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Modern approaches in the treatment of Achilles tendinopathy: future technologies and standards of modern therapy

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ABSTRACT

Achilles tendon tendinopathy is a common musculoskeletal condition with clinical difficulties for both clinicians and patients. This review describes current management modalities, ranging from traditional methods such as eccentric exercises, corticosteroid injection and shock wave therapy to more recent approaches including biomaterials, nanotechnology, gene therapy and stem cells. The advantages and limitations of the various approaches were highlighted, as well as favorable research reports on the use of personalised treatments in chronic diseases. The role of new technologies in improving therapeutic efficacy and patients' quality of life, especially in the context of drug-resistant diseases, was highlighted further. While significant issues were enumerated, such as high cost, lesser accessibility of new therapies and lack of long-term follow-up to confirm their efficacy and safety. The path of future research should involve the implementation of these innovations into clinical practice, refinement of the treatment protocol to optimize outcomes and the development of targeted medicine to improve the management of Achilles tendinopathy.

Keywords: Tendinopathy, Achilles tendon, Conservative treatment, New technologies

1. INTRODUCTION

Achilles tendon tendinopathy is a chronic degenerative condition of the Achilles tendon, which connects the calf muscles to the calcaneus. It is characterized by pain, stiffness and motor function impairment, drastically reducing the quality of life of patients. Pathological processes are dominated by degeneration of the collagen matrix and microdamage leading to weakening of the tendon structure. The condition is found in approximately 0.2-0.3% of the general population but among runners, its frequency is 7-9% per year. It is responsible for approximately 30% of tendon-muscle pathologies in the athlete population (Wang et al., 2022).

Risk factors include vigorous training, inadequate stretching, poor footwear and running on a hard surface. People over 30 years, overweight, abnormal foot biomechanics and previous injuries are at most risk. The pathophysiology of the condition is complex and requires further investigation to understand exactly how it develops (Van der Vlist et al., 2019).

The purpose of this review is to present a complete and up-to-date treatment summary for Achilles tendinopathy with focus on more recent technology and future directions for treatment.

