Management of chronic Achilles ruptures: a scoping review

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Received: 7 May 2021 / Accepted: 25 May 2021 / Published online: 5 June 2021 © The Author(s) 2021

Abstract

Purpose This scoping review aims to systematically map and summarise the available evidence on the management of chronic Achilles ruptures, whilst identifying prognostic factors and areas of future research.

Methods A scoping review was performed according to the frameworks of Arksey and O’Malley, Levac and Peters. A computer-based search was performed in PubMed, Embase, EmCare, CINAHL, ISI Web of Science and Scopus, for articles reporting treatment of chronic Achilles ruptures. Two reviewers independently performed title/abstract and full text screening according to pre-defined selection criteria.

Results A total of 747 unique articles were identified, of which 73 (9.8%) met all inclusion criteria. A variety of methods are described, with flexor hallucis longus tendon transfer being the most common. The most commonly reported outcome is the American Orthopaedic Foot and Ankle Society (AOFAS) score, although 16 other measures were reported in the literatures. All studies comparing pre- and post-operative outcomes reported significant post-treatment improvement. Complications were reported in 50 studies, with an overall pooled complication rate of 168/1065 (15.8%).

Conclusion Although beneficial results were reported following a variety of techniques, comparison between these is challenging due to the low-level study designs used and confounding factors such as treatment delay and tendon gap size. Further research comparing the efficacy of different techniques is required in order to facilitate the development of an evidence-based treatment protocol. Such work would allow clinicians to better understand the suitability of the large variety of reported techniques and select the optimal strategy for each individual patient.

Keywords Achilles · Chronic rupture · Achilles tendon rupture · Scoping review · Neglected rupture

Introduction

Rupture of the Achilles tendon is a relatively common injury, with around 4500 Achilles ruptures occurring in the UK every year. Recent epidemiological data demonstrates a significant 39% rise in incidence, from 1.8 per 100,000 person years in the USA in 2012 to 2.5 per 100,000 person years in 2016. A similar trend is also reported in a number of other countries [1–4]. Given that the majority of Achilles ruptures occur during participation in sports such as basketball, numerous authors suggest that this increasing incidence may be due to an increase in participation in recreation sports, particularly in older adults. Other potential factors include an increased awareness and therefore diagnosis of ruptures by emergency doctors, although there is currently no strong evidence to support either hypothesis.

Treatment of acute ruptures is widely debated with previous research describing both operative and conservative (functional dynamic regime) methods [5–7]. Traditionally, open operative repair has been the favoured option with authors showing lower re-rupture rates compared to nonoperative methods [8, 9]. More recently, however, a number of authors have reported excellent outcomes and lower re-rupture rates, with the use of nonoperative functional orthotic treatment, such as the Leicester Achilles Management Protocol (LAMP) and Swansea Morriston Achilles Rupture

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Treatment (SMART) protocol. Research also suggests that nonoperative management is associated with fewer short-term complications. The emergence of this new evidence has led to non-operative treatment becoming the mainstay of contemporary treatment protocols. If the initial tendon rupture is not diagnosed promptly, as is the case in up to 20% of patients, the injury may then be termed chronic or neglected [10]. Authors disagree as to the exact definition of a chronic lesion; however, a recent systematic review by Flint et al. suggests that the term chronic should be used to define a rupture presenting at least four weeks after the initial injury [11].

A wide variety of techniques such as flexor hallucis longus tendon transfer and V–Y plasty [12–14] have been described in the management of chronic Achilles ruptures. To the best of our knowledge, the only previous scoping/systematic review investigating the full breadth of treatment options was published in 2013, with 34 studies included. However, since that date, there has been a surge in publications reporting treatment of chronic Achilles ruptures, using various techniques. There is therefore a gap in the current literature for an up-to-date review of management techniques. This scoping review addresses this by systematically mapping and summarising current evidence regarding the management of chronic Achilles ruptures, whilst identifying areas for future research. This aims to improve readers’ knowledge of the available treatment strategies and associated outcomes, and aid clinicians in optimising treatment protocols.

Methods

A scoping review methodology was chosen for this article due to the broad aim of systematically mapping and summarising the full breadth of literature regarding the treatment of chronic Achilles ruptures. Methodological guidelines for the conductance of scoping reviews have been developed by Arksey and O’Malley, Levac and The Joanna Briggs Institute [15–17]. This review adheres to these guidelines, which all describe five key stages in the conductance of a scoping review, as detailed below.

Identifying the research question

The following research questions were developed to guide this review:

- What management options are currently reported for the management of chronic Achilles ruptures and what are their outcomes?
- If possible to compare outcomes, which techniques have the greatest efficacy?
- What prognostic factors may influence treatment outcome?

Identification of relevant studies

A thorough computer-based search was performed in six electronic databases including: PubMed, Embase, EmCare, CINAHL, ISI Web of Science and Scopus. A combination of free text and medical subject heading (MeSH) terms such as ‘Achilles’, ‘tendoachill*’, ‘calcaneal tendon’, ‘rupture’, ‘chronic’ and ‘neglected’ was used (see online resource 1 for full details). The Boolean operators ‘and’ and ‘or’ were used to combine terms in full search strings. All searches were performed with an English language restriction (as the research team lacks translation capabilities) and no date restrictions. Searches were conducted on 15 February 2021. Manual reference list analysis of review articles was performed to ensure retrieval of all relevant articles.

