Outcomes of Limited Open Achilles Repair Using Modified Ring Forceps

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Background: The optimal treatment of acute Achilles tendon ruptures remains controversial. When surgical repair is undertaken, the reported rate of infections and wound-healing complications ranges from 2% to 5%. Meta-analyses have demonstrated that minimally invasive approaches have equivalent rerupture rates, a significantly lower risk of superficial infections, and higher patient satisfaction rates compared with traditional open Achilles repair techniques.

Purpose: To review the clinical outcomes of acute, limited open Achilles tendon repair using modified ring forceps and to analyze functional results using foot and ankle–specific outcome measures.

Study Design: Case series; Level of evidence, 4.

Methods: The clinical records of 32 consecutive patients (mean age, 44 years) with 33 acute Achilles tendon ruptures were retrospectively reviewed. All patients underwent limited open repair with modified ring forceps through a 2- to 3-cm midline incision. Suture placement into the tendon stumps was guided using a pair of ring forceps bent 30°. Three No. 2 nonabsorbable sutures were placed in the proximal and distal segments, the tendon ends were reapproximated, and the sutures were tied to secure the tendon. Outcomes from a 10-cm visual analog scale (VAS), the Foot and Ankle Ability Measure (FAAM), and the Victorian Institute of Sport Assessment–Achilles (VISA-A) were assessed.

Results: At final follow-up (mean, 42.1 months [range, 6-90 months]), 31 of 32 patients (33 Achilles tendons) reported no pain in their Achilles, with a mean Achilles VAS score of 0.7 ± 4.2 of 100. The mean postoperative VISA-A score was 82.3 ± 19.5 of 100. The mean FAAM activities of daily living and sports subscores were $96.5\% \pm 5.2\%$ and $85.1\% \pm 21.2\%$, respectively. Regarding current functional level, 19 of 33 tendons (57.6%) were rated as "normal," 10 (30.3%) as "nearly normal," and 4 (12.1%) as "abnormal"; none were rated as "severely abnormal." There was 1 case (3.0%) of a superficial infection; there were no cases of deep infections, sural neuritis, or reruptures. The cost of the modified ring forceps technique is 5.3 to 12.1 times less than commercially available devices.

Conclusion: Limited open Achilles repair with modified ring forceps provides an economical repair with excellent pain relief, favorable functional outcomes, and a very low complication rate at midterm follow-up.

Keywords: Achilles; rupture; limited open; ring forceps; outcomes

Acute Achilles tendon ruptures have an annual incidence as high as 21.5 to 24 per 100,000 persons.[17,31] Despite the relative frequency with which orthopaedic surgeons encounter this condition, their treatment remains controversial. Options include nonoperative management or surgical repair via minimally invasive or traditional open techniques. Minimally invasive techniques are further subdivided into entirely percutaneous methods, where the tendon tear site is not directly exposed with the fixation site at least partially placed external to the paratenon, and limited open methods, which involve direct visualization of the tear via a small incision with the fixation site entirely placed within the paratenon sheath. While there are conflicting reports in the literature, meta-analyses have demonstrated decreased rerupture rates with surgical repair (2.7%-3.6%) compared with nonsurgical treatment (4.2%-13%).[4,25,50,51] However, infections and wound-healing complications occur in 2.4% to 4.7% of surgical patients[4,25,50] and increase to 10.4% in patients with risk factors such as diabetes, smoking, or steroid use.[6]

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In an effort to diminish the frequency and severity of surgical complications, minimally invasive approaches have increasingly received a great deal of interest. Since the first report of percutaneous Achilles tendon repair in 1977,[33] numerous minimally invasive techniques have been described,[2,9,23,24,29,33,47,49] and several devices are commercially available to address acute Achilles tendon ruptures.[3,11,21,41] While there is some disagreement between individual studies comparing the complication rates of minimally invasive with traditional open techniques,[5,19,23,28,32,45,47] a meta-analysis has demonstrated that minimally invasive approaches yield equivalent rerupture rates with a significantly lower risk of superficial infections and higher patient satisfaction rates.[40]

A previous publication described the operative technique for limited open Achilles repair with modified ring forceps.[15] To our knowledge, this is the first study to report the clinical results of this repair method. The objective of the present study was to review the clinical outcomes of this technique and to analyze functional results using validated outcome measures. It was hypothesized that limited open Achilles repair with modified ring forceps would yield reproducible results with low rates of rerupture, sural nerve injury, and wound-healing problems.

