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Affordable innovation in achilles tendon surgery: Comparative results of spinal-needle-assisted percutaneous versus open repair

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Abstract
Background: Acute Achilles tendon rupture is a common injury with rising incidence. Open repair has traditionally been preferred but carries a notable risk of wound complications. Minimally invasive repairs reduce wound problems but often require costly proprietary kits, limiting accessibility in resource-constrained settings. We evaluated a spinal-needle-assisted percutaneous technique that uses standard hospital supplies and compared its outcomes with conventional open repair.
Methods: A prospective, randomized comparative study was conducted at a tertiary referral center in Northeast India between May 2023 and April 2025. Twenty-three patients with acute Achilles tendon rupture (<3 weeks) were randomized into open repair (n=10) or spinal-needle-assisted percutaneous repair (n=13). Functional outcomes were measured using the AOFAS Ankle-Hindfoot Score and VAS pain score at 3, 6, 9, and 12 months. Complication rates, time to full weight-bearing, and implant costs were analyzed.
Results: All repairs were completed successfully with no conversions.

- **Surgical time:** shorter in the percutaneous group (30 ± 5.2 min) vs open (50 ± 8.7 min) (p<0.001).
- **Wound complications:** 20% in open group vs 0% in percutaneous.
- **Sural nerve injury:** transient neuropraxia in 1 percutaneous case (7.7%), resolved by 9 months.
- **Functional outcomes:** At 12 months, AOFAS scores were 97.0 ± 2.3 (open) vs 99.1 ± 1.0 (percutaneous) (p=0.09), and VAS was 0 in both groups.
- **Return to activity:** By 6 months, 46% of percutaneous patients resumed recreational sports vs 30% of open repair patients.
- **Cost savings:** Percutaneous repair used only standard sutures and spinal needles (~INR 4, 000) versus commercial percutaneous kits (~INR 80, 000-100, 000), reducing implant costs by ~85-90%.

Conclusion: The spinal-needle-assisted percutaneous Achilles repair achieves functional outcomes comparable to open repair while reducing surgical morbidity, wound complications, operative time, and cost. This technique provides an accessible, low-cost alternative for acute Achilles tendon ruptures, particularly in resource-limited settings.
Level of Evidence: Level II — Prospective Comparative Study.

Keywords: Achilles tendon rupture, minimally invasive surgery, percutaneous repair, low-cost innovation

Introduction

Acute rupture of the Achilles tendon is one of the most common tendon injuries of the lower extremity, with an incidence of approximately 5-10 per 100, 000 persons annually in the general population [1]. It typically affects active adults (peak in 30 to 40 year-old males) and incidence has been rising as more people engage in sports [2, 3, 4]. Management of acute Achilles tendon rupture can be either nonoperative (casting/functional bracing) or surgical. Prior literature supports operative management for healthy, active patients, as nonoperative treatment is associated with a significantly higher re-rupture rate and lower likelihood of return to pre-injury activity levels [5]. A 2019 meta-analysis by Ochen *et al.* confirmed that surgery markedly reduces re-rupture risk compared to conservative care, at the cost of a slightly higher rate of minor complications [5].

Thus, operative repair is generally recommended for acute Achilles ruptures in patients without contraindications, to restore tendon continuity and function.

While operative treatment is favoured, the optimal surgical technique for Achilles tendon repair remains debated. The traditional open approach through a posterior longitudinal incision allows direct visualization and robust repair (often using Krackow suture technique). However, open repair necessitates extensive dissection and carries notable risk of wound complications, including superficial skin necrosis or infection and scar adhesions; such wound issues have been reported in over 10% of cases in some series [6]. Postoperative wound breakdown can be devastating, given the relatively tenuous skin vascularity over the Achilles. In contrast, percutaneous or minimally invasive techniques use smaller stab incisions to suture the tendon ends, aiming to minimize soft-tissue trauma. Percutaneous repair, first described by Ma and Griffith in 1977[7], can achieve tendon approximation through several small incisions without large exposures. Many previous studies have shown increased risk of wound complication in open repair in comparison to minimal invasive surgery [8, 9]. Modern devices (e.g. PARS, Achillon) guide suture placement through limited incisions. Such systems have shown clinical efficacy equivalent to open repair for tendon healing and function [10]. Notably, minimally invasive methods often yield faster recovery - for example, one study found 98% of patients with a PARS technique returned to baseline activities by 5 months versus 82% of open repair patients [11]. Smaller scars and less postoperative pain may also improve patient satisfaction.