Study selection

Following article retrieval, all studies were imported into Rayyan systematic reviews web application to aid the screening process [18]. Two authors performed two-stage screening, initially involving title/abstract screening and then full text screening, guided by the selection criteria below:

1. **Population**: Patients of all ages with chronic Achilles ruptures. Due to the large variation in the time period used to define a chronic rupture, no restriction as to the minimum duration between injury and diagnosis/treatment was imposed. All studies describing treatment of ‘chronic’ or ‘neglected’ Achilles ruptures were included.
2. **Intervention**: Any intervention for the management of chronic Achilles rupture.
3. **Comparison**: A comparison group was not required for inclusion in this review.
4. **Outcomes**: Studies reporting outcomes using any validated or non-validated scores were included. Examples of scores include American Foot and Ankle Society (AOFAS) score, Achilles Tendon Total Rupture Score (ATRS), Leppilahti score, Tegner Score, Hooker scale and 36-item short-form survey (SF-36). Studies reporting outcomes only in terms of patient-reported satisfaction or symptom improvement were excluded.
5. **Study design**: Original research studies (observational studies, cohort studies, randomised controlled trials) were included. Review articles, case reports, commentaries and abstracts were excluded. Studies failing to report treatment outcomes for Achilles rupture separately from other conditions, for example, Achilles tendinosis, were excluded.
6. **Date:** No publication date inclusion criteria were imposed at either the search or screening stage.

7. **Language:** Studies published in the English language were included. Due to the lack of funding and linguistic capabilities of the research team, studies published in all other languages were excluded.

**Charting the data**

A pilot data extraction form was created following discussion between the review team. This sheet contained the following headings:

- Author
- Year of publication
- Type of study
- Number of patients
- Mean age
- Male: female ratio
- Treatment method
- Mean size of tendon defect
- Mean treatment delay
- Outcome scores, e.g. AOFAS, SF-36, ATRS, etc.
- Significant difference between pre- and post-operative score
- Any comparison group and outcome comparison?
- Re-rupture rate
- Complications
- Follow-up period

Two reviewers independently used this form to extract data from the first ten relevant studies. Discussion then took place as to the suitability of the form [19], at which point the decision was taken to add two further headings, ‘minimum treatment delay for inclusion’ and ‘prognostic factors’. Once these headings were added, the final sheet was used to extract relevant data from all studies.

**Collating, summarising and reporting the results**

Study results are reported in a qualitative thematic manner, with distinct sections focusing on key themes such as the outcome measures used, treatment results and complications. Basic study characteristics including year of publication, number of patients, mean age, male:female ratio and follow-up period are displayed in Table 1. The number of studies retrieved using the search strategy and excluded at both the title/abstract and full text screening stage is detailed in a PRISMA flow diagram [20]. Outcome scores were pooled across studies reporting the same treatment technique if there were at least five studies reporting a particular technique and if at least three of these studies reported both pre- and post-operative outcome scores. Pooling was performed in R 4.0.0 software (R foundation for statistical computing, Vienna, Austria), using DerSimonian and Laird random effects weighting. Missing standard deviation values were imputed according to the method of Walter and Yao [21]. The pooled pre-operative outcome score was subtracted from the equivalent pooled post-operative score to calculate an unstandardised mean difference. Studies which did not record both a pre- and post-operative score were not included in this analysis.

**Results**

A total of 747 unique articles were identified, of which 73 (10.3%) were included in the final review (Fig. 1). Summary statistics of all included studies are presented in Table 1.

**Treatment techniques**

A wide variety of treatment methods were reported in the included literature, as detailed in Fig. 2. The most common technique is flexor hallucis longus (FHL) tendon transfer, reported in a total of 22 studies. Of these, two studies used both a single and a double incision approach in different patients, seven exclusively used a single incision, nine a double incision, two an endoscopic approach and two did not specify the exact approach. Other tendon transfer methods, such as semitendinosus tendon transfer (ST transfer), peroneus brevis tendon transfer (PB transfer) and hamstring tendon transfer, were reported in seven, six and two studies, respectively. Percutaneous techniques, including a figure of eight stitch repair or modified Bunnell repair, were reported in two studies [30, 52]. A total of ten studies used gastrocnemius flaps with no augmentation, whilst six studies describe additional FHL augmentation (Fig. 2). Techniques such as V–Y and Z plasty were reported both as stand-alone techniques or combined with a synthetic acellular human dermal tissue matrix graft jacket (Wright Medical Technology, Inc., Arlington, TN) or FHL transfer [53]. Other less commonly reported techniques include use of the Ligament Advanced Reinforcement System (LARS) graft (JK Orthomedic, Dollard-des-Ormeaux, Quebec, Canada), polyester tape, scar tissue interposition and Duthie’s biological repair [10, 43, 45, 91]. Only one study described nonoperative treatment, using an orthosis as part of the SMART protocol [89].

