, a reliability analysis of the 10 questions was performed.

3. Statistics

Statistical analyses were performed using SPSS for Windows, Version 22.0 (SPSS Inc. U.S.A). Metric variables were presented as mean or median values, while the ranges were specified as standard deviations and quartiles. Categorised and/or nominal data were specified as absolute and relative frequencies.

The normal distribution of metric variables was assessed using the Kolmogorov-Smirnov test. The tested variables predominantly did not show a normal distribution (Kolmogorov-Smirnov test: $p < 0.05$). Thus, only nonparametric tests for samples without normal distribution were used when comparing the samples. When comparing 2 independent samples without normal distribution, the Mann-Whitney-U test was used. Categorised data were analysed using the Chi-square test and the Fisher's exact test. Correlation between 2 parameters was

calculated using the correlation coefficient according to Spearman's rho. Reliability analysis on the new clinical score was conducted using Cronbach's alpha. A two-sided significance test was performed for all tests, and a p-value of <0.05 was considered statistically significant for all statistical tests. The calculation of the physical and psychological subscores of the SF-12 questionnaire was performed using the standardised and validated evaluation software of the Hogrefe publishing company. In doing so, the 12 collected items were encoded in accordance with the instructions and processed with SPSS.

4. Results

It was possible to identify 146 patients (between 2009 and 2014) who met the inclusion criteria. A subpopulation of 75 patients had received surgical revision (between 2009 and 2012) in accordance with the technique described by Kirchmayer und Kessler [6] plus additional fibrin sealing (first group). Moreover, a total of 71 patients had received treatment using Dresden instruments [7] between 2012 (when the new percutaneous technique was introduced) and 2014 (second group). According to the Kolmogorov-Smirnov test, all collected data of the two groups were not normally distributed, and subsequent statistical procedures were selected accordingly. Descriptive data of the total population are summarised in **Table 1**. It was possible to recruit 25 patients of each group for follow-up.

The mean time until follow-up was 52.7 months (range 25 - 81) in the first group and 24.5 months (range 14 - 36) in the second group. Additional descriptive data for both groups are summarised in **Table 1**.

The data collected for the length of time between accident and skin incision, length of time between incision and suture, and length of hospital stay are shown in **Table 1**.

Clinical examinations in the first group showed that 23/25 patients had an identical range of motion on both sides. Of the 2 remaining patients, dorsal extension was reduced by 10˚ in one, and plantar flexion was reduced by 10˚ in the other patient, when compared to their healthy side. In the second group, 21/25 patients had an identical range of motion on both sides. In 2 patients dorsal extension was reduced by 10˚ and in the remaining 2 patients plantar flexion was reduced by 10˚, when compared to their healthy side. All patients of both groups showed thickening of the Achilles tendon on palpation, one patient in the second group experienced pain on palpation. Median duration of incapacity for work was 56 days (range 3 - 168) in the first group, and 42 days (range 7 - 349) in the second group, without statistical differences.

All patients reported complications and their frequencies are summarised in **Table 2** showing a significantly

Table 1. Demographic data of the total study population; n: 146.

Total population	First group n = 75	Second group n = 71	Statistic test
Age (years)	46 (range 21 - 78)	48 (range 25 - 83)	n.s. (Mann-Whitney-U test)
Right/left side	39/36	28/43	n.s. (Fisher's test)
Male/female	60/15	58/13	n.s. (Fisher's test)
ASA classification 1/2 3	 38/36 1	 40/26 5	 n.s. (Chi-square test)
Duration of surgery (min)	43 (range 15 - 84)	24 (range 15 - 60)	p = 0.0001 (Mann-Whitney-U test)
Time of hospitalisation (days)	4 (range 2 - 8)	3 (range 2 - 6)	p = 0.0001 (Mann-Whitney-U test)
Time between accident and skin incision (hours)	77 (range 5 - 168)	60 (range 10 - 165)	n.s. (Mann-Whitney-U test)

n.s. = not significant.

Table 2. Surgical complications in total population.

Complications	First group; n = 75	Second group; n = 71	Statistical analysis
Delayed wound healing, without revision	1	0	n.s. (Fisher's test)
Infection, with surgical revision	5	1	p = 0.0001 (Fisher's test)
Re-rupturing	2	1	n.s. (Fisher's test)
Total	8 (10.6%)	2 (2.8%)	p = 0.0001 (Fisher's test)

n.s. = not significant.

lower revision rate for percutaneous suturing. Ultrasound evaluation did not reveal any significant differences between the two groups (see **Table 3**).

SF-12 analyses in both groups demonstrate similar results for psychological and physical subscores when compared to an age-matched healthy normal population (**Table 4**). Similarly, the analyses of the AOFAS back foot scores in both groups predominantly demonstrated very good and good results and did not show any significant differences (**Table 4**). One patient of the second group who underwent multiple revisions (e.g. due to suture fistula) showed a poor result with persisting functional impairment and persisting pain.