METHODS

Patient Population

Institutional review board approval was obtained before study initiation. Between 2009 and 2016, a total of 49 consecutive patients who underwent surgical management of an acute Achilles tendon rupture were identified through a retrospective review of a single hospital's orthopaedic database. The diagnosis of an acute Achilles tendon rupture was made based on patient history and a physical examination. Inclusion criteria for this study were patients with an acute rupture of the Achilles tendon occurring between 2 and 8 cm proximal to the calcaneal insertion on palpation. Exclusion criteria were skeletally immature patients, those with connective tissue disorders, and patients lost to follow-up before 6 months. Also excluded were patients with proximal or insertional ruptures, periosteal sleeve avulsions, chronic tears (defined here as >6 weeks old), and reruptures from prior failed operative or nonoperative management. Routine magnetic resonance imaging was not performed. All tendon ruptures were confirmed to be 2 to 8 cm proximal to the Achilles tendon insertion at the time of surgery. All clinic and operative notes, physical therapy evaluations, and imaging studies were carefully reviewed to ensure the inclusion of only those with an acute Achilles tendon rupture.

Surgical Technique

All patients underwent Achilles tendon repair by 1 of 2 fellowship-trained orthopaedic foot and ankle surgeons (E.M.B. and J.T.S.). A limited open repair technique with modified ring forceps has previously been published[15] and is based on early work described by Kupcha and Mackenzie.[29]

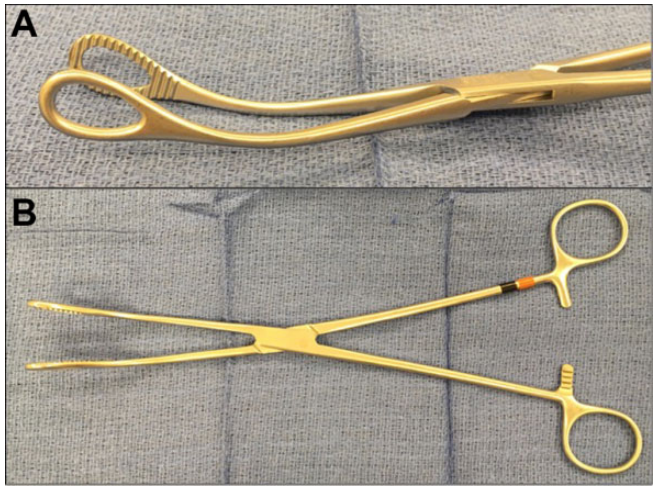

Figure 1. (A, B) Modified ring forceps are fashioned by bending the distal aspect of a standard pair of straight ring forceps approximately 30° with a VSP plate bender (DePuy Synthes) or a tabletop plate bender.

Modified ring forceps were fashioned by bending the distal aspect of a standard pair of straight ring forceps approximately 30° with a VSP plate bender (DePuy Synthes) or a tabletop plate bender (Figure 1, A and B). The bend helped the forceps clear the heel and prominent calf musculature and was particularly advantageous in patients with a larger body habitus.

The patients were positioned prone with a bump under the ankle, allowing the operative foot to hang relaxed off the end of the table. General anesthesia and/or popliteal/saphenous nerve blocks were administered. A tourniquet was placed around the thigh and utilized for hemostasis at the surgeon's discretion. A 2- to 3-cm vertical midline incision was made over the palpable defect in the Achilles tendon (Figure 2A); this approach was preferred, as it reduced the risk of iatrogenic injuries to the sural nerve and is more extensile should additional procedures be indicated in the future. Alternatively, a transverse incision can be used. The approach was carried down through the paratenon, which was preserved for subsequent repair. The tendon stumps were gently cleared of hematoma and debris. To improve control of the tendon stumps, they were secured with an Allis clamp. A small malleable retractor or Freer elevator was used to break up adhesions between the paratenon and Achilles tendon both proximally and distally (Figure 2B).

The modified forceps were inserted into the tendon sheath beneath the paratenon, and the proximal Achilles tendon stump was gently grasped at a stable portion above the rupture site (Figure 2, C and D). Proper positioning of the Achilles between the ends of the ring forceps was confirmed by palpation. A No. 2 nonabsorbable braided suture (Orthocord; Depuy Mitek) was loaded onto a noncutting, free Keith needle. The needle was then passed sequentially through the lateral skin and paratenon, the lateral ring of the forceps, the tendon, the medial ring, and then out of the