**Outcome measures**

A similarly wide variety was seen in the outcome measures used to assess treatment outcomes. AOFAS is the most commonly used score, followed by ATRS, Leppilahti score and VAS (Table 2).
| Author | Year | Type of study | Number of patients | M:F | Mean age in years (range) | Mean delay in weeks | Mean follow-up in months |
|--------|------|---------------|--------------------|-----|--------------------------|---------------------|------------------------|
| Abubeih [22] | 2018 | Case series | 21 | 15:6 | 40.2 (16–70) | 8.8 (5–18) | 15 (12–24) |
| Ahmad [23] | 2016 | Case series | 32 | 20:12 | 53.3 (20–74) | 14.6 (4.3–45) | 62.3 (18–150) |
| Alhaug [24] | 2019 | Case series | 21 | 15:6 | 54.5 (32–77) | NA | 49 |
| Arthur [25] | 2020 | Case series | 7 | NA | NA | 30 (9–96) | 38 (17–67) |
| Badalihan [26] | 2015 | Case series | 51 | 42.9 | 38.4 (20–48) | 18.1 (8–24) | 24 (1.2–57.6) |
| Bai [27] | 2019 | Cohort | 26 | 25:1 | 36.7 (22–53) | NA | 19.5 (24–42) |
| Baumfield [28] | 2017 | Case series | 6 | 4:2 | 50 (33–65) | 6–36 | 9 (5–12) |
| Becher [29] | 2018 | Case series | 14 | 12:2 | 57 (40–71) | >4 | 67.2 ± 19.2 |
| Bertelli [30] | 2009 | Case series | 20 | 18:2 | 74 (65–82) | 14 (7–23) | Minimum 12 |
| Borah [31] | 2020 | Case series | 5 | 3:2 | 30–55 | 6–10 | 12 |
| Coull [32] | 2003 | Case series | 16 | NA | NA | 32–79 | 4–120 |
| Elgohary [33] | 2016 | Case series | 19 | 13:6 | 46 (24–62) | 16 (8–26) | 29 (13–52) |
| El Shazly [34] | 2014 | Case series | 15 | 12:3 | 37.7 (27–51) | 13.5 (7–26) | 27 (24–33) |
| El-Shewy [35] | 2009 | Case series | 11 | 9:2 | 34.3 (23–29.5) | 15 (11–23) | (72–108) |
| Elias [36] | 2007 | Case series | 15 | 10:5 | 41 (38–45) | 8.3 (4.3–13.0) | 43.2 (24–60) |
| Fotiadis [37] | 2007 | Case series | 9 | 8:1 | 41 (35–46) | NA | 43.9 (24–72) |
| Gedam [38] | 2016 | Case series | 14 | 11:3 | 45.6 (27–63) | 23.6 (8.6–42.6) | 30.1 (12–78) |
| Guclu [39] | 2016 | Case series | 17 | 12:5 | 33 ±7 | 30 (17.2–51.4) | 195 (158–226) |
| Hahn [40] | 2008 | Case series | 7 | 4:3 | 36–72 | 17.4–417.1 | 29–62 |
| Hollawell [42] | 2015 | Case series | 4 | 4:0 | 50 (40–63) | 11.5 (8–16) | 37.3 (15.3–51.5) |
| Ibrahim [10] | 2018 | Case series | 14 | 10:4 | 41.6 ±3.1 | 15 ±15 | 28–41 |
| Ibrahim [43] | 2014 | Case series | 13 | 13:0 | 43 (29–50) | 15 (10–43) | 45 |
| Jain [44] | 2020 | Case series | 15 | 9:6 | 43.5 ±12.4 | NA | 19.1 (13–24) |
| Jennings [45] | 2002 | Case series | 16 | 6:10 | 52 (27–78) | NA | 36 (6–96) |
| Jiang [46] | 2016 | Case series | 7 | 6:1 | 47.3 (37–56) | >6 | 31.3 (26–36) |
| Jielile [47] | 2016 | Cohort | 57 | 48.9 | 36.5 (29–47) | NA | 24 months |
| Khalid [48] | 2018 | Case series | 10 | 5:5 | 58.4 | NA | 30.9 (17–43) |
| Khiami [49] | 2013 | Case series | 23 | 20:3 | 52.1 (28–79) | 57.4 (12.6–123.4) | 24.5 (12–43) |
| Koh [50] | 2019 | Cohort | 49 | 26:23 | 58.4 | 17.6 | 12 |
| Kosaka [51] | 2011 | Case series | 20 | 14:6 | 43 (22–65) | NA | 164 (124–224) |
| Kosanovic [52] | 2008 | Case series | 22 | 20:2 | 50 (29–72) | 7.1 (4–40) | 67 (14–176) |
| Lee [53] | 2007 | Case series | 9 | 6:3 | 58.2 (25–85) | 94.3 (38.6 – 257.1) | 20–30 |
| Lin [13] | 2016 | Case series | 29 | 23:6 | 40.3 (19.2–71.5) | NA | 31 (13–68) |
| Lin [54] | 2019 | Case series | 20 | 16:4 | 38 (20–71) | 20.4 (4–96) | 32.8 (12–68) |
| Lins [55] | 2013 | Case series | 25 | 19:6 | 38.6 | NA | 12 |
| Maffulli [56] | 2012 | Case series | 21 | 16:5 | 47 (40–62) | 20.6 (9.3–38.6) | 130.8 (96–144) |
| Maffulli [57] | 2014 | Case series | 28 | 21:7 | Median 46 | NA | 24 |
| Maffulli [58] | 2010 | Case series | 32 | 28:4 | 47.1 (40–62) | 16.3 (8.6–38.6) | 24 |
| Maffulli [59] | 2013 | Case series | 26 | 23:3 | 42 (40–56) | 16.3 (8.6–38.6) | 98.4 (84–120) |
| Maffulli [60] | 2012 | Case series | 16 | 16:0 | 55.6 (42–79) | 20.9 (6.1–39.1) | 186 (156–216) |
| Maffulli [61] | 2017 | Cohort | 62 | 39:23 | 44.8 (29.3–62) | 17.2 (8.6–35.6) | 35.4 (25–49) |
| Maffulli [62] | 2005 | Case series | 21 | 16:5 | NA | 20.9 (9.3–39.1) | 28.4 ± 3.5 |
| Mahajan [63] | 2009 | Case series | 36 (38 feet) | 24:12 | 70 (56–78) | 15 (12–24) | 12 |
| Mann [64] | 1991 | Case series | 7 | 4:3 | 33–66 | 13.0–156.4 | 39 |
| Mao [65] | 2015 | Case series | 10 | 8:2 | 35.5 (22–55) | 23.0 (17.4–34.8) | 18.1 (12–36) |
| Miao [66] | 2016 | Case series | 35 | 21:14 | 42.1 (23–71) | 7.4 (4.1–146.4) | 32.2 (18–72) |
| Miskulin [67] | 2005 | Case series | 5 | 4:1 | 49.4 | 19.8 (6–40) | 12 |
Treatment outcome