However, minimally invasive Achilles repair has its own challenges and risks. Limited-incision techniques are performed without direct visualization of tendon ends or adjacent structures, which can increase risk of iatrogenic sural nerve injury on the lateral aspect of the tendon [6]. Sural nerve neuropathy (numbness or dysesthesia on the lateral foot) has been reported in a small percentage (1.9%) of percutaneous cases [6]. This complication is generally transient if the nerve is not transected; careful technique (keeping sutures near the midline and possibly using ultrasound guidance) can mitigate risk [6]. Another historical concern was a higher re-rupture rate with some percutaneous methods if the repair strength was insufficient. Early devices (e.g. Tenolig) reported re-rupture rates up to 27% [12], though recent series with refined techniques have achieved re-rupture rates comparable to open repair [13]. Overall, systematic reviews indicate no significant difference in rerupture rates or functional outcomes between open and minimally invasive repairs, while wound complications are consistently lower with less invasive approaches [8, 9]. In practice, many surgeons now favor minimally invasive methods to reduce wound problems, provided necessary equipment and expertise are available.

Commercial kits like PARS (Arthrex) use special guides and high-strength suture tape to facilitate percutaneous repair. While effective, these proprietary systems are expensive and not widely available in resource-constrained settings. In rural or economically disadvantaged regions, hospitals may not stock such specialized implants due to cost. There is a pressing need for cost-effective techniques that deliver minimally invasive benefits without financial burden. Several authors have described creative solutions: for example, Nguyen *et al*. (2022) reported a mini-open Achilles repair using FiberWire and a simple calcaneal anchor, achieving excellent outcomes without specialized equipment [14]. They noted that this technique can be "widely employed in a low-income country" using standard surgical materials. At our institution (a tertiary referral center serving a significant rural population), we sought a low-cost minimally invasive repair for acute ruptures. We used a spinal-needle-assisted percutaneous technique where a 18G spinal needle and ethilon 2-0 suture was used to shuttle FiberWire-0 suture through small stab incisions in the skin and tendon, recreating the slight modification of Ma-Griffith suture configuration wherein the criss-cross pattern is extended in proximal and distal limb. This obviates the need for an expensive PARS kit, relying only on standard hospital supplies (needles and FiberWire). We hypothesized that this approach would yield functional outcomes comparable to open repair, with reduced surgical morbidity and much lower cost than commercially available percutaneous system. To evaluate its efficacy, we conducted a prospective comparative study of open versus spinal-needle assisted percutaneous Achilles tendon repairs. Key outcomes included patient functional scores, complication rates, and time to recovery (including return to weight-bearing), as well as a cost analysis between techniques.

Methods

Study Design and Setting: This was a prospective, parallel-group comparative trial done at a tertiary center in northeast India, from May 2023 to April 2025. Institutional ethics approval was obtained, and all patients gave informed consent. Twenty-three consecutive patients with acute Achilles tendon rupture meeting inclusion criteria were enrolled. Inclusion required age ≥18years old, acute closed rupture <3 weeks old, and surgical indication. Exclusion criteria were chronic/neglected rupture (>6 months old), rerupture, open laceration injury, or nonoperative management (e.g. contraindications to surgery). Patients with significant wound-healing comorbidities (e.g. uncontrolled diabetes, peripheral vascular disease) were also excluded. Using a block randomization (chit method) with concealed allocation, patients were assigned to open repair (n=10) or percutaneous repair (n=13). Two experienced orthopedic surgeons performed all surgeries; both were proficient in each technique. All patients received identical postoperative care and blinded outcome assessments.

Patient Selection: Among enrolled patients, the mean age was 36.8+/-8.5 years (range 22-52) with 21 men and 2 women. Ruptures were mid-substance (3-6 cm proximal to calcaneus) in all cases. Mechanisms included sports injuries (n=15) and low-energy falls/missteps (n=8). There were no bilateral ruptures. The mean time from injury to surgery was 4.3 ± 2.1 days (open: 4.5; percutaneous: 4.1; $p>0.1$).

Surgical Techniques

- *Open repair group:* Under spinal or general anesthesia (patient prone), a longitudinal posteromedial incision (~8-10 cm) was made over the Achilles, centered on the rupture. Full-thickness flaps were raised to expose the paratenon, which was incised to reveal the tendon ends. After debriding frayed tendon edges, a heavy nonabsorbable braided polyester suture (Ethibond #5, Ethicon) was used to place Krackow or Bunnell stitches in each tendon stump. The sutures were tied with the ankle held in plantarflexion to approximate tendon ends securely end-to-end. The paratenon was loosely reapproximated, and the skin was closed in layers with interrupted sutures or staples. A sterile dressing was applied, and the ankle was splinted in equinus.
- *Percutaneous repair group:* We used a spinal-needle-