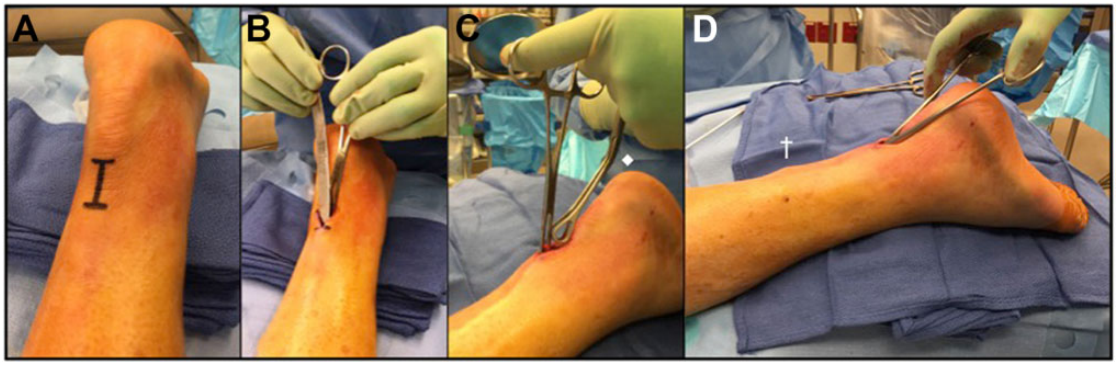

Figure 2. Limited open Achilles repair with the modified ring forceps technique: approach. (A) A small 2- to 3-cm incision is made just medial to the palpable gap of the Achilles rupture. (B) Adhesions are cleared with a malleable retractor, and (C) the tendon stump is grasped with an Allis clamp; note how the curve in the forceps easily clears the patient's heel (♦). (D) The modified ring forceps pass deep to the paratenon and gently grasp the Achilles tendon; the forceps are easily palpable and allow triangulation through the skin and subcutaneous tissue (†).

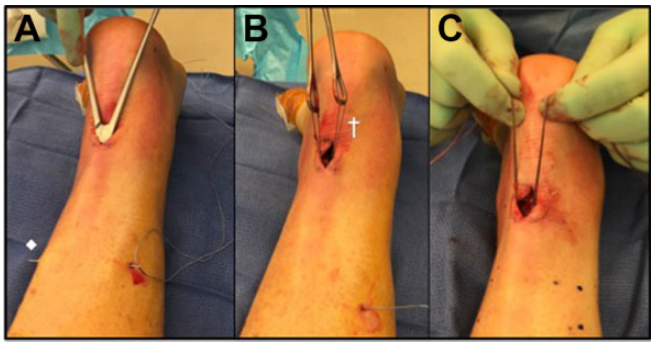

Figure 3. Limited open Achilles repair with the modified ring forceps technique: proximal tendon stump preparation. (A) A straight Keith needle with No. 2 braided nonabsorbable suture is passed through the skin, lateral ring, paratenon and tendon, medial ring, and far skin (♦). (B) The suture is passed out of the wound (†); (C) gentle traction on the suture confirms adequate purchase in the Achilles tendon.

medial paratenon and skin (Figure 3A).[29] The ring forceps were withdrawn approximately 1 cm and another suture was passed. This sequence was performed a total of 3 times in each tendon stump, but more sutures may be placed if desired. Withdrawing the ring forceps from the surgical wound delivered the suture tails from the incision (Figure 3B). Adequate purchase in the Achilles tendon was confirmed with gentle traction on the sutures (Figure 3C). Care was taken to keep the medial and lateral suture ends separated. The same process was repeated on the distal Achilles tendon stump (Figure 4).

Gently plantar flexing the foot reapproximated the tendon ends, and the sutures from the proximal stump were tied firmly to the sutures from the distal stump (Figure 5A). To prevent prominent suture knots, all but 1 of the suture tails on each side were cut. The remaining suture tail laterally was passed deep to the tendon with a right-angle clamp or snap and tied to the remaining suture tail medially (Figure 5B). This displaced the knots anteriorly (deep),

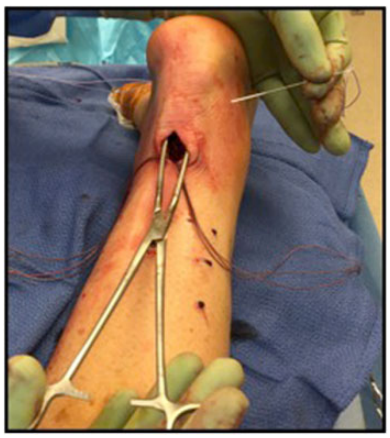

Figure 4. Limited open Achilles repair with the modified ring forceps technique: distal tendon stump preparation. A straight Keith needle with No. 2 braided nonabsorbable suture is passed through the skin, lateral ring, paratenon and tendon, medial ring, and far skin.

away from the skin. Optional oversewing of the rupture site was performed at the surgeon's discretion. Layered closure of the paratenon, subcutaneous tissue, and skin was completed, and the extremity was splinted in resting equinus (Figure 5, C and D).