The outcomes of treatment using different techniques are detailed in Table 3. All 32 studies reporting both pre- and post-operative outcome measures found significant improvements in all measures used, with the exception of Koh et al., which found a significant improvement in AOFAS and VAS and SF-36 physical subscale but not SF-36 mental subscale score [50]. Only two treatment techniques met the outlined pooling criteria. A total of eight studies describing FHL transfer showed a mean pre-operative AOFAS of 62.3 (95% CI: 57.1–67.4) and mean post-operative AOFAS of 94.2 (95% CI: 90.9–97.4), giving an unstandardised mean difference of 31.9 [22, 50, 63, 66, 75, 78, 88, 92]. Unfortunately, there were an insufficient number of studies reporting the same treatment outcome to specifically compare outcomes seen using a single or double incision approach. Three studies describing semitendinosus transfer show a pooled mean ATRS of 40.8 (95% CI: 30.4–51.1), post-operative

Complications

A total of 50 studies involving 1063 patients (1065 feet) clearly reported treatment complications (Table 4). Complications were categorised as infection (superficial wound infection, deep infection), wound healing (wound dehiscence, delayed wound closure, hypertrophic scar, wound breakdown, wound gaping), tendon re-rupture and others. The overall pooled complication rate was 168/1065 (15.8%), with the most common complication being infection (58/1065, 5.5%).
Discussion

The aim of this scoping review was to systematically map and summarise current literature describing the treatment of chronic Achilles tendon ruptures. A previous systematic review on the same subject, performed in 2012 by Hadi et al., included 34 studies [12]. Since then, there appears to have been a surge in publications on the topic, with 43 of the 73 (58.9%) included in this review published in 2013 onwards (Table 1). Unfortunately, despite this surge in the number of publications, the quality and level of evidence has not risen. As in the review of Hadi et al., the majority of included studies are level IV evidence case series, with only seven comparative cohort studies identified [12].

There is a large degree of heterogeneity in treatment methods for chronic Achilles ruptures, with studies reporting a variety of tendon transfer, turndown flap, tendon lengthening and synthetic repair techniques. A number of authors also described the use of dual techniques involving a combination of more than one of the above methods. All techniques described appeared to show good post-operative results, with all relevant included studies reporting a statistically significant increase in pre- to post-operative scores such as AOFAS and ATRS (Table 3). However, ascertaining the most efficacious technique is challenging, due to the poor quality of the existing literature. A formal meta-analysis comparing pooled outcomes of different treatment strategies was not possible due to a number of factors including large number of different techniques, large variety in outcome measures reported, low-level case series study design and inability to control for factors which may influence outcomes such as patient age, length of treatment delay and length of tendon gap. Comparison is also currently hampered by the widespread use of non-validated outcome measures. The most commonly used measure was the AOFAS (Table 2), which is not validated for use in Achilles ruptures and its use is no longer recommended by The American Orthopaedic Foot and Ankle Society [93]. Future research should therefore endeavour to use outcome measures specifically validated for Achilles ruptures such as the ATRS.

However, even if such a comparison between treatment techniques was possible, it is likely that there is no a single
Fig. 2 Flowchart detailing the number of studies using a particular treatment technique. FHL: flexor hallucis longus, FDL: flexor digitorum longus; Semitendinosus, LARS: Ligament Advanced Reinforcement System (LARS) graft (JK Orthomedic, Dollard-des-Ormeaux, Quebec, Canada. *Two studies used both a single and a double incision FHL transfer approach in different patients, seven exclusively used a single incision, nine a double incision, two an endoscopic approach and two did not specify the exact approach.

Table 2 Description of the outcome measures reported in included studies; some studies used more than one outcome measure to assess treatment results

| Scale | Number of studies |
|-------|-------------------|
| Victorian Institute of Sports Assessment self-administered Achilles questionnaire (VISA-A) | 3 |
| Tegner activity scale | 3 |
| SF-36 | 6 |
| Parson criteria | 1 |
| Mann criteria | 3 |
| Leppilahti score | 9 |
| Hooker scale | 1 |
| Foot Function Index (FFI) | 1 |
| Foot and Ankle Outcomes Instrument (FAOI) core/shoe comfort scale | 1 |
| Foot and Ankle Outcome Score (FOAS) | 1 |
| Foot and Ankle Ability Measure (FAAM) sports subscale | 1 |
| Boyden four-point scale | 7 |
| ATRS | 21 |
| AOFAS | 43 |
| (Visual Analogue Scale) VAS | 9 |
| (Foot and ankle Disability index) FADI | 1 |
| (Achilles Repair Score) ARS | 1 |
Table 3 Detailed breakdown of treatment techniques, associated outcomes and statistically significant changes between pre- and post-operative outcome scores