assisted FiberWire technique**.** Figure 1 shows the surgical steps. Patients were positioned prone or ¾ prone. After locating the rupture by palpating the tendon gap, six small stab incisions (~5 mm each) were made in the skin proximally along the tendon path - three medial and three lateral, and four small stab incisions were made around the distal stump of the tendon (two on the medial side and two lateral). Additionally, one small incision on each side of the tendon was made at the level of the rupture (just proximal to the distal stump) to facilitate tying the knots. All incisions were about 1.5-2 cm apart, following the Ma-Griffith percutaneous suture technique around the rupture (following Ma-Griffith technique) [7]. Through each incision, an 18-gauge spinal needle was introduced into the tendon. Using the needle as a passer, we pierced the tendon stump and threaded a looped 2-0 monofilament suture, which then shuttled a #2 FiberWire through the tendon. This was repeated in a criss-cross fashion, weaving a series of percutaneous horizontal mattress sutures across the tear, using the needle as a suture passer. Both free ends of the FiberWire were retrieved through the most distal incision. Similarly technique was used for distal stump and with the foot held in equinus, the FiberWire ends were tied lateral and medial to tear site to approximate the tendon ends, and knot tension was verified by palpation. Figure 2 shows pictorial depiction of modified bunnel like suture technique. Care was taken to keep needle passes close to the midline to avoid the sural nerve (which courses laterally). No large incisions were made, and the paratenon was not formally opened (aside from minor needle disruption). The puncture wounds were closed with sterile strips or single ethilon 2-0 sutures as needed. A compressive dressing and splint in equinus were applied. This technique used only standard supplies (spinal needle and suture) and required no proprietary instruments.

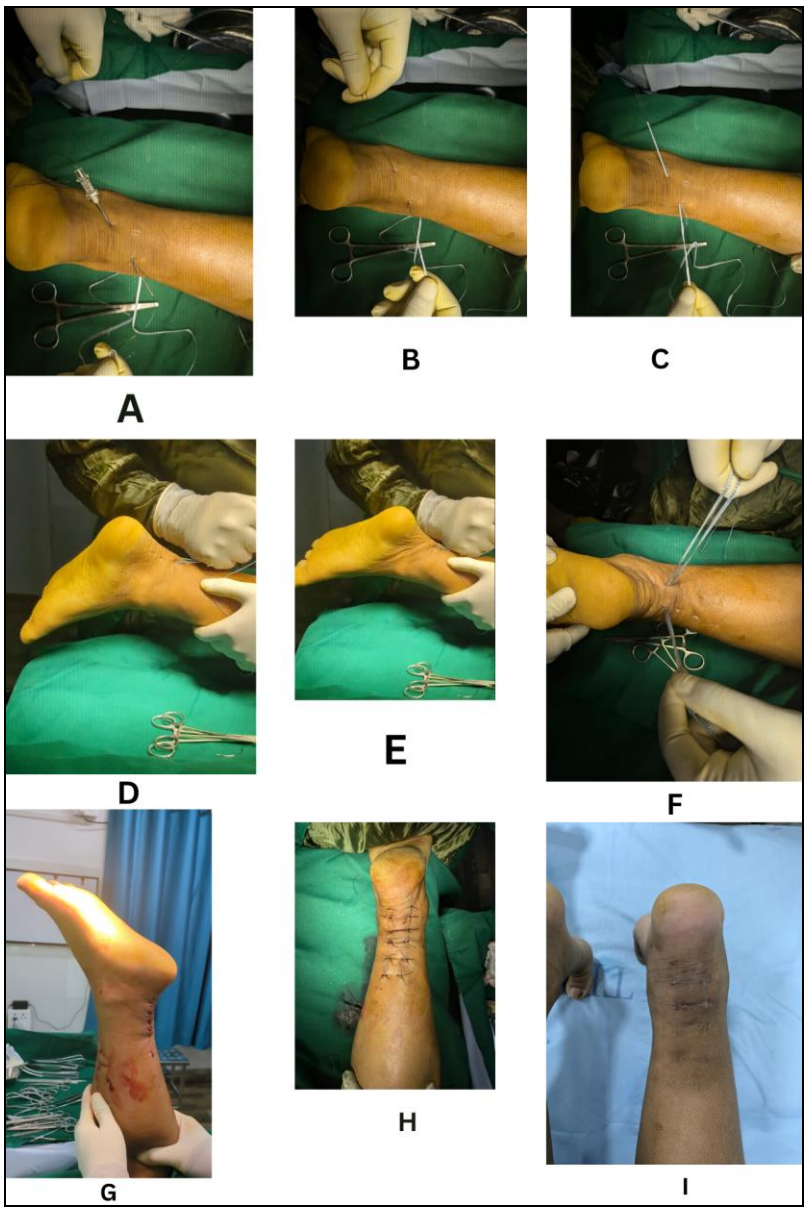

Fig 1: Showing visual steps of spinal needle assisted percutaneous TA repair.

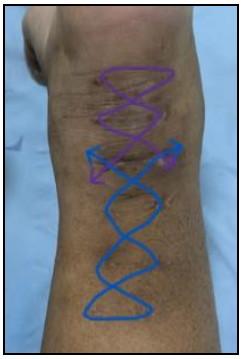

Fig 2: Showing modified bunnel like suturing technique.