Postoperative Protocol

Postoperatively, patients were maintained nonweightbearing in a short leg splint in resting equinus for 2 weeks. At 2 weeks, the sutures were removed, and the patient was transitioned to a tall removable immobilizer boot with 2 heel lifts (Breg) (Figure 6) and allowed full weightbearing. The wedges were removed sequentially at 4 and 6 weeks postoperatively, and at 8 weeks postoperatively, the patient was weaned out of the cam boot into a regular athletic shoe. Low-impact activity (ie, jogging on a flat track) was begun

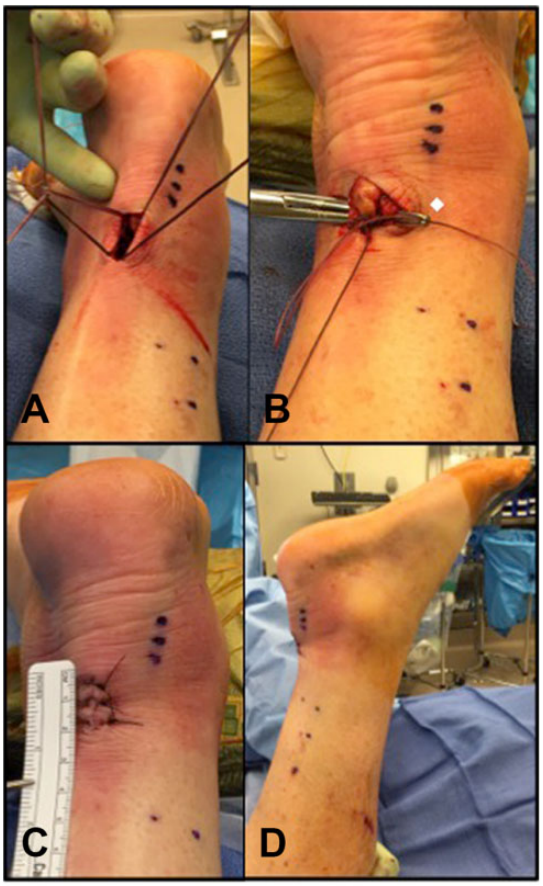

Figure 5. Limited open Achilles repair with the modified ring forceps technique: repair and knot burial. (A) The tendon stumps are reapproximated, and the proximal and distal sutures are tied firmly. (B) The suture knots are passed deep (anterior) to the Achilles tendon (♦) and tied together to prevent symptomatic knots. (C) Postoperative photograph demonstrating the small, limited open incision; note the purple dots demarcating the locations where the suture was passed proximally and distally. (D) Final repair demonstrating the restored resting equinus position of the foot.

12 weeks after surgery, and high-impact and cutting athletic activity was initiated at 16 weeks. Patients were allowed full, uninhibited activity at 20 weeks postoperatively. Patients without any known risk factors for deep vein thrombosis took daily aspirin for prophylaxis until they were weaned out of the walking boot. Patients with risk factors or a documented history of thromboembolic events took enoxaparin or rivaroxaban for 6 weeks and then aspirin until they were fully weaned out of the boot.

Outcome Measures

Validated patient-reported outcome measurement tools were administered to patients. The instruments used were the visual analog scale (VAS), the Foot and Ankle Ability Measure (FAAM),[36] and the Victorian Institute of Sport Assessment–Achilles (VISA-A).[44]

Figure 6. Boot with 2 heel wedges (Breg) after Achilles tendon repair. At 2 weeks postoperatively, patients began weightbearing as tolerated in the boot with 2 wedges. The wedges were removed sequentially at 4 and 6 weeks postoperatively.

A 10-cm continuous VAS was used to evaluate patients' current level of pain. Higher perceived pain is represented by higher scores, with a maximum score of 100 (worst imaginable pain) and a minimum score of 0 (no pain).

The FAAM was used to assess patients' perceived level of function. This validated instrument consists of the 21-item activities of daily living (ADL) subscale and the 8-item sports subscale.[36] Higher subjective levels of function are represented by higher scores, with maximum achievable scores of 84 and 28 on the ADL and sports subscales, respectively. The minimal clinically important difference is 8 points for the ADL subscale and 9 points for the sports subscale.[36] Construct validity, reliability, and responsiveness have been previously demonstrated.[36,37] The FAAM has been shown to be a better indicator of physical function than both the American Orthopaedic Foot & Ankle Society (AOFAS) clinical rating systems and the Foot Function Index.[36] In this study, FAAM scores are reported as a percentage of the maximum achievable score.

The VISA-A is an Achilles tendon–specific instrument with domains for pain, function, and activity. It is used to measure the severity of Achilles lesions and monitor outcomes after treatment. Originally validated for Achilles tendinopathy,[44] it has been used to report outcomes after Achilles tendon rupture repair.[48] Higher levels of function are represented by higher scores, with a maximum achievable score of 100; healthy patients typically have scores of 96 to 100. The minimal clinically important difference has been reported to be 6.5 points.[38] The VISA-A assesses the degree of pain and stiffness in the Achilles, the patient's ability to perform a single-leg heel rise and single-leg hop, and the duration and intensity of the sport activity as it relates to Achilles health and function. For these reasons,

the VISA-A, while not validated for Achilles ruptures, provides useful information on patients' level of function as they recover from an Achilles tendon tear.