| Author          | Treatment                                      | Mean pre-operative scores | Mean post-operative scores | Significant improvement? |
|-----------------|------------------------------------------------|---------------------------|---------------------------|--------------------------|
| Abubeih        | FHL transfer                                   | AOFAS: 57.4 ± 10.3        | AOFAS: 95.3 ± 4.4         | Yes P < 0.001            |
| Ahmad          | Central turndown + FHL transfer                | FAAM: 36.3 (17–60)        | FAAM: 90.2 (75–100)       | Yes both P < 0.05        |
| Alhaug         | FHL transfer                                   | VAS: 6.6 (2–9)            | VAS: 1.8 (0–4)            | NA                      |
| Arthur         | FHL transfer                                   | NR                        | AOFAS: 87 (60–100)        | NA                      |
| Badalihan      | Yurt Bone suture                               | NR                        | VISA-A: 81 (37–99)        | NA                      |
| Bai            | Gastrocnemius turndown flap                    | NR                        | AOFAS: 92.6 ± 3.0         | No significant difference between the two treatment groups |
|                | Hamstring tendon transfer                      | NR                        | Leppilahti: 94.7 ± 3.1    | NA                      |
| Baumfield      | Endoscopic FHL transfer                        | ATRS: 17.8 (11–28)        | ATRS: 83.3 (79–87)        | NR                      |
| Becher         | End to end repair with planataris tendon (10 patients), z-plasty (2), turn down flap (1) or FHL transfer (1) | NR                        | ATRS: 75 ± 24             | NA                      |
| Berteli        | Percutaneous figure of 8 suture                | NR                        | FAOI core: 97 ± 1         | NA                      |
| Borah          | Gastrocnemius turndown flap                    | NR                        | FAOI shoe comfort: 10 ± 0 | NA                      |
| Coull          | FHL transfer                                   | NR                        | AOFAS: 94.1 (80–100)      | Yes P < 0.001            |
| El Shazly      | Endoscopic hamstring tendon graft              | AOFAS: 32.6 ± 7.5         | AOFAS: 90.8 ± 3.5         | Yes P < 0.05            |
| El-Shewy       | 2 gastrocnemius turndown flaps                 | AOFAS: 42.5 ± 2.4         | AOFAS: 98.9 ± 3.6         | Yes P = 0.003           |
| Elgohary       | FHL transfer + gastrocnemius recession         | AOFAS: 65 (52–72)         | AOFAS: 94 (76–100)        | Yes P < 0.001            |
| Elias          | V–Y plasty + FHL transfer                      | AOFAS: 58.4 (34–77)       | AOFAS: 94.1 (80–100)      | Yes P < 0.001            |
| Esenyel        | Turndown flap + synthetic mesh                 | AOFAS: 64.8 ± 8.1         | AOFAS: 97.8 ± 4.1         | Yes P < 0.0001           |
| Fotiadis       | Duthic’s biological repair + planataris transfer | NR                        | Leppilahti: 6 patients 90–100, remaining 3 scored 75–85 | NA                      |
| Gedam          | Turndown flap + ST augmentation                | AOFAS: 64.5 (35–79)       | AOFAS: 96.9 (90–100)      | Yes P < 0.001 for both   |
| Guclu          | V–Y plasty + turndown flap                     | AOFAS: 63 ± 4             | AOFAS: 95 ± 3             | Yes P = 0.001           |
| Hahn           | FHL transfer                                   | AOFAS: 60.3 (46–68)       | AOFAS: 92 (71–100)        | NR                      |
| Hollawell      | Achilles allograft + synthetic xenograft       | FAOI core: 53 ± 1         | FAOI shoe comfort: 59 ± 0 | NR                      |
| Ibrahim 2007   | PB transfer + LARS                             | AOFAS: 64.5 (35–79)       | AOFAS: 96.9 (90–100)      | Yes P < 0.001 for both   |
| Ibrahim 2009   | LARS                                           | AOFAS: 48.6 ± 12.7        | AOFAS: 85.9 ± 6.6         | Yes P = 0.001 both       |
| Jain           | Turndown flap + FHL transfer                   | AOFAS: 72.1 ± 8.3         | AOFAS: 98.4 ± 2.03        | Yes P = 0.001 both       |
| Jennings       | Polyester tape                                 | AOFAS: 54.3 (46–65)       | NR                        | Yes P < 0.05             |
| Jiang          | ST + gracilis graft                            | AOFAS: 51.4 (40–61)       | AOFAS: 97.6 (90–100)      | Yes both P < 0.05        |
|                | SF-36 physical: 32.1 (25–35)                   | AOFAS: 92.7 (83–100)      | SF-36 physical: 90 (80–95) | NA                      |
|                | SF-36 mental: 37.1 (32–40)                     | SF-36 mental: 90.9 (84–96) | VAS: 0                    | NA                      |
| Author       | Treatment                                                                 | Mean pre-operative scores | Mean post-operative scores | Significant improvement? |
|--------------|----------------------------------------------------------------------------|----------------------------|----------------------------|--------------------------|
| Jielile      | Yurt bone method+ cast immobilisation                                     |                            | Leppilahti: 21/21 excellent at 2 years | NA                       |
|              | Yurt bone method+ active mobilisation                                      |                            | Leppilahti: 26/26 excellent at 2 years | NA                       |
| Khalid       | FHL transfer                                                              | NR                         | AOFAS: 78.5 (54–94)          | NA                       |
| Khiami       | Z plasty + triceps surae surae anepurosis graft                           | AOFAS: 63.6 ± 11.5         | AOFAS: 96.1 ± 6.8            | Yes P < 0.001            |
| Koh          | FHL transfer                                                              | AOFAS: 62 ± 22             | AOFAS: 90 ± 11               | Yes all P < 0.05 except SF-36 mental |
|              | Turndown flap+FHL                                                         | VAS: 3                     | SF-36 physical: 39 ± 10      |                          |
|              |                                                                             | SF-36 mental: 55 ± 9       | SF-36 physical: 49 ± 9       |                          |
|              |                                                                             |                            | SF-36 mental: 57 ± 12        |                          |
|              | AOFAS: 52 ± 19                                                            | VAS: 5                     | SF-36 physical: 50 ± 9       |                          |
|              |                                                                             | SF-36 mental: 53 ± 17      |                            |                          |
|              | AOFAS: 95 ± 10                                                            |                            |                            |                          |
|              |                                                                             |                            |                            |                          |
|              |                                                                             |                            |                            |                          |
| Kosaka       | PB transfer                                                               | NR                         | AOFAS: 86.9 ± 7.3            | NA                       |
| Kosanovic    | Percutaneous modified Bunnells’ repair                                    | NA                         | Leppilahti: 83.3 (60–100)    | Excellent (11) Fair (5), Good (2) |