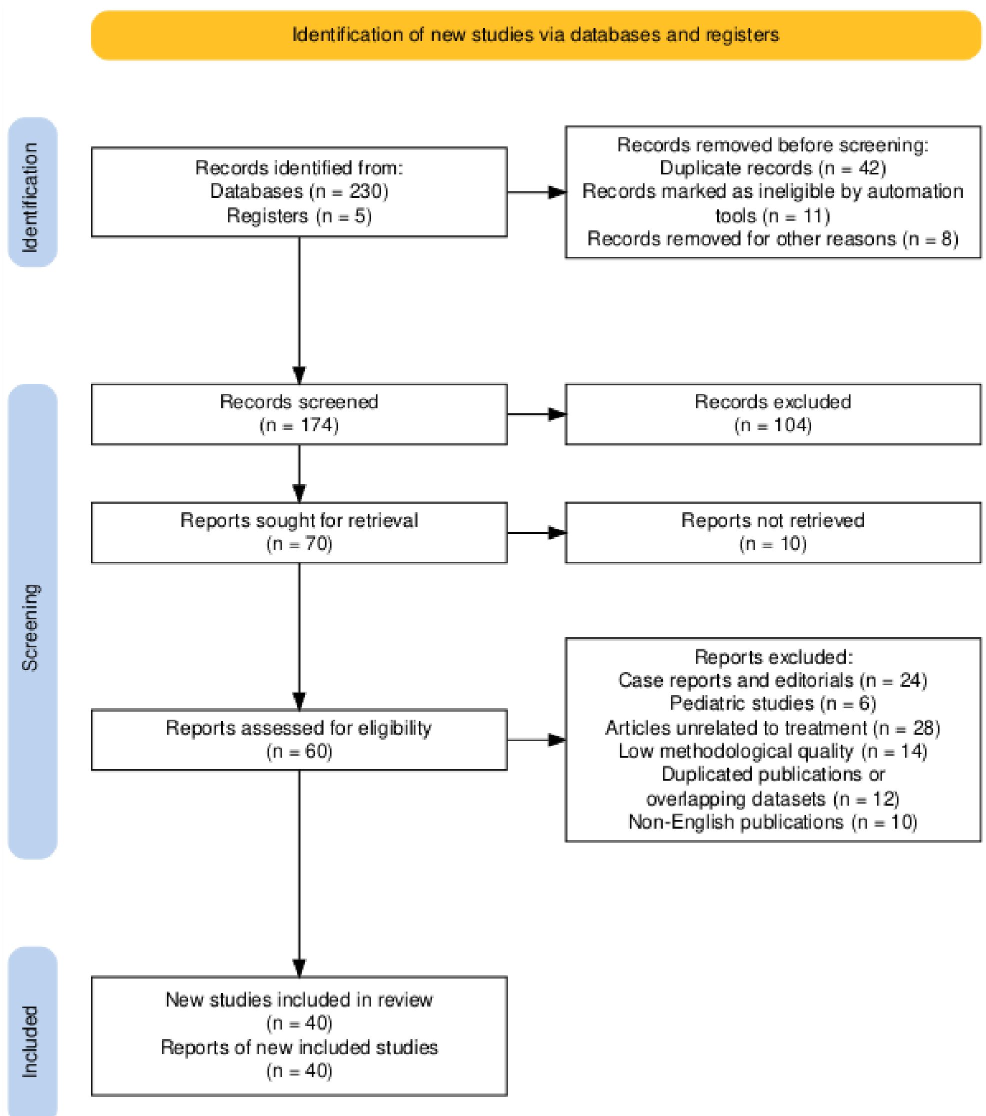

Figure 1. PRISMA 2020 flow diagram illustrating the study selection process for this narrative review.

2. REVIEW METHODS

The present narrative literature review consists of articles published between January 2010 and June 2024 and is based on an extensive PubMed, Scopus, and Google Scholar database search. The search terms employed were words that were synonyms of the key words such as "Achilles tendinopathy," "eccentric exercises," "shockwave therapy," "platelet-rich plasma," "stem cells," "nanotechnology," "scaffolds," and "3D printing." Inclusion was based on studies with tendinopathy of the Achilles tendon in human beings or related preclinical models, with an emphasis placed on the treatment methods. Adequate journals were original high-methodological-quality and clinically significant research articles, randomized controlled trials, systematic reviews, and meta-analyses.

To ensure that the review presents the latest and most pertinent information, particular attention was given to recent studies within the defined time period. Case reports, pediatric studies, editorials, and articles unrelated to treatment were excluded. After removing duplicates, 174 records were screened, with 40 articles ultimately included for detailed analysis (Figure 1).

3. RESULTS & DISCUSSION

Conservative therapies - Eccentric exercises

Of the non-pharmacological interventions, the Alfredson protocol, an eccentric exercise-based regimen, is one of them. It was created by Hakan Alfredson. In the regimen, controlled calf muscle lengthening with contraction provokes remodeling of collagen and reduces swelling around the tendon, with the consequence of pain reduction and functional improvement. The protocol involves two exercises: plantar flexion with bent and straight knees. The original Alfredson method consists of performing both exercises 180 times per day, seven days a week. Because of the relative lack of pain relief or functional improvement, modified versions of this therapy were suggested. Secondly, the nature of the first course necessitated investigation of modification of the scheme already in use. Adjustments encompass alterations in repetitions (90-600 daily), varied protocol lengths (6-24 weeks), the number of days exercised weekly (2-7 days/week), and the exercise divided into sets (typically 3 sets of 15 repetitions, 2-4 times a day).

Eccentric exercises result in characteristic MRI and ultrasound changes. Short-term outcomes include heightened intensity on ultrasound and MRI scanning, and long-term outcomes include reduced swelling and volume of the Achilles tendon, as well as reduced neovascularization of the area. Eccentric exercise is thus still the gold standard for Achilles tendon tendinopathy treatment, and their efficacy is attested to by numerous clinical trials. They are thought to be helpful in a return to physical exercise in a safe manner. Further adaptations will enhance them and render them more accessible to patients (Kaizaki and Chang, 2024).