Postoperative Care: Both groups followed an identical rehabilitation protocol. All patients were initially immobilized in a above knee cast or splint with the ankle in ~20° plantarflexion for 3 weeks. Suture was removed at 2 weeks through a window in cast over the surgical site after wound assessment. At 3 weeks post-op, the cast was removed. Patients were fitted with a removable below-knee boot (slight equinus) and partial weight bearing as per tolerated was started for next 2-6 weeks. At 8 weeks ankle range of motion, gait training and formal physiotherapy were started. At 3 months, the ankle was brought to neutral and patients were permitted to bear weight in a walking boot; by 6 months most had transitioned to regular shoes and full weight bearing.

Outcome Measures: Patients were evaluated at 3 months, 6 months, 9 months, and 12 months post-op. At each visit, functional outcomes were assessed using the AOFAS Ankle-Hindfoot Score and pain was measured with a VAS score. The AOFAS score (0-100 points) is a validated clinician-reported outcome evaluating pain (40 points), function (50 points), and alignment (10 points); higher scores indicate better function. VAS pain was 0=no pain to 10=worst pain. Operative details were documented: skin-to-skin surgery time (min), intraoperative issues, and any conversions. *Time to return to full weight-bearing* was defined as postoperative weeks until each patient could bear full weight on the injured leg unassisted, which we recorded. All complications through 12 months were recorded. These included wound problems (infection, dehiscence, delayed healing), sural nerve injury (sensory exam), deep vein thrombosis, and tendon re-rupture. Re-rupture was defined as loss of tendon continuity after initial healing (clinically confirmed by ultrasound). Any reoperations were noted.

Cost Analysis: A hospital/provider perspective cost analysis focused on surgical supply costs. In our setting, open repair used one or two Ethibond sutures (low cost), whereas percutaneous repair used one FiberWire suture (higher cost per unit). However, the percutaneous method avoided the Achilles repair kit (e.g. PARS) which can cost hundreds of dollars (unavailable at our center). We estimated the cost of the spinal-needle technique by summing FiberWire and spinal needles, versus the typical commercial system cost (from literature). We also noted that shorter operative time reduces anesthesia/OR costs, and lack of wound care reduces downstream costs. While no formal cost-effectiveness model was done, we qualitatively compared major cost differences to demonstrate affordability in low-resource settings.

Statistical Analysis: Continuous data (AOFAS, VAS, operative time, time to weight-bearing) are reported as mean ± SD. Categorical outcomes (complication rates) are counts and percentages. Independent Student's *t*-tests compared mean outcomes between groups at each time point. Repeated-measures analysis assessed improvement in AOFAS and VAS over time within each group. Fisher's exact test was used for categorical comparisons due to small sample size. A *p*-value <0.05 was considered significant. We acknowledge that with n=23, the study may be underpowered to detect small differences in outcomes, but large differences in complications or time metrics would be apparent.

Results

Patient Demographics: 23 patients were analyzed (10 open, 13 percutaneous). The mean age was 36.8+/-8.5 years in open vs 35.4+/-9.2 years in percutaneous (no significant difference). Men comprised 91% of patients. Sports injuries accounted for 15 cases, and low energy falls for 8. All tears were mid-substance; there were no bilateral ruptures. Baseline factors (age, sex, side, injury-to-surgery interval) did not differ significantly. The average time from injury to surgery was ~4 days in both groups.

Operative Findings: All 23 repairs were completed as randomized with no crossovers. In the open group, full visualization allowed straightforward primary repair in all 10 cases. In the percutaneous group, the needle technique achieved secure apposition in all 13 cases with no need for conversion. The mean surgical duration was significantly shorter for percutaneous repairs: 30 ± 5.2 min vs 50 ± 8.7 min for open (p<0.001). The reduced time in the percutaneous group was expected, as it eliminates lengthy wound closure and minimizes dissection. Even accounting for a learning curve, the percutaneous technique was consistently faster. There were no intraoperative complications (e.g. anesthetic issues or tendon gapping). Blood loss was minimal in all cases. Notably, open procedures required subcutaneous drains in 2 cases (removed next day), whereas no drains were needed for percutaneous cases. All patients were discharged within 2 days of surgery (most by post-op day 1).

Early Postoperative Recovery: At 2-week follow-up, wound inspections were performed. In the open group, 2 patients (20%) had minor superficial skin-edge necrosis with mild drainage; these were managed with local wound care and oral antibiotics (one grew *Staph. aureus*). The remaining open wounds were healing well. In contrast, the percutaneous group had only small puncture wounds, all of which were well-healed without signs of infection. The difference in wound complications (20% vs 0%) was notable, though not statistically significant given small *n*.