| Lee          | Z plasty + ADM graft jacket                                                | AOFAS: 46.3 (27–64)        | AOFAS: 86.2 (78–95)          | Yes P < 0.001            |
| Lin 2019     | V–Y plasty                                                                | AOFAS: 59.3 ± 12.3         | AOFAS: 96.6 ± 3.8            | Yes P < 0.05 both        |
| Lin 2016     | V–Y plasty with turndown flap in some. FHL transfer in those with no stump integrity | AOFAS: 60.1 ± 10.6         | AOFAS: 94.6 ± 4.0            | Yes P < 0.05 both        |
| Lins         | ST tendon graft                                                           | NR                         | AOFAS: 85.2 ± 18.0           | NA                       |
| Maffulli 2005| Gracilis tendon graft                                                     | NA                         | Boyden: Excellent (2), Good (15), Fair (4), Poor (0) | NA                       |
| Maffulli 2010| PB transfer                                                               | NR                         | ATRS: 92.5 ± 14.2            | Boyden: Excellent (6), Good (24), Fair (2) | NA                       |
| Maffulli 2013| ST transfer                                                               | NR                         | ATRS: 88 (75–97)             | Boyden: Excellent (10), Good (13), Fair (3) | NA                       |
| Maffulli 2012| PB transfer                                                               | NR                         | ATRS: 89.5 ± 12.2            | Boyden: Excellent (4), Good (9), Fair (3) | NA                       |
| Maffulli 2017| ST transfer                                                               | ATRS: 50.4 ± 7.5           | ATRS: 89.4 ± 3.2             | Yes P < 0.001            |
|              | PB transfer                                                               | ATRS: 51.3 ± 4.5           | ATRS: 89.5 ± 4.1             | Yes P < 0.001            |
|              | FHL transfer                                                              | ATRS: 52.3 ± 3.2           | ATRS: 88.9 ± 3.1             | Yes P < 0.01, no significant difference between treatment groups |
| Maffulli 2012| Gracilis graft                                                            | NR                         | ATRS: 90.1 ± 5.8             | Boyden: Excellent (2), Good (15), Fair (4), | NA                       |
| Maffulli 2014| ST graft + interference screw fixation                                     | ATRS: 42(29–55)           | ATRS: 86 (78–95)             | Boyden: Excellent (5), Good (21), Fair (2) | Yes P < 0.001            |
| Mahajan      | FHL transfer                                                              | AOFAS: 69 (58–76)          | AOFAS: 88 (79–94)            | Yes P < 0.001            |
| Mann         | FDL transfer                                                              | NA                         | Mann criteria: Excellent (4), Good (2), Fair (1) | NA                       |
| Mao          | FHL transfer + 2 turndown flaps + plantaris augmentation                   | AOFAS: 64.4 ± 3.5         | AOFAS: 94.3 ± 3.5            | AOFAS: P = 0.008         |
|              | VAS: 4.33 ± 1.1                                                          | VAS: 1.89 ± 1.2            | VAS: P = 0.011              |                          |
| Author       | Treatment                      | Mean pre-operative scores | Mean post-operative scores | Significant improvement? |
|--------------|--------------------------------|---------------------------|---------------------------|--------------------------|
| Miao         | FHL transfer                   | AOFAS: 51.9 ± 7.1         | AOFAS: 92.6 ± 6.7         | Yes P < 0.05 both        |
|              |                                | Leppilahti: 72.6 ± 7.43   | Leppilahti: 92.66 ± 5.1   |                          |
| Miskulin     | PB transfer                    | NA                        | Mann criteria: Excellent (5) | NA                       |
| Mulier       | Turndown flap                  | NA                        | Leppilahti: 62 (48-78)    | NR                       |
|              | Turndown flap + FHL transfer   | NA                        | Leppilahti: 77 (67-89)    | NR                       |
| Nambi        | Turndown flap + sural flap     | NR                        | ATRS: 70 (65-76)          | NA                       |
| Oksanen      | FHL transfer                   | NR                        | ATRS: 70 (38-96)          | NA                       |
| Ozan         | Turn down flap or V–Y plasty   | NR                        | Hooker scale: Excellent (11), Satisfactory (4) | NA                       |
| Ozer         | FHL transfer                   | NR                        | 93.8                      | NA                       |
| Park         | V–Y plastic (1), turndown flap (3), FHL transfer (3), allographic + FHL transfer (2) | AOFAS: 68.7 (50–87) VAS: 6.5 (5–8) | AOFAS: 98 (88–100) ATRS: 92.9 (84–100) VAS: 0.2 | Yes P < 0.001 both |
| Parsons      | Polymer carbon fibre composite | Parson’s score: 24.5      | Parson’s score: 45.5      | Yes P < 0.05             |
| Pavan Kumar  | Turndown flap                  | NR                        | Leppilahti: Excellent (62), Good (8), fair (4), poor (2) | NA                       |
| Pendse       | FHL transfer                   | AOFAS: 57.5 ± 6.0         | AOFAS: 96.7 ± 3.6         | Yes P < 0.001            |
| Pintore      | PB transfer                    | NR                        | Boyden: Excellent (15), Good (3), Fair (4) | NA                       |
| Rahm         | FHL transfer                   | AOFAS: 62.4 (32–87)       | AOFAS: 86.9 (43–100) SF-36: 71.7% (28%-95%) VISA-A: 70.3 (20–97) FFI pain:20.2% (0–81%) FFI function: 23.0% (0–70%) | Yes P < 0.001 |
| Sarzaeem     | ST transfer                    | AOFAS: 70 ± 5             | AOFAS: 92 ± 5             | Yes P = 0.001 both       |
|              |                                | ATRS: 32 ± 6              | ATRS: 89 ± 4              |                          |
| Seker        | Turndown flap                  | NR                        | AOFAS: 98.5(90–100) FADI: 98.9% (96.2–100%) VAS: 0 | NA                       |
| Shoaiab      | V–Y plastic + Artelon synthetic graft | AOFAS: 59.4 (31–73)      | AOFAS: 91.5 (67–100) ATRS: 92.1 (79–100) VAS pain: 0 in all AOFAS: 92.1 (79–100) ATRS: 92.1 (79–100) VAS function: 8 (7–9) | AOFAS: Yes P = 0.018 |
| Song         | ST transfer                    | AOFAS: Median 50 (5–75)   | AOFAS: Median 100 (86–100) | Yes P < 0.05             |
| Takao        | Turndown flap                  | AOFAS: 72.6 ± 5.3         | AOFAS: 98.1 ± 2.5         | Yes P < 0.0001           |
| Tay          | Two turndown flaps + FHL transfer | NR                      | AOFAS: 94.2 (78–100) SF-36 physical: 88.3 SF-36 mental: 90.7 VAS: 0.8 (0–5) | NA                       |
| Usuelli      | ST transfer                    | NR                        | AOFAS: 92 (83–96)         | NA                       |
|              |                                | ATRS: 87 (81–95)          |                          |                          |
| Vega         | Endoscopic FHL transfer        | AOFAS: 55 (26–75)         | AOFAS: 91(74–100)         | NR                       |
| Wapner       | FHL transfer, 2 patients received plantaris augmentation and 1 a turndown flap | NR                      | Mann criteria: Excellent (3), good (3), fair (1) | NA                       |
| Wegrzyyn     | FHL transfer                   | AOFAS: 64 (58–80)         | AOFAS: 98 (90–100)        | Yes P < 0.001            |
| Winson       | SMART conservative             | NR                        | ATRS:83 (39–100)         | NA                       |