Statistical Analysis

Patient responses to the VAS, FAAM, and VISA-A were collected using the Research Electronic Data Capture tool (Vanderbilt University) hosted at our institution.[18] Patients were initially contacted electronically via email. Patients who did not respond to email then received a series of up to 3 telephone calls from our research team in an effort to increase enrollment. Statistical analyses including means, ranges, SDs, and percentiles were performed using Excel (Microsoft).

RESULTS

Forty-nine patients, with 50 acute Achilles tendon ruptures, underwent limited open Achilles repair with modified ring forceps during the study period. All injuries occurred during sport; there were no medication-related or attritional ruptures. Of these patients, 17 (34.7%) could not be reached by telephone, letter, or email for completion of the final survey and were considered lost to follow-up. The final study population of 33 acute Achilles tendon ruptures in 32 patients included 27 (84.4%) male and 5 (15.6%) female patients. One female patient with a medical history notable for rheumatoid arthritis, who was taking multiple immune-modulating agents, sustained bilateral Achilles tendon ruptures. These were from independent injuries 1.5 years apart. In her case, separate surveys were collected for the right and left Achilles repairs. One patient had diabetes, 1 had psoriasis, 1 had hyperlipidemia, 4 had hypertension, and 4 had a history of deep vein thrombosis or thromboembolic events. One patient was an active smoker, and 7 additional patients were prior smokers who had quit before their Achilles tendon rupture. The mean age of the patients at the time of injury was 44 years (range, 21-76 years), and the mean final follow-up was 42.1 months (range, 6-90 months).

At final follow-up, 31 of 32 patients answered "no" to the question, "Are you having Achilles pain?" The mean Achilles VAS score was 0.7 ± 4.2 of 100. Ten patients reported pain elsewhere in their body, with a mean total body VAS score of 13.9 ± 24.3 of 100.

The mean postoperative VISA-A score was 82.3 ± 19.5 of 100 (Figure 7A). Patients reported 26 (78.8%) tendons as pain free while "stretching the Achilles tendon fully over a step," and only 2 patients reported more than minor discomfort after 30 minutes of walking on flat, even ground. Twenty-two of 33 tendons (66.7%) were pain free during a single-leg heel rise. Ten or more single-leg hops could be achieved by 26 of 33 (78.8%) repaired sides without pain, with only 1 patient reporting an inability to hop because of pain. Patients reported no pain in their Achilles while undertaking Achilles-loading sports in 27 of 33 tendons (81.8%). Pain during sport was experienced in the remaining 6 Achilles tendons, which did not stop the patients from completing their training or practice. The patients who

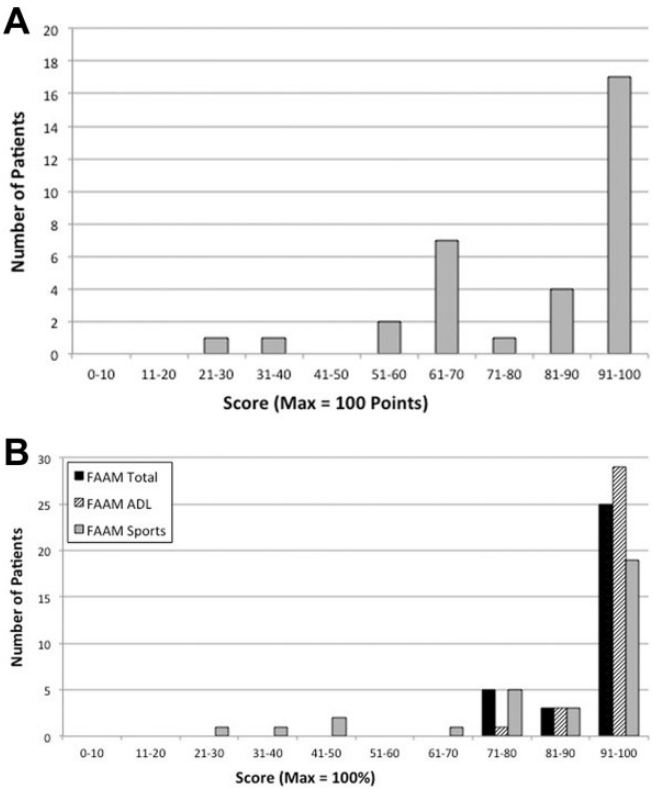

Figure 7. Patient outcomes using the (A) Victorian Institute of Sport Assessment–Achilles (VISA-A) and (B) Foot and Ankle Ability Measure (FAAM). ADL, activities of daily living.

reported less than excellent results on the VISA-A were fairly evenly distributed across age groups (Figure 8).