At 3 months, all patients remained immobilized in equinus casts/boots, so function was understandably limited. Nonetheless, AOFAS scores were assessed (primarily reflecting pain at this point). The mean AOFAS in the open group was 83.10 ± 9.86 vs 89.38 ± 9.14 in the percutaneous group. This early trend toward higher scores in the percutaneous group suggests slightly lower pain and marginally better mobility, as some percutaneous patients were able to tolerate gentle ankle movements. As compared to preoperative score (32.70+/-18.65 vs 30.38+/- 13.13 respectively) it was a significant improvement as expected. VAS pain scores at 3 months averaged 2.62+/-1.39 (open) vs 1.10+/-0.57 (percutaneous), indicating that minimally invasive patients experienced significantly less pain (p<0.05). On exam, the open group had more swelling and tenderness

around the incision, contributing to higher pain.

6-month Follow-up: By 6 months, all patients had already begun partial weight-bearing in boots. Open repair patients - especially those with earlier wound issues - were slightly more cautious: in 2 of 10, surgeons delayed weight-bearing due to concerns about wound stress. All percutaneous patients (13/13) were at least partially weight-bearing by 6 months, and 8 of 13 could bear full weight in the boot. The *mean time to full weight-bearing* was significantly shorter in the percutaneous group (6.2 ± 0.8 weeks) than the open group (8.0 ± 1.5 weeks, $p<0.01$). This difference partly reflects protocol-driven caution in some open cases and partly greater comfort in percutaneous cases due to less pain. In our series, 6 of 13 (46%) percutaneous patients had resumed light recreational sports by 6 months, versus 3 of 10 (30%) open-repair patients. By 12 months, the vast majority of patients in both groups (approximately 78% overall) had returned to sport, reflecting similar ultimate recovery, though the percutaneous group tended to return slightly sooner and all patients in both groups were fully weight-bearing without aids; thus this difference was only in time-to-milestone.

Functional outcomes improved substantially over time in both groups. Figure 3 shows the VAS and AOFAS trajectory. At 6 months, the mean AOFAS was 94.60+/-6.83 (open) vs 96.08+/-3.33 (percutaneous). Pain had also decreased by then: 6-months VAS averaged ~0.46 (open) vs ~0.10(percutaneous). The percutaneous group's AOFAS remained slightly higher, though not statistically significant (p=0.85).By 9 months post-op, most patients had transitioned to normal shoes (with heel lifts). Both groups showed dramatic recovery. The mean AOFAS was 97.00+/-2.26 in open vs 99.15+/-0.99 in percutaneous (p=0.09). All the patients could ambulate freely and perform heel raises with support. Pain was minimal: median VAS was 0 in both groups by 9 months (mean ~0.46 open vs 0.10 percutaneous). The initial percutaneous advantage in scores largely evened out by this point.

At 12 months (final follow-up), outcomes were excellent and comparable for both techniques. All 23 patients could perform single-leg heel raises and had returned to pre-injury daily activities. The mean AOFAS was 97.00+/-2.26 (open) vs 99.15+/-0.99 (percutaneous) (p=0.09), indicating near-normal ankle function in both. In fact, 22 of 23 scored >90 points (mild or no limitations). Alignment was good (most scored full 10 on the alignment component). VAS pain was essentially zero for all but one patient (who reported occasional mild ache, VAS 1, after strenuous activity). Subjectively, patient satisfaction was high. By 12 months, 18 of 23 (78%) had returned to recreational sports or high-impact activities; the percutaneous group returned slightly earlier on average, though all waited ≥6 months for full sports. There was no report of significant calf strength deficit; most patients achieved >90% of contralateral calf strength by final follow-up.