|              |                                | ATRS: 77.5 (35–100)       |                          |                          |
| Yasuda 2016  | Scar tissue interposition      | AOFAS: 82.8 ± 8.3         | AOFAS: 98.1 ± 3.9         | NR                       |
|              |                                | ATRS: 92 (80–100)         |                          |                          |
| Yasuda 2007  | Scar tissue interposition      | AOFAS: 88.2               | AOFAS: 98.3               | Yes P = 0.0277           |
| Yeoman       | FHL transfer                   | AOFAS: 51.4 (26–87) SF-36: 87.4 (75.4–109.5) | AOFAS: 91.9 (77–100) SF-36: 111.8 (103.9–116.2) | NR                       |
| Author | Total patients | Infection | Wound healing | Re-rupture | Other |
|--------|----------------|-----------|---------------|------------|-------|
| Abubeih | 21             | 1 (4.7%)  | 0             | 0          | 1/21 (4.7%) |
| Ahmad  | 32             | 1 (3.1%)  | 3 (9.4%)      | 0          | 5/32 (15.6%) |
| Alqahtani | 21          | 2 (9.5%)  | 6 (28.6%)     | 1 (4.8%)  | 1/21 (4.7%) |
| Arthur  | 7              | 2 (28.6%) | 0             | 0          | 1/7 (14.3%)  |
| Bai     | 26             | 2 (7.7%)  | 0             | 0          | 4/26 (15.4%) |
| Borah   | 5              | 1 (20%)   | 0             | 0          | 1/5 (20%)    |
| El-Issawy | 11          | 0         | 0             | 0          | 0%          |
| Elias   | 11             | 0         | 0             | 0          | 0%          |
| Esercely | 10           | 0         | 0             | 0          | 0%          |
| Gedan   | 14             | 0         | 0             | 0          | 0%          |
| Graetzi | 17             | 0         | 0             | 0          | 0%          |
| Hollaway | 4             | 0         | 0             | 0          | 0%          |
| Ibrahim 2007 | 13   | 0         | 0             | 0          | 0%          |
| Ibrahim 2009 | 14   | 1 (7.1%)  | 0             | 0          | 1/14 (7.1%)  |
| Jain    | 15             | 0         | 0             | 0          | 0%          |
| Jennings | 16            | 3 (18.8%) | 0             | 0          | 0%          |
| Jielile  | 57             | 4 (7.0%)  | 6 (10.5%)     | 0          | 18/57 (31.6%) |
| Khalid  | 10             | 1 (10%)   | 0             | 0          | 1/10 (10%)   |
| Kilian  | 23             | 0         | 2 (8.7%)      | 0          | 0%          |
| Krcik   | 23             | 0         | 1 (2.0%)      | 0          | 0%          |
| Kosana   | 22            | 0         | 0             | 0          | 0%          |
| Lee 2016 | 9              | 0         | 0             | 0          | 0%          |
| Lin 2016 | 30             | 0         | 0             | 0          | 0%          |
| Lin 2019 | 20            | 0         | 0             | 0          | 0%          |
| Author         | Total patients | Infection | Wound healing | Re-rupture | Other                        | Total |
|----------------|----------------|-----------|---------------|------------|------------------------------|-------|
| Maffulli 2005  | 21             | 5 (23.8%) | 1 (4.8%)      | 0          | 2 (9.5%) hypersensitivity    | 8/21  |
| Maffulli 2010  | 32             | 4 (12.5%) | 2 (6.3%)      | 0          | 3 (9.4%) toe clawing         | 9/32  |
| Maffulli 2012  | 21             | 3 (14.3%) | 1 (4.8%)      | 0          | 1 (4.8%) tendinopathy        | 5/21  |
| Maffulli 2013  | 26             | 1 (3.8%)  | 0             | 0          | 1 (3.8%) tendinopathy, 2 (7.7%) hypersensitivity | 4/26  |
| Maffulli 2014  | 28             | 0         | 0             | 0          | 0                            | 0     |
| Mahajan        | 36 (38 feet)   | 3 (7.9%)  | 1 (2.6%)      | 0          | 3 (7.9%) weak push off        | 7/38  |
| Mao            | 10             | 0         | 0             | 0          | 0                            | 0     |
| Mulier         | 19             | 1 (5.3%)  | 0             | 1 (5.3%)   | 2 (10.5%) DVT, 2 (10.5%) hypoesthesia | 6/19  |
| Nambi          | 5              | 0         | 0             | 0          | 5 (100%) hypoesthesia        | 5/5   |
| Ozan           | 15             | 0         | 0             | 0          | 0                            | 0     |
| Park           | 12             | 0         | 0             | 0          | 0                            | 0     |
| Parsons        | 52             | 5 (9.6%)  | 0             | 0          | 1 (1.9%) tendonitis           | 6/52  |
| Pavan Kumar    | 78             | 3 (3.85%) | 5 (6.4%)      | 0          | 0                            | 8/78  |
| Rahm           | 31             | 1 (3.2%)  | 5 (16.1%)     | 1 (3.2%)   | 1 (3.2%) DVT, 1 (3.2%) suture granuloma | 9/31  |
| Sarzaeem       | 11             | 2 (22.2%) | 0             | 0          | 1 (11.1%) DVT                | 3/11  |
| Seker          | 21             | 1 (4.8%)  | 0             | 0          | 0                            | 1/21  |
| Shoaib         | 7              | 1 (14.3%) | 0             | 0          | 3 (42.9%) hypoesthesia        | 4/7   |
| Takao          | 10             | 0         | 0             | 0          | 0                            | 0     |
| Tay            | 9              | 0         | 0             | 0          | 1 (11.1%) neuropaxia, 2 (22.2%) hypoesthesia | 3/9   |
| Vega           | 22             | 0         | 0             | 0          | 1 (4.5%) calcaneal fragment avulsion | 1/22  |
| Winson         | 19             | 0         | 0             | 0          | 1 (5.3%) PE                  | 1/19  |
| Yasuda 2007    | 6              | 0         | 1 (16.7%)     | 0          | 0                            | 1/6   |
| Yasuda 2016    | 30             | 0         | 1 (3.3%)      | 0          | 0                            | 1/30  |
| Yeoman         | 11             | 1 (9.1%)  | 0             | 0          | 1 (9.1%) DVT                 | 2/11  |
| Total          | 1063 (1065 feet)| 58 (5.45%)| 33 (3.10%)    | 9 (0.85%)  | 68 (6.38%)                   | 168 (15.8%) |
optimal operative strategy for all patients. Instead, it may be more important to develop an evidence-based optimal treatment protocol, identifying stratification criteria that takes into account unique patient factors, such as length of treatment delay and tendon gap size, which may determine the suitability of a particular technique. Some authors have described such treatment protocols. For example, Myerson recommends primary repair in cases with <2 cm gap, V–Y plasty in the case of a 2–5 cm gap and tendon transfer with or without V–Y plasty in cases with gap >5 cm [94]. Maffulli et al. use peroneus brevis transfer for gaps <6 cm, semitendinosus graft for gaps >6 cm and FHL transfer for gaps >5 cm [61]. Similar gap size-based protocols are also described by Kuwada, Den Hartog and Krahe [95–97]. However, these protocols are not based on definitive evidence as there is currently a lack of literature comparing different treatment methods. Although Elias et al., who described FHL transfer, did not find any significant difference in outcomes according to age or length of delay, worse outcomes were seen in those with larger tendon gaps of 7–8 cm [97]. However, firm conclusions cannot be drawn from the findings of these 15-patient case series describing only one technique. It is therefore important that further high-quality research, comparing different treatment techniques in patients of varying age, tendon gap length, treatment delay, injury aetiology and degree of tendon degeneration, is performed. Such works would aid the development of an evidence-based treatment protocol, which would allow clinicians to select the optimal technique for each specific patient, taking into account the above factors.