Analysing the new clinical Achilles tendon score (**Figure 1**), a highly significant difference ($p = 0.0001$) is shown when comparing reference population ($n = 200$) and patient population ($n = 50$) using the Mann-Whitney U test. The correlation coefficient of the correlation analysis in comparison to the AOFAS hind foot score showed an r-value of 0.700 ($p = 0.0001$). The reliability analysis on the 10 items resulted in a Cronbach's alpha of 0.892. The analysis has a maximum of 40 points and is split up into the following sections: 40 - 36 points: Very good; 35 - 31 points: Good; <30 points: Poor.

5. Discussion

The current literature-Matilla *et al*. in Finland [14] and Huttunen *et al*. in Sweden [15]-shows that the number of surgically treated acute Achilles tendon ruptures has clearly declined over the past years, after it had continuously increased before. The assumed reason is that-while re-rupturing rates remain the same-functional results are good, and there is no surgical risk when early conservative, functional follow-up is performed [5] [16]. On

Table 3. Patient characteristics and examination data of the follow-up population.

Follow-up study patients	First group; n = 25	Second group; n = 25	Statistical analysis
Nicotine abuse, yes/no	6/19	2/23	n.s. (Mann-Whitney-U test)
BMI (kg/m^2)	25 (range 19 - 47)	28 (range 21 - 34)	n.s. (Mann-Whitney-U test)
Follow-up (months)	53 (range 25 - 81)	24 (range 14 - 36)	n.s. (Mann-Whitney-U test)
Ultrasound examination (mm)			
1	5.6 (range 3 - 9)	5.5 (range 0 - 13)	n.s. (Mann-Whitney-U test)
2	5.4 (range 2 - 10)	5.3 (range 0 - 10)	
Calf circumference (cm)			
3	0.2 (range −1 to 1.5)	0.24 (range −1 to 5)	n.s. (Mann-Whitney-U test)
4	−1.8 (range −3 to −0.5)	−1.4 (range −4 to 4)	

1: Difference in longitudinal diameters of the Achilles tendon compared between both sides, and measured 4 cm above the calcaneal attachment site (treated side-healthy side). 2: Difference in cross-sectional diameters of the Achilles tendon compared between both sides, and measured 4 cm above the calcaneal attachment site (treated side-healthy side). 3: Difference in calf circumferences of the Achilles, measured 10 cm above the calcaneal attachment site (as confirmed by ultrasound) (treated side-healthy side). 4: Difference in calf circumferences of the Achilles, measured 20 cm above the calcaneal attachment site (as confirmed by ultrasound) (treated side-healthy side). n.s. = not significant.

Table 4. Results of the outcome scores.

Scores	First group; n = 25	Second group; n = 25	Statistical analysis
AOFAS			
Very good	18 (72%)	19 (76%)	
Good	6 (24%)	4 (16%)	n.s. (Chi-square test)
Moderate	1 (4%)	1 (4%)	
Poor	0 (0%)	1 (4%)	
SF-12			
Physical	51.49	50.04	n.s. (Mann-Whitney-U test)
Mental	55.18	53.70	
Regensburg score			
Very good	19 (76%)	16 (64%)	n.s. (Chi-square test)
Good	4 (16%)	6 (24%)	
Poor	2 (8%)	3 (12%)	

n.s. = not significant.

the other hand, the data analysis conducted by Soroceanu *et al*. [5] demonstrated that surgically treated patients return to their workplace on average 19 days earlier, while their range of motion, lower leg circumference, and functional outcome were equivalent. Contrary to that, Wang *et al*. [17] had demonstrated in their analysis of 12,570 patients in the United States that the percentage of surgically treated patients has remained stable or even increased slightly. However, even with this very large number of patients, no significant difference of the re-rupturing rate between surgically and conservatively treated patients was shown. Recent publications show that no evidence-based recommendations in favour of any procedure can be made, despite the still increasing number of Achilles tendon ruptures of the past years [3] [14] [15] [17] [18]. Gross *et al*., for example, advocate individual treatment, due to the lack of prospective randomised clinical studies [18]. These reports were also taken into account when considering the surgical treatment of patients in our hospital. Accordingly, we opted for the surgical treatment of an 83-year-old patient, because his biological age was much lower and he still exercised extensively.

Nevertheless, our patient population was comparable to the current literature both in terms of age distribution and with regard to the number of patients [4] [16] [17] [19]-[23]. For example, in a systematic review conducted by Del Bunno *et al*. [2] case numbers between 19 and 237 patients were considered.

In accordance with the published literature [2] [12] [16] [19], we also explicitly excluded patients with diabetes mellitus, chronic venous insufficiency, or PAD from surgical treatment (both open and percutaneous). However, nicotine abuse in patients with confirmed perfusion was no contraindication.

"Stop and Go" sports are regarded as the major injury mechanism, followed by other sports injuries-as described by Gross *et al*. and Gigante *et al*. [16] [18]. This was confirmed in our analysis.