Conservative therapies - Manual therapy

Manual therapy is also used in the management of Achilles tendon tendinopathy. It involves the mobilization of the individual lower limb joints. Mobilization of the ankle joint improves the range of movement, decreases pain, and shortens the plantar flexor muscles. This reduces the load on the Achilles tendon during walking and running. Hip joint mobilization through stretching, however, allows heel elevation from the ground during walking or running, thus decreasing the workload on the Achilles tendon. Another treatment method is deep tissue massage. Studies show it is an effective procedure that accelerates the regeneration of damaged tissue and relaxes tense muscles, which can impair the range of motion in the ankle joint and excessively load tendons of the posterior group of lower leg muscles. Stretching exercises for the gastrocnemius and soleus muscles are also applied. In conclusion, manual therapy and stretching exercises are effective and safe methods for supporting the treatment of Achilles tendon tendinopathy (Dungkong, 2023).

Conservative therapies - Unloading

The main goal in the orthopedic management of Achilles tendinopathy is to lessen the loading of the involved tendon. Based on type of tendinopathy and disease stage, multiple types of shoes and medical orthotics are utilized. In insertional tendinopathy, it is advised to use an open heel shoe or orthotics such as "Achilles sleeves". In non-insertional tendinopathy, particularly in the acute stage where mobilization of the tendon should be restricted, CAM shoes are preferred. In chronic Achilles tendinopathy, case-specific orthotics have been found to be helpful by randomized controlled trials. Orthotics are worn to pad the foot, especially painful pathological areas, to prevent joint instability, realign, and, where pain-conducting, limit movement within its range (Mohaddis et al., 2023). Physical activities are also advised to be minimized except for wearing cushioning insoles and footwear (Butler et al., 2024).

Physical therapies - Shockwave therapy

Shockwave therapy (ESWT, Extracorporeal Shock Wave Therapy) is an ambulatory treatment for chronic Achilles tendinopathy. Though the procedure is in general utilized when other treatments have not been effective, it is not FDA-approved for this use. ESWT is conducted by applying focused longitudinal acoustic waves to injured tissue. Mechanism of treatment action, through mechanotransduction, involves heightened local perfusion about the tendon, enhanced cell proliferation, and calcification absorption. Clinical trials have further revealed that ESWT induces type I collagen synthesis. It was found to be safe and well tolerated. In a double-blind placebo-controlled trial, 8 weeks of intervention had resulted in significant pain relief in the NRS scale and statistically significant improvement in the VISA-A score in the research group. Ultrasound scans, however, did not reveal structural changes in the tendon after treatment (Katolický et al., 2024).

One meta-analysis established that best pain relief was achieved by using low-intensity shockwave therapy (less than 10 Hz) for an extended duration (5 or more sessions). It was further stated that the outcome of the treatment is affected by age and BMI. Patients above 30 years and having a BMI above 25 are likely to respond to ESWT. Because it can trigger natural repair mechanisms, shockwave therapy may positively influence the regeneration of the injured tendon (Majidi et al., 2024).

Physical therapies - Low-Level Laser Therapy (LLLT)

Low-Level Laser Therapy (LLLT) is also among the preferred treatments for chronic Achilles tendinopathy. LLLT uses light of red and near-infrared wavelength (600-1000 nm) to preferentially treat pathologically altered tissue. Its mechanism of action is through the stimulation of cellular metabolism via enhancement of angiogenesis, fibroblast growth, and consequently collagen production. In addition, it is theorized that this method affects cellular processes—apparently by maximizing mitochondrial function, ATP production, and reducing the inflammatory reaction (Shriya et al., 2024; Anziano, 2024).

No significant evidence up to the present day has been found for the efficacy of this technique. The lack of standardized procedures, due to differences in procedure duration, power utilized, wavelength, and frequency, precludes a comparison of effects among studies. No additional effect of the combination of eccentric exercises with LLLT over the utilization of eccentric exercises was observed by studies (Shriya et al., 2024). However, it is assumed that this treatment can be particularly beneficial in the management of fluoroquinolone-sensitive Achilles tendinopathy. The mentioned points show that more studies are needed on optimizing and evaluating the effectiveness of this therapy (Anziano, 2024).

Physical therapies - Ultrasound Therapy and Cryotherapy

Ultrasound therapy and cryotherapy are other adjunctive treatment modalities for tendinopathy e.g., for Achilles tendinopathy (Maffulli et al., 2019). Ultrasound produces thermal and non-thermal effects. The local rise in temperature as a result of the thermal effect stimulates blood circulation. This in turn reduced swelling, relaxed constricted muscles, and enhanced flexibility of collagen fibers. Non-thermal effects are cavitation which could destroy the cell membrane structure and functions and make it more permeable and help in tissue repair (Dedes et al., 2020).