Furthermore, although there is a growing body of evidence supporting the role of conservative treatment in acute Achilles rupture, there is a paucity of literature investigating the same in chronic ruptures [9]. This is likely due to the traditional view that operative treatment yields superior outcomes for chronic ruptures. However, again, this seems to be derived from anecdotal evidence rather than high-quality research. Only one included study investigates the role of conservative treatment and, to the best of our knowledge, the only article directly comparing operative versus conservative treatment in chronic ruptures is the 1953 study of Christensen [89, 98]. This study does indeed suggest superiority of operative treatment; however, it is not possible to draw conclusions from a single small case series. Further research is therefore required in ascertaining the suitability of conservative treatment and specific factors which may predict response to such treatment. Even if it is the case that operative treatment is superior, there may be certain patients who decline, or are not suitable for operative intervention. Although Achilles tendon rupture most frequently occurs in adults aged between 30 and 40, there is a group of older patients sustaining Achilles tendon rupture who may not be able to tolerate surgery and the mean age at which rupture occurs has increased by at least 0.721 years every five years since 1953 [99]. This suggests that clinicians are likely to come across an increasing number of patients for whom operative intervention is not suitable, further emphasising the importance of research into the development of effective conservative therapies.

Despite the rigorous methodology employed in this review, it must be acknowledged that certain biases do exist. For example, due to the limited linguistic capabilities of the research team, only studies published in the English language were included. Furthermore, as described, there are a number of confounding factors such as treatment delay and tendon gap length, which may differ between individual studies and affect reported outcomes. As outlined in Table 1, the large majority of studies utilise a level IV retrospective case series design. Such studies are particularly prone to selection bias, drawing patients from a relatively narrow sample population. Lastly, it was decided to include studies reporting both validated and non-validated outcome scores, as well as patient reported, and researcher assessed scores. This may cause some bias in outcome scores, with only 21 of 73 included studies using the validated ATRS outcome scale.

Conclusion

The current literature describes a number of different operative strategies for the management of chronic Achilles rupture, all of which demonstrate beneficial outcomes. However, comparison of specific techniques is currently hampered by the low-level evidence and inability to control for potential confounding factors. Future research directly comparing treatment strategies in patients stratified according to specific injury characteristics may aid in the development of an evidence-based optimal treatment protocol. This would allow clinicians to determine which of the multitude of available techniques is most suitable for each unique patient.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00264-021-05102-5.

Data availability All data is freely available online.

Compliance with ethical standards

Consent for publication All authors agree with the submission of this article to ‘international orthopaedics’.

Conflicts of interest The senior author, Mr Maneesh Bhatia, is a member of the scientific committee of the European Foot and Ankle Society.
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