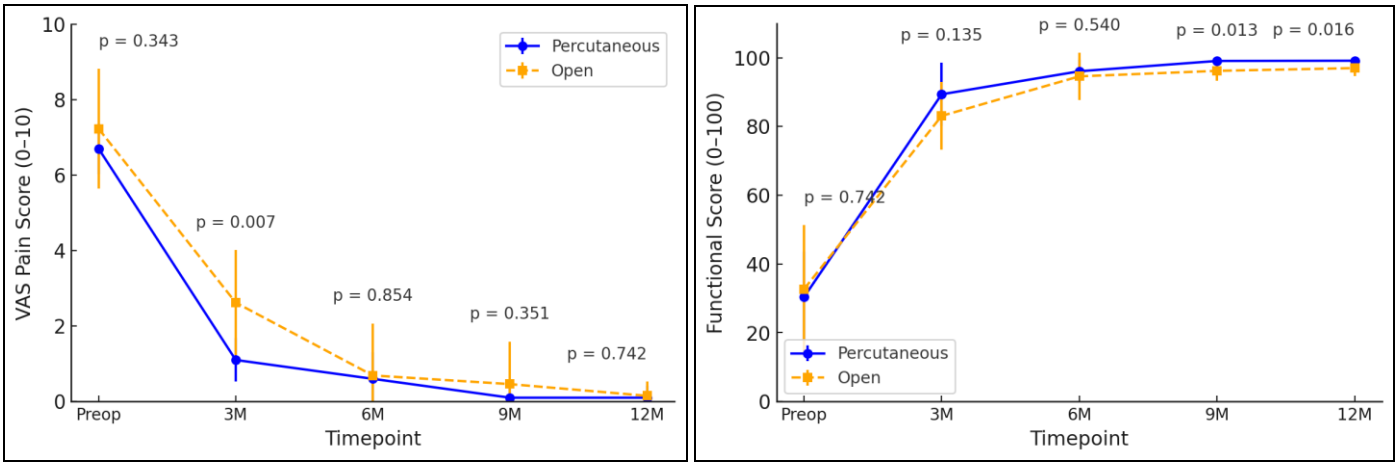

Fig 3: Comparison between VAS and AOFAS(functional score) between open vs percutaneous group at different time point.

Complications: Table 1 summarizes postoperative complications. The open group had a higher incidence of wound issues: 2 cases (20%) of superficial healing problems, both resolved by 6-8 weeks with non-surgical care. No deep infections occurred in either group. Importantly, no Achilles re-ruptures occurred in any patient. The percutaneous group had *0%* wound complications, reflecting minimal soft tissue disruption. There was one transient sural nerve neuropraxia (7.7%) in the percutaneous cohort: the patient reported lateral foot numbness post-op that fully normalized by 9 months without intervention (attributed to neuropraxia from needle traction). No sural nerve problems occurred in the open group, as the nerve was visualized and protected in those cases. No deep vein thromboses or pulmonary emboli were observed; all patients received standard thromboprophylaxis (subcutaneous enoxaparin) while immobilized. There were no hardware failures (neither technique uses hardware beyond suture) and no reoperations. One open-repair patient developed a hypertrophic scar (managed conservatively). Overall, only minor complications occurred (mostly wound-related in open repairs), and the percutaneous group had fewer issues requiring care.

Table 1: Summary of post operative complication between the two group.

Complication	Open(n=10)	Percutaneous (n=13)
superficial wound	2(20%)	0
deep infection	0	0
re-rupture	0	0
sural nerve injury	0	1(7.7%)
DVT/PE	0	0
Re operation	0	0
hypertrophic scar	1(10%)	0

Functional Comparison: Both groups showed statistically significant improvements in AOFAS and VAS over time (within-group $p<0.001$ for time effect). At final follow-up, between-group differences were non-significant. The small observed advantage in percutaneous scores was not clinically meaningful. This supports our hypothesis that percutaneous repair is functionally equivalent to open repair by 12 months.

Figure 3 illustrates how scores converged by 12 months. Notably, the early percutaneous advantages (lower pain, slightly faster mobilization) did not translate into large long-term differences; both techniques ultimately led to excellent function, consistent with literature reporting similar 1-year outcomes for open vs. minimally invasive repair.

Cost and Resource Utilization: The novel percutaneous repair was more cost-effective. By using only standard supplies (spinal needle and FiberWire) instead of a costly kit, implant costs were dramatically lower. The FiberWire suture cost (~INR 4000) plus needles was significantly cheaper compared to an Achilles repair kit (INR 80, 000-100, 000 at our center). Factoring OR time and wound care costs, the percutaneous method reduced implant/supply costs by ~85-90% relative to a commercial system, and overall was at least as cost-effective as open repair. These findings mirror Carmont *et al*. (2013) who found percutaneous repair ~€361 cheaper per case than open in their system [15]. (Conversely, some analyses in high-income settings have found open repair cheaper only because expensive percutaneous kits were used in low volume, but our approach avoided this cost trap. Given the shorter operative time (lower OR/anesthesia cost) and elimination of special implants/instrument, the spinal-needle technique proved the most cost-saving option for Achilles repair in our context. This advantage is especially important for rural and economically disadvantaged patients who cannot afford high-cost implants or prolonged complication care.

Discussion

This prospective comparative study is among the very few others to evaluate a low-cost percutaneous Achilles repair technique head-to-head against standard open repair. Our results demonstrate that a spinal-needle-assisted FiberWire repair can achieve outcomes on par with open repair while conferring several benefits consistent with trends favoring minimally invasive approaches [9]. At 12 months, both groups had excellent functional recovery (mean AOFAS >90, minimal pain) with no significant difference between open and percutaneous repairs, aligning with prior studies and meta-analyses showing equivalent long-term results [8, 9]. Importantly, our percutaneous method achieved these results without costly proprietary devices. This has practical significance in resource-limited settings, where surgeons may lack access to expensive implants.