Cryotherapy use is popular because it has an analgesic effect, reduces metabolism in the degenerated tendon and reduces swelling (Maffulli et al., 2019). Some authors also recommend concomitant application of both modalities has greater effect in pain reduction and functional improvement as compared to ultrasonic therapy alone (Agostini et al., 2023). Similar efficacy between eccentric exercises and ultrasound therapy was also reported by a pilot randomized study. Despite the numerous advantages of these methods, more research is needed, especially with a larger patient population, to support the effectiveness of both therapies (Maffulli et al., 2019).

Biological therapies - Platelet-rich plasma

Platelet-rich plasma (PRP) is an autologous blood platelet concentration. The platelets, when activated, release key growth factors such as PDGF, TGF-β, VEGF, IGF-1 and EGF. These growth-stimulating substances initiate regenerative processes such as cell proliferation, angiogenesis and extracellular matrix regeneration, thus promoting the healing of damaged tissues (Gołos & Treliński, 2014). A 2024 systematic review and meta-analysis of six trials consisting of 422 patients with chronic Achilles tendinopathy showed no difference in Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire score or decrease in tendon thickness following PRP injection as compared to the control group. The primary limitations of the study were the lack of blinding and heterogeneity of PRP administration protocols. Better results were registered in studies with younger patients, less severe illness and with multiple PRP injections. The method of injection, such as under ultrasound guidance, and the region of administration (into tendon and surrounding tissues) may have affected the success of the therapy. Variations in the injected material, including platelet and leukocyte counts, also affected the outcomes.

Biological therapies - Stem cells

The ability to develop into various cell types, such as tendon cells, is exemplified by stem cells, in particular mesenchymal stem cells (MSCs). By converting into tendon cells and enabling them to replace damaged tissue, releasing cytokines and growth factors that reduce inflammation and aid in the healing process, and acting on local cells to encourage their proliferation and enhance function, they aid in the regenerative processes when introduced into the site of injury (Renata, 2018). Ten individuals with chronic Achilles tendinopathy received autologous MSC injections as part of a research study. After 24 weeks, there were no significant adverse effects; however, there were improvements in clinical scores (MOXFQ, EQ-5D-5L, and VISA-A), a decrease in VAS discomfort, and an average 0.8 mm decrease in tendon thickness. Most patients saw improvements of more than 12 points in their VISA-A and MOXFQ Pain ratings. The safety and promise of MSCs in treating tendinopathy are confirmed by this trial, underscoring the need for further investigation (Goldberg et al., 2024).

Pharmacological treatment - Non-steroidal anti-inflammatory drugs

Oral NSAIDs are not recommended for the treatment of chronic tendinopathy, but they can provide short-term pain relief for 7-14 days. There are a number of NSAID options on the market, and none have shown superiority over others in the treatment of Achilles tendinopathy (McClinton et al., 2016). A trial of athletes with chronic Achilles tendinopathy evaluated the efficacy of topical therapy with 10% diclofenac gel. There were no significant differences between the diclofenac and placebo groups in any of the parameters evaluated after 4 weeks of treatment. This included pain severity as assessed numerically, changes in patient-reported symptoms, compression pain threshold, tendon stiffness, and scores on the Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire, both after 4 and 12 weeks (Bussin et al., 2021).

Pharmacological treatment - Corticosteroids

Topical corticosteroid injections are commonly used to treat tendinopathies, despite the lack of conclusive evidence for their clinical efficacy. They may be temporarily effective, with symptom relief and function, but long-term results are generally poor. Symptoms can also become worse, with rupture of the Achilles tendon, which could occur shortly after injection (1 or 2 weeks) or later, after a few months (Malmgaard-Clausen et al., 2021). Recent studies seem to hold promise. A proved that corticosteroid injections along with exercise therapy was superior to the treatment of Achilles tendinopathy with placebo injections. It does seem that a combination of these processes may be indicated as a treatment for the treatment of chronic Achilles tendinopathy (Abate et al., 2016).