When analysing the duration of surgery in the open group, our data show an average procedure time of 43 minutes, which is comparable with the results of other authors who reported average intervals between incision and suturing of 45 minutes [4] [16] [20]. The percutaneous technique was associated with significantly shorter procedure times with a mean reduction of 19 minutes and 80%, when compared to the open technique. Other authors have also reported such short and rapid procedure times for the percutaneous technique [16] [19], which represents a clear and considerable advantage when compared to the open technique.

Finally, we also demonstrated a significantly shorter hospital stay (3 versus 4 days), which had already been reported by Cretnik *et al*. (8 versus 3 days) [19]. Analyses of other studies did not take into account this criterion [2] [16] [22].

No differences between the two groups were found in our clinical follow-up in terms of the following criteria: thickening of the treated Achilles tendon, reduction of muscles of the treated side, ultrasound examination of the Achilles tendon. This also applies to the collected AOFAS and SF-12 scores. It remains unclear as to whether the different follow-up intervals had any influence. Possibly, a certain improvement-of the still good to very good results-can be expected in the percutaneous group due to the clearly shorter follow-up intervals (24 versus 53 months). Nevertheless, our results correspond closely to other publications [16] [19].

In the review conducted by Del Buono *et al*. [2], only 2 of 9 studies showed a better range of ankle movement with the percutaneous technique, while all other studies showed equivalent results. Thus, the authors conclude in the discussion section of their paper that the range of motion level of both techniques can be considered as equivalent.

In terms of surgical complications, we were able to demonstrate a highly significant difference in favour of the percutaneous technique. The complication rate of 11% in the open group is comparable with that of other studies [2] [20]. Only Lim *et al*. [4] report a clearly higher complication rate (27%), which might be due to the fact, that only 66 patients had been recruited in their study over a period of 30 months-but in 6 different hospitals-possibly resulting in a lack of routine. The study does not provide more detailed patient characteristics with regard to the infection rate of 21%.

Principally, it appears to be difficult to compare results within the range of the percutaneous technique, since there is a diversity of methods that have been used; for example, in the publication of Lim *et al*. [4] the original technique of Ma and Griffith was used, whereas Haji *et al*. [20] used a modified suturing method, and Hsu *et al*. [22] used PARS® (manufactured by Arthrex®). Even the review conducted by Del Buono *et al*. [2] contained different methods, including the technique described by Amlang [7], which we were using. In the study by Krueger *et al*. [23], the Tenolig® system was compared with the technique according to Amlang and with a modified suturing method described by Ma and Griffith. Functionally equivalent results were shown in all of the three studies, and the number of supposed major complications was low. However, any comparison of results is

limited and under reserve, since each surgical technique has its own specific complications. This also applies to the comparison between conservative and surgical treatment [5] [24].

Many studies are based on small numbers of cases and follow-up patients [2] [4] [11]. This may be because many patients are very satisfied with the surgical outcome and can see no reason for returning to the hospital for examinations, or that they have moved to another place in the meantime, and the journey might take too long. Furthermore, score assessment is time-consuming, and patients might not be willing to undertake this task. We were able to achieve results similar to those in the literature when using the common AOFAS tool. For example, Del Buono *et al*. [2] predominantly reported total AOFAS scores of 96 points for the open technique and 97 points for the percutaneous methods (equivalent to very good results). The SF-12 score results are also consistent with those observed by Gigante *et al*. [16], who reported a psychological subscore of 50.4 and a physical subscore of 50.7.

Moreover, it was our objective to develop an instrument that can be sent to the patients by post in order to collect data that would otherwise require time-consuming clinical examinations. Our score, which was evaluated in a reference population of 200 healthy subjects, has shown very good correlation results when compared to the AOFAS. Based on the good statistical results, it seems to be a good instrument; however, it still must be evaluated in further studies.

Finally, the weaknesses of the study must be highlighted: this is a retrospective study with an associated low level of evidence (Level 4), and the number of patients lost to follow-up may be considered high. Furthermore, the follow-up interval was different for the two groups. Nevertheless, the follow-up sample from the total population can be regarded as representative, particularly in terms of the descriptive data. This population mainly encompassed working young patients who were not motivated to return to the hospital for clinical follow up (with all the related effort and expenditure of time), given their good to very good clinical outcomes. Particularly for this reason, we implemented a new clinical questionnaire that 1) is easily comprehensible, 2) can be completed independently, 3) can be completed at the patient's home within a short period of time. This could be a tool to increase the clinical follow-up rate in the future.

6. Conclusion

Percutaneous Achilles tendon suturing showed significantly lower complication rates, significantly shorter procedure times, and significantly shorter hospitalisations when compared to open suturing. However, percutaneous suturing did not show clinical improvements of the good to very good results that were achieved with open suturing (as measured with the AOFAS hind foot score and the SF-12 questionnaire). The implementation of a new and simple score for clinical evaluation of Achilles tendon injuries resulted in a good to very good consistency and, thus, offered a straightforward and rapid alternative when compared to the established but more elaborate scores. Furthermore, patients are not required to return to the hospital.

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