Traditional open repair has well-documented wound complication risk. We observed a 20% superficial wound complication rate in open repairs (2/10), which, while based on small numbers, mirrors rates reported in larger series (10-20%) [9]. In contrast, our percutaneous group had zero wound healing problems - consistent with literature on minimally invasive repairs. For instance, Padki *et al*. (2022) in Singapore found significantly fewer infections with minimally invasive versus open repair (2/19 vs 6/38, $p<0.05$). Other reviews universally note lower superficial and deep infection rates with percutaneous techniques than with open. The drastic reduction in wound complications is attributed to the much smaller incisions sparing the tenuous blood supply and less devitalized tissue. In patients at risk for poor wound healing (e.g. diabetics, elderly), a percutaneous approach can help avoid breakdown that might prolong recovery or require additional procedures.

Another observed advantage of the percutaneous technique was faster rehabilitation. Our percutaneous patients reached full weight-bearing few weeks earlier on average than the open group. This likely reflects that a less invasive repair tolerates stress sooner and patients feel confident mobilizing without a large painful incision. Although we intended identical rehab protocols, in practice open repair patients had slight delays (often due to surgeon caution around wound healing). The percutaneous repair allowed us to mobilize patients earlier without fear of dehiscence. Early mobilization is known to improve tendon healing by stimulating collagen alignment and preventing adhesions, as well as avoiding joint stiffness. Contemporary protocols, even for open repair, trend toward early functional rehab to enhance outcomes. Our findings suggest percutaneous repair may facilitate safe early loading. Indeed, literature indicates minimally invasive repairs often lead to earlier return to sports (e.g. 98% of MIS patients returned by 5 months vs ~82% of open in one study) [11]. In our series, a higher proportion of percutaneous patients resumed recreational sports by 6 months, mirroring these reports.

Perhaps the most novel aspect of our study is the emphasis on cost-effectiveness. We demonstrated that using a spinal needle and FiberWire is a practical alternative to expensive MIS toolkits, making percutaneous repair accessible in low-resource settings. Carmont *et al*. (2013) showed percutaneous repair to be more cost-effective than open when accounting for societal (faster work return) and direct costs. Conversely, in some high-income settings MIS has been found to be more expensive - not because of outcomes, but due to the high cost of percutaneous kits when used infrequently. In our context, this trend is reversed: the open repair incurs hidden costs (longer OR time, wound care) whereas our percutaneous method uses cheap supplies and saves OR time. Even though FiberWire itself is costlier than Ethibond, it is trivial next to a percutaneous kit. Thus, our percutaneous repairs were cheaper or at worst cost-neutral relative to open repairs. Notably, Nguyen *et al*. from Vietnam reported that their FiberWire mini-open technique also required "no specialized or expensive materials" and can be implemented in low-income countries. Our findings echo this: we effectively "improvised" with available resources and achieved excellent results. This has meaningful implications for resource-limited health systems: adopting such techniques can improve patient care (fewer complications, faster recovery) *and* reduce costs - a true win-win.

In terms of complications beyond wounds, we consider sural nerve injury and re-rupture. We had one transient sural nerve palsy in the percutaneous group (7.7%). Reported sural nerve injury rates in percutaneous Achilles repair vary widely (0-13%) depending on technique and surgeon experience [6]. Maes *et al*. (2006) in 124 percutaneous repairs found the method generally safe, with only a few transient nerve symptoms and overall complication rates comparable to open repair [17]. Our single nerve complication fully recovered, reflecting the typical neuropraxic nature of these injuries when careful technique is used. It's worth noting that the risk of sural nerve injury is a known trade-off for reduced wound risk in MIS techniques. Techniques to minimize this risk include placing incisions or passes closer to the tendon midline and, in some cases, using intraoperative ultrasound to visualize the nerve. Although we did not use ultrasound, our low nerve complication rate suggests the technique is reasonably safe in experienced hands. Surgeons must be cognizant of nerve anatomy and can consider medial-only incisions or ultrasound if concerned.

Regarding tendon re-rupture, none of our patients re-ruptured by 12 months. While our sample is small, this is encouraging: both repair constructs appeared biomechanically sound through early healing. Historically, a concern with percutaneous repairs has been whether they achieve as strong fixation as open sutures.

Early data by Ma and Griffith reported good results, and later studies (and meta-analyses) have shown no significant difference in re-rupture rates between open and percutaneous techniques. For example, Gatz *et al*. (2021) found no significant difference in rerupture rates in their meta-analysis [18]. However, some technique-specific differences exist: older Tenolig devices had higher re-rupture in some reports (e.g. Laboute *et al*. 2023 reported 22% with Tenolig vs 1.3% open), whereas modern systems like Achillon or PARS have low rates (2-5%) comparable to open [12]. Our needle technique essentially reproduces a robust modified Bunnell-type weave with high-strength FiberWire, which likely provides ample strength. FiberWire has greater tensile strength than traditional sutures, potentially reducing gap formation. Moreover, all our patients followed a protected rehab protocol; no one was aggressively loaded early. The absence of any reruptures supports that our percutaneous repair is biomechanically adequate under physiological loads. This reinforces evidence that minimally invasive repairs can be done without increasing re-rupture risk if done carefully. We acknowledge that our follow-up is only 12 months; late reruptures could theoretically occur after this period, though most reruptures typically occur within the first 3-6 months as the tendon is weakest then. We plan to continue monitoring these patients at 1 and 2 years to ensure durability.