Eccentric exercise combined with high volume injection (HIV) has also been evaluated in patients with chronic Achilles tendinopathy. This is an innovative treatment involving injection of a large amount of saline, a corticosteroid and a local anesthetic at the junction of the Achilles tendon and Kager's fat pad. HVI with corticosteroid had superior short-term reduction of pain symptoms, improvement in activity, and ultrasound tendon thickness and Doppler activity reduction in comparison to HVI without corticosteroid. These results offer the promise of subsequent research into this method (Johannsen et al., 2022).

Pharmacological treatment - Collagen therapy

Athletes may benefit from dietary supplementation with gelatin or hydrolyzed collagen, as collagen peptides have been found to increase collagen synthesis and alleviate tendon and joint pain. According to one study, oral ingestion of particular collagen peptides can enhance the effects of a well-planned calf muscle strengthening program and facilitate the return to running in individuals with Achilles tendinopathy (Boesen et al., 2019). While there may be minimal benefits on tendon stiffness and microcirculation, using collagen supplements in conjunction with exercise training may help reduce pain and increase the tendon's cross-sectional area and thickness (Praet et al., 2019). It's also important to remember that collagen can be directly injected to the damage site in the form of a scaffold. Samuel Ka-Kin Ling and colleagues described the endoscopic administration of a collagen implant in the treatment of Achilles tendinopathy, suggesting that this approach can be used to treat the ailment in a safe and efficient manner (Boldt et al., 2023).

Indications for surgical treatment of Achilles tendinopathy

Surgical intervention in Achilles tendinopathy is indicated in those patients in whom non-surgical therapies have not been successful and symptoms have been present for a long duration. Indications for surgery are largely those of chronic tendinopathy that are also resistant to conservative therapy for a period of a minimum six months. Even after conservative management with physiotherapy, pharmacotherapy or biological therapy, patients still experience pain and loss of function. In such cases, failure to recover in spite of these interventions can be a cause for surgery. The second strong indication is severe structural damage to the tendon as evidenced by imaging tests like ultrasound or MRI. Gross deforming lesions or tendon deformities might need surgical debridement or reconstruction, which can be highly therapeutic to patients (Ling & Yung, 2024).

Surgical techniques for the treatment of Achilles tendinopathy

Surgical treatment of Achilles tendinopathy is reserved for those patients who have failed conservative management - physiotherapy, pharmacotherapy and biologic treatment - for at least six months and imaging studies, i.e., ultrasound or MRI, reveal widespread degenerative change of the tendon (Ling & Yung, 2024). Different surgical techniques are used in a hospital environment, their choice based on the extent of damage to the tendon and the overall health of the patient. One of the most significant techniques is debridement, or removal of injured tendon tissue by surgery, and it is performed through open and minimally invasive surgery, providing relief from pain and limping of the limb (Feng et al., 2024). Alternatively, in instances where selective excision of affected pathologically changed tissues is necessary, ultrasound-guided tenotomy is employed, which gives accurate surgery and shortens the recovery time (Weinfeld, 2014). Where the above procedures are not good enough, tendon transfer is performed. This involves substituting healthy tendons like the flexor long toe tendon (FHL) for the weakened Achilles tendon. Based on research, reconstructions with the FHL tendon transfer result in stability and function that is superior in most patients (Wegrzyn et al., 2010).

New technologies - Scaffold therapies

Biomaterial scaffolds, such as the DuRepair™ matrix, have been shown to have great potential for enhancing tendon repair. DuRepair™ is composed of type I and III collagen, which offers a porous matrix (10–20 μm) that encourages cell adhesion and integration into native tissue. When tested under wet conditions, the biomechanical properties of DuRepair™ scaffolds, including stiffness (30–40 N/mm), were comparable to native rat Achilles tendons and hence a promising candidate for tendon tissue engineering. Scaffolds also act as carriers for regeneration cells. iTenocytes derived from induced mesenchymal stem cells (iMSCs) demonstrated increased expression of tendon-specific markers mohawk homeobox and tenomodulin after 12 days in vitro culture on scaffolds. In vivo studies confirmed that iTenocyte-seeded DuRepair™ scaffolds significantly enhanced healing in a rat Achilles tendon injury model. Functional recovery, as determined by gait analysis, at 9 weeks was considerably improved in the seeded-scaffold-treated animals compared to unseeded scaffold or suture-alone repairs. In vivo analysis at week 9 revealed iTenocyte-seeded DuRepair™ scaffolds to yield structural and functional tendon regeneration. Healed tissue tensile strength was 80% of the optimal native tendon potential, far better than controls.