The mean FAAM ADL and sports subscores were 96.5% ± 5.2% and 85.1% ± 21.2% of the maximum achievable score, respectively (Figure 7B). Postoperatively, patients reported that their overall functional level was 94.1% of their preinjury level when performing ADL and 80.7% when participating in sports. No patient had any difficulty with performing personal care. Only 7 patients (21.9%) reported any level of difficulty with "heavy work" including pushing, pulling, carrying, and climbing; 1 patient did not engage in heavy work for reasons unrelated to the Achilles. Twenty-four patients (75.0%) reported no difficulty with recreational activity. Twenty-six (81.3%) could participate in their sport with a normal technique, and 1 patient listed this question as "not applicable." Nineteen of 30 patients (63.3%) could participate in their desired sport for as long as they liked, while 3 patients did not engage in sports activity.

Regarding current functional level, 19 of 33 tendons (57.6%) was rated as "normal," 10 (30.3%) as "nearly normal," 4 (12.1%) as "abnormal," and none as "severely abnormal."

Complications

There was 1 case (3.0%) of a superficial infection that resolved uneventfully with oral antibiotics and local wound

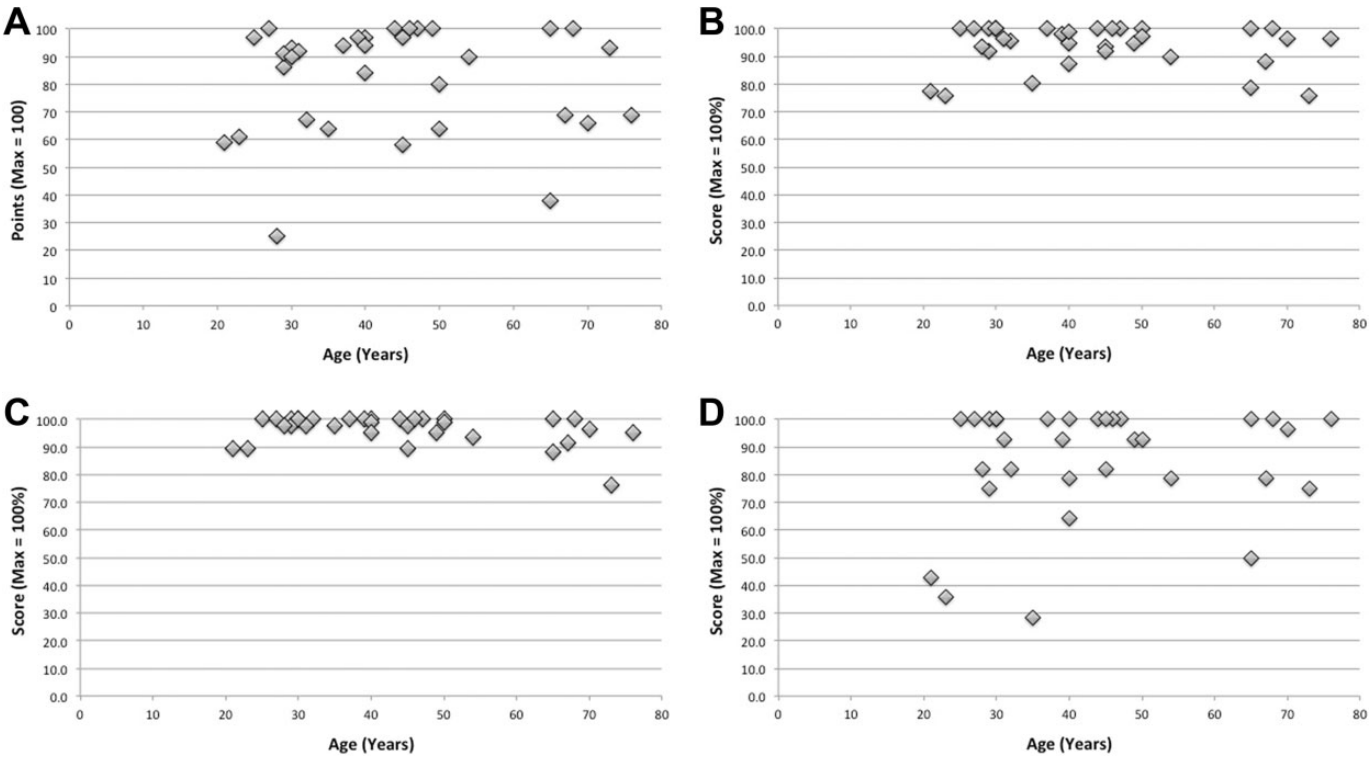

Figure 8. Patient outcomes by age group using the (A) Victorian Institute of Sport Assessment–Achilles (VISA-A) and (B) Foot and Ankle Ability Measure (FAAM), with the FAAM (C) activities of daily living and (D) sports subscales. There was no apparent trend for improved outcomes with younger age groups.

care. There were no cases of wound dehiscence, deep infections, significant hematomas, sural neuritis, deep vein thrombosis, adhesions, symptomatic suture knots, or reruptures in this cohort.