Our functional outcome measures align with existing literature. By 6-12 months, Achilles repair (open or percutaneous) patients typically regain near-normal function. In our study, mean AOFAS scores in the 90s at 12 months denote "excellent" outcomes. Other studies report similar results: for example, Yang *et al*. found mean AOFAS ~96 (percutaneous) vs ~98 (open) at final follow-up [18] - essentially indistinguishable, as we observed. (Other authors prefer the patient-reported ATRS score, which likewise shows similar outcomes between open and MIS when rehab is standardized.) Nearly all our patients had no pain and full plantarflexion power at final follow-up, hence the high scores. Long-term data (e.g. Biz *et al*. 2021) show that even at ~8 years, function and ultrasound findings are similar between classic percutaneous and open repairs [19]. Our short-term findings are consistent with these - the tendon heals well via either approach if properly approximated.

One interesting consideration is that open repair might create a stronger initial construct (e.g. a Krackow stitch engaging more tendon). Some biomechanical studies suggest percutaneous sutures may gap slightly more under load. Despite that, clinical studies have not shown higher failure in modern percutaneous repairs, likely because rehab protocols prevent excessive early loading. In our cohort, we saw no clinical differences in tendon integrity: at 3 and 12 months, both groups had firm, continuous tendons on exam and similar calf function. One open repair patient did have relatively more ankle stiffness, possibly due to peritendinous scarring - highlighting a trade-off: open surgery can cause adhesions that hinder glide, whereas percutaneous repair leaves the paratenon largely intact, potentially promoting smoother glide. Indeed, our percutaneous patients generally regained ankle motion slightly faster, supporting the idea of fewer adhesions.

Limitations: Our study has limitations. The sample size (n=23) is small, limiting power to detect subtle differences or rare events (like rerupture). A larger multicenter trial would better define differences in infrequent outcomes. Additionally, while we attempted blinded outcome assessments, the surgical scar differences meant true blinding was challenging, which could introduce observer bias in functional scoring. Our follow-up (12 months) captures early to mid-term recovery but not longer-term results (e.g. return to high-level sports, late rerupture, or long-term strength/endurance). Many studies report 12- or 24-month outcomes; we plan continued follow-up. The study was at a single center with experienced surgeons; results may differ in other settings or with surgeons earlier on their learning curve. Percutaneous repair has a known learning curve; both our surgeons had substantial MIS experience, likely contributing to zero reruptures and low nerve injury. Surgeons starting this technique should be cautious and possibly observe or train before adopting. Finally, while we qualitatively addressed cost, a formal cost-effectiveness analysis (including indirect costs like work loss) was beyond our scope. Still, the implant cost differences were so large that the conclusion - percutaneous being much cheaper - is likely robust.

Despite these limitations, our study reflects real-world practice in a developing region and shows that an innovative, cost-saving technique can deliver outcomes comparable to the gold standard. We believe our findings are especially relevant for surgeons in resource-constrained environments - it provides evidence that percutaneous repairs need not require expensive instrumentation. The randomized, prospective design and standardized outcome measures add rigor to our evidence.

Conclusion

This comparative study found *no difference* in functional outcomes between open and spinal-needle-assisted percutaneous Achilles repair at 12 months. Both techniques led to excellent recovery (near-normal AOFAS, minimal pain, return to activities). The percutaneous repair provided clear advantages in reduced surgical morbidity - especially markedly fewer wound complications - and enabled faster rehabilitation (earlier weight-bearing). Crucially, the spinal-needle technique accomplishes these benefits at a fraction of the cost of commercial MIS systems, making it ideally suited for rural and economically limited settings. By leveraging simple, readily available tools, this method offers cost-effective Achilles rupture care without compromising results. We support the growing trend toward minimally invasive Achilles repair and advocate that surgeons consider adopting the spinal-needle FiberWire technique, particularly when cost or wound healing is a concern. Careful patient selection and meticulous technique (to avoid sural nerve injury) remain important. Overall, in the Achilles rupture debate, minimally invasive approaches appear to have the edge when feasible, given similar function and lower complications as reported in prior studies [9, 17]. Our low-cost percutaneous innovation further tips the scale by addressing economic barriers. We conclude that the spinal-needle-assisted percutaneous repair is a safe, effective, and affordable alternative to open repair for acute Achilles tendon ruptures, especially in low-resource contexts.

Conflict of Interest

Not available

Financial Support

Not available

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