New technologies - Nanotechnology

Nanotechnology has also been a method of innovation in tissue engineering and tendon regeneration. The integration of scaffolding material with nanostructure, for example, nanoparticles or nanofibers, stimulates controlled release of growth factors as well as increased cell adhesion and proliferation. Nanostructure-based scaffolds not only have been proved to have the ability to mimic the native extracellular matrix but also increased mechanical strength and bioactivity. For instance, in a study, researchers found that TDSCs were promoted at tenogenic differentiation and collagen production by employing nanofiber scaffolds (He et al., 2024).

Nanoparticles facilitate the controlled release of bioactive molecules to obtain sustained therapeutic effects at the site of injury. One study revealed that preconditioned tendon-derived stem cells preloaded with growth factor nanocarriers differentiated further into tenocytes with higher upregulation of tendon-specific marker tenomodulin and scleraxis. Site-specific drug delivery system reduced the requirement of systemic delivery and side effects (Hafeez et al., 2021). Incorporation of nanomaterials such as graphene oxide or titania nanoparticles into scaffolds has also improved their biomechanical functions. In recent studies, graphene oxide-functionalized hydrogels were reported to trigger TDSC adhesion and growth, leading to augmented tendon tissue mechanical function regenerated in vivo.

New technologies - 3D printing in regenerative medicine

3D printing has transformed regenerative medicine through the development of highly personalized tissue engineering scaffolds. With biocompatible biomaterials like silk fibroin, hydrogels, and calcium phosphate, 3D printing is able to have total control over scaffold architecture like mechanical properties and porosity to mimic the extracellular matrix (ECM). Recent work emphasized the biocompatibility of silk fibroin printed via 3D printing, which exhibited better cell adhesion, proliferation, and differentiation, especially in bone and cartilage tissue engineering (Farokhi et al., 2019). The addition of nanoparticles to scaffolds printed by 3D printing improves their biological and mechanical properties. Magnesium oxide (MgO) nanoparticle scaffolds, for instance, exhibit antioxidant and anti-inflammatory activities to enhance healing of the tissue. These nanocomposites also exhibited enhanced mechanical stability and osteogenic differentiation, set forth by upregulation of the osteogenic markers Runx2 and OPN (Grant et al., 2021). In the same way, calcium phosphate scaffolds with nanostructured surfaces facilitated biocompatibility and decreased inflammation to allow bone regeneration even in inflammatory conditions (Fasolino et al., 2020).

Hydrogels play a key role in 3D bioprinting owing to their water-retention and ECM-mimicking nature. Some of the recent advancements with hydrogel-based 3D printing involve incorporating bioactive nanoparticles such as graphene oxide, not only augmenting mechanical strength but also cell proliferation and alignment. The hydrogels are most useful in tendon and ligament repair, providing a controlled growth medium for cells (Grant et al., 2021; Gebreel et al., 2021). There still exist some issues, however, despite the revolutionary potential of 3D printing for regenerative medicine. The clinical application must address ensuring scalability of the processes of production and long-term biocompatibility. Regulatory schemes, also, must shift so that they are able to accommodate the sophisticated nature of 3D-printed biomaterials as well as with advanced therapies (Farokhi et al., 2019).

New technologies - Intelligent Monitoring Devices

The latest sensor technologies are implemented in intelligent wearables, which take on an increasingly significant role in biomechanics and rehabilitation. The wearables supply real-time feedback regarding tendon load, muscle activity, and range of motion in a manner that enables clinicians and patients to better monitor rehabilitation. For example, devices that incorporate force sensors and accelerometers have been shown to be able to quantify biomechanical stress within tendons during different physical activities and thereby enhance rehabilitation procedures (Kárason et al., 2024). Wearable rehabilitative devices solely used for tendon rehabilitation use integrated force sensors to quantify momentary tendon load. The device not only monitors mechanical stress but also employs machine learning mechanisms to forecast likely overuse injury (Singh et al., 2019). They are generally provided with biofeedback devices, which give instant corrective remarks to the wearer. For instance, those with electromyographic sensors track the activation of muscles and send reminders to keep the tendon in the optimum load in exercises. The intervention has been shown to improve compliance with rehabilitation exercises, leading to an easy recovery process (Giraldo-Pedroza et al., 2020). The therapeutic choices described are presented in Table 1, providing a clear summary of the available treatment options for Achilles tendinopathy.