DISCUSSION

The optimal treatment of acute Achilles tendon ruptures remains controversial. The American Academy of Orthopaedic Surgeons Clinical Practice Guidelines provides only "weak" recommendations in support of either operative or nonoperative management.[12] When surgery is selected, the goals of treatment focus on restoring tendon length and tension[13,14,35,46] as well as early rehabilitation.[7,13,20,39] There has been recent enthusiasm for minimally invasive techniques as a means of maximizing strength and function while minimizing complications. The present study is the first to report the clinical outcomes and complications of limited open Achilles repair with modified ring forceps[15] and is one of the first studies to report validated Achilles-specific outcomes (VISA-A) after acute repair.

The modified ring forceps technique presented here compares favorably with prior investigations of minimally invasive Achilles tendon repairs. Studies utilizing commercially available devices via limited open approaches have reported postoperative AOFAS scores ranging from 93 to 96.8[1,3,22] and an average VISA-A score of 92.[26] Investigations using a variety of other percutaneous or limited open techniques have also generally reported positive outcomes, with AOFAS scores ranging from 93.3 to 97.7,[2,24,47] 12-Item Short Form Health Survey (SF-12) scores of 104.8,[16] and an average VISA-A score of 93.1 in a cohort of professional athletes.[48] Although widely utilized, the AOFAS score remains an unvalidated outcome measure[8] and has been shown to overemphasize pain and underemphasize functional outcomes such as strength and stiffness in acute percutaneous Achilles tendon repairs.[10] As such, we elected to use the FAAM, which has been shown to be a better indicator of physical function than the AOFAS score.[36]

In this study, the mean FAAM ADL and sports subscores were 96.5% and 85.1% of the maximum achievable score, respectively, indicating an overall satisfactory functional outcome for the modified ring forceps technique. Additionally, our patients were essentially pain free in their tendons, with a mean VAS score of less than 1. The VISA-A score was slightly lower, at 82.3 of 100. This finding was not surprising given that the VISA-A evaluates only the Achilles tendon, and any dysfunction or discomfort in the Achilles would therefore lower the overall score to a greater degree than a more general measure of foot and ankle function (AOFAS) or general health assessment tool (SF-12/SF-36 [36-Item Short Form Health Survey]). Notwithstanding, the data indicate that the large majority of the modified ring forceps cohort achieved excellent results, with approximately 80% of patients reporting no pain when hopping, stretching their Achilles, or engaging in Achilles-loading

sports. The remaining 20% had some degree of functional limitation or discomfort attributable to the Achilles, and 3 patients (9%) did not return to sport. This compares favorably with open repair techniques in which an inability to perform a single-limb calf raise or return to any sport has been reported in up to 8% and 16% of patients, respectively.[42] In addition, all patients in the current study were still able to engage in sport, and 87.9% rated their functional level as normal or nearly normal.

Several studies have reported outcomes of minimally invasive repair of acute Achilles tendon ruptures using analogous instruments.[2,23,24,48] Amlang et al[2] and Keller et al[24] reported average postoperative AOFAS scores of 96% and 97.7% in their respective studies using a percutaneous technique with 2 separate ringed instruments inserted on either side of the Achilles tendon superficial to the paratenon. The rerupture rates were 3.2% and 2%.[2,24] Similarly, Kakiuchi[23] bent 2 Kirschner wires into rings and inserted them deep to the paratenon in a limited open fashion. While a formal outcome tool was not used, 83.3% of patients were pain free, 75% returned to their prior sport, and there were no reruptures.[23] Using the technique described by Kakiuchi,[23] Vadala et al[48] reported an average postoperative VISA-A score of 93.1 and no reruptures in a cohort of 36 professional athletes.

Here, we report a mean VISA-A score of 82.3, with 17 Achilles tendons (51.2%) scoring 91 or greater (see Figure 7A). Our cohort was a mean 14 years older (44 years) than the professional athletes in the study by Vadala et al[48] (average age, 29.7 years) and presumably had a lower average level of fitness, which may partially explain this difference.

The functional results of this study compare favorably with those of traditional open Achilles tendon repair techniques. One study of open Achilles repair reported an average postoperative VISA-A score of 82,[26] nearly identical to the VISA-A score of 82.3 in the present study. Another study of open Achilles repair reported an average AOFAS score of 96.7.[47] While AOFAS scores were not recorded in this study, other investigations of minimally invasive Achilles repair have reported similar AOFAS scores of 93.3 to 97.7.[2,24,47] Multiple studies of open Achilles repair have noted residual weakness[42,43,51] or calf atrophy[51] in the operative tendon after surgery. One investigation noted that 16% of patients had not resumed sport as a result of their injury at 1 year after open Achilles repair, and at 2 years after injury, 8% could not perform a single-limb heel rise.[42] In the current study, only 3 patients (9%) did not return to sport, with the vast majority of patients reporting that they could engage in their sport with a normal technique.