Table 1. Comparison of classic and modern therapies in the treatment of Achilles tendinopathy

Therapy type	Example	Mechanism of action	Evidence of effectiveness	Limitations
Eccentric exercises	Alfredson protocol	Collagen remodeling, reduces neovascularization	Strong clinical support, gold standard	Requires high compliance, less effective in severe degeneration
Manual therapy	Joint mobilization, massage, stretching	Increases ROM, reduces overload, improves muscle function	Effective adjunct	Limited when used alone
Unloading	Orthotics, CAM shoes	Reduces mechanical load on tendon, provides cushioning	Effective in chronic cases	Requires customization, passive strategy
Shockwave therapy (ESWT)	Focused acoustic pulses	Stimulates collagen synthesis, improves blood flow	Supported by RCTs	Operator-dependent, no FDA approval for Achilles
Low-Level Laser Therapy (LLLT)	Red–NIR laser light	Stimulates ATP, angiogenesis, fibroblast activation	Promising in theory	Lack of protocol standardization
Ultrasound & Cryotherapy	Thermal and non-thermal modalities	Enhances tissue elasticity, reduces swelling and pain	Some supportive evidence	Requires frequent sessions

Platelet-Rich Plasma (PRP)	Autologous growth factor injection	Enhances regeneration, stimulates angiogenesis and ECM remodeling	Mixed clinical outcomes	Variability in preparation and response
Stem cells (MSCs)	Injection of mesenchymal stem cells	Differentiation into tendon cells, cytokine-mediated repair	Early clinical promise	High cost, ethical & regulatory issues
NSAIDs	Oral or topical diclofenac	Temporary analgesic and anti-inflammatory effect	Short-term relief only	Not effective long-term
Corticosteroids	Injection, HVI	Anti-inflammatory, improves short-term function	Better when combined with exercise	Risk of tendon rupture, relapse
Collagen therapy	Oral peptides, scaffold implants	Supports tendon remodeling and pain relief	Promising in combination with rehabilitation	Scaffold-based use experimental
Surgical treatment	Debridement, tenotomy, tendon transfer	Removal of damaged tissue or reinforcement with grafts	Effective in refractory cases	Invasive, requires long rehabilitation
Nanotechnology	Nano-scaffolds, drug-loaded nanoparticles	Controlled release of bioactives, enhances tenocyte response	Experimental preclinical support	No human clinical trials yet
3D bioprinting	Personalized hydrogel scaffolds	Tailored ECM-like structures for regeneration	High potential in tissue engineering	Cost, biocompatibility, regulatory uncertainty
Intelligent monitoring devices	Wearables with sensors and feedback	Tracks tendon load and motion, improves rehab adherence	Supportive in real-time training monitoring	Not yet widely available clinically

4. CONCLUSION

Achilles tendinopathy continues to pose a major therapeutic problem with conventional treatment like eccentric exercise, shockwave therapy, and corticosteroid injection only partially beneficial at best. Although these remain the current standard practice, they are usually impaired in their efficacy, particularly in chronic and resistant conditions. Advances in regenerative medicine, including biomaterials, nanotechnology, gene therapy, and cell-based regenerative therapies derived from stem cells, hold great promise by targeting the disease-causing mechanisms of tendon degeneration. Nonetheless, their universal clinical use is hampered by undue costliness, unavailability, and the absence of long-term efficacy and safety information. Combining personalized medicine and intelligent rehabilitation technologies would enhance therapy effectiveness by delivering therapies tailored to individual patients' specific needs. Standardization of treatment protocol, greater access to new therapies, and further research into the integration of traditional and regenerative methods are areas that future studies should explore to deliver better and more sustainable therapy for Achilles tendinopathy.

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Data and materials availability
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