Compared with prior studies of ringed instruments,[2,23,24,48] the modified ring forceps are easy to use. The 2 rings are joined together at the waist, allowing the surgeon to easily position them on either side of the Achilles at the same level and depth. In addition, the surgeon can hold the instrument with one hand while passing sutures with the other. The modified ring forceps achieve a box stitch–style construct, analogous to the Achillon construct. The absence of locking sutures in this technique did not adversely affect healing rates or clinical outcomes, and there were no reruptures in the study population. While locking sutures and divergent suture patterns increase tendon purchase[13] and more effectively limit gapping in cadaveric models[13] we have not found these modifications to be clinically necessary.

We believe that the limited open technique is advantageous because it allows a direct inspection of the ruptured tendon ends, which greatly aids in re-establishing the native Achilles tendon length and resting tension. By keeping the final position of the sutures deep to the paratenon, injuries to the sural nerve are avoided. Furthermore, working within the paratenon, and passing the suture knots deep (anterior) to the Achilles tendon, also eliminates prominent suture knots, which is a reported complication of percutaneous and limited open techniques.[24,33] The learning curve of the modified ring forceps is short, and while it was not formally investigated in this study, we have found the surgical time (approximately 40 minutes) to be comparable with that of commercially available devices.

Sural nerve entrapment is of particular concern during minimally invasive repair because the nerve is not directly visualized or protected. Historically, sural nerve injury rates have ranged as high as 9% to 18%[27,30,34]; however, the rate drops to 0% to 3.3%[3,22,24] with more modern techniques. There were no observed cases of sural neuritis in our series. We believe that working within the paratenon protects the sural nerve from blunt trauma due to the forceps and prevents snaring of the nerve by sutures. Another major advantage of minimally invasive techniques is the low incidence of wound-healing complications and the low infection risk.[40] It has been well established that this risk is much higher in open procedures.[40] Our study supports this finding, with only a 3.0% rate of superficial infections using a limited open approach and no cases of deep infections. These results compare favorably with the body of literature on minimally invasive repair.[2,9,23,24,29,33,47,49] Finally, no cases of reruptures were observed at a mean 42.1-month follow-up, demonstrating that the modified ring forceps technique presented here achieves a robust and durable repair.

In the current climate of escalating health care expenditures, the modified ring forceps technique is an economically attractive option. The ring forceps (US$13.25; AliMed) are reusable and compatible with any commercially available suture material. Our preference is to use No. 2 Orthocord ($34.00/single suture pack), bringing the total implant cost at our institution to $204.00 per case in addition to the initial purchase of the ring forceps. In comparison, the Achillon (Integra) jig is a single-use disposable kit costing $1462 per surgery. The Percutaneous Achilles Repair System (PARS; Arthrex) has a reusable jig ($4250) and requires a single-use suture kit costing $1072 per surgery. The optional supplement of the Achilles Midsubstance SpeedBridge (Arthrex), which allows the surgeon to secure the proximal tendon stump into the calcaneus with suture anchors after using the PARS, costs an additional $1393 per case, which can bring the total to $2465 for the single-use items alone. While some institutions may be able to negotiate more favorable rates, looking at the single-

use items alone, the modified ring forceps are 5.3 to 12.1 times less costly per case than the commercially available jigs. It is important to note that a formal cost analysis has not been performed; a true cost analysis would include a direct comparison of outcomes as well as costs related to any complications, follow-up appointments, and/or therapy. However, when comparing surgical equipment alone, over the course of 10 acute Achilles tendon repairs, the cost savings can be $8680 to $22,610.

Limitations

The biggest limitation of this study is the lack of a control group with an acute Achilles tendon rupture treated either nonoperatively, with traditional open repair, or with an alternative minimally invasive technique. Additionally, objective functional outcomes such as biomechanics, plantar flexion strength, push-off strength, or jump height were not measured. However, by using an Achilles-specific outcome measure (VISA-A), we believe that our results offer an accurate representation of the functional outcomes that are achieved using this technique. This study also had a relatively short follow-up period, averaging 42.1 months. In our experience, the vast majority of complications will have occurred within this time period, notably reruptures, wound-healing issues, and infections. Seventeen patients (34.7%; mean age, 38 years) could not be reached for final survey results. The mean age and health of this cohort were comparable with those of the final study population. It is possible that this cohort experienced worse outcomes than the study population, however there were no reported reruptures or complications in these patients at a mean follow-up of 7.5 months, which is beyond the typical early postoperative period when most reruptures and other complications occur.

CONCLUSION

The results of the current study demonstrate that limited open Achilles rupture repair with modified ring forceps provides an economical repair with excellent pain relief and favorable functional outcomes at midterm follow-up. The complication rate was extremely low, making this technique an attractive alternative to traditional open techniques. Furthermore, this technique is easy to learn, utilizes readily available instruments, and is cost-effective, without the requirement for commercial single-use kits.

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