Effectiveness of Percutaneous Needle Tenotomy for Tendinopathies: A Systematic Review

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Context: Tendinopathy is a disease state characterized by tendon disorder with pain or decreased function that can cause significant disability. Multiple treatment modalities exist; however, no single treatment is superior. Ultrasound-guided percutaneous needle tenotomy (PNT) and TENEX are emerging as promising treatment options for tendinopathy.

Objective: To review the current literature of reported outcomes for PNT, TENEX, and TENJET, for the treatment of tendinopathy, including pain relief, change in function, and patient-reported outcomes.

Data Sources: A comprehensive search was conducted from database inception to September 2023 in Ovid Medline, Ovid Embase, and Cochrane Library.

Study Selection: Keywords and index terms related to tendon injury, ultrasound, and tenotomy were used in combination to identify relevant literature that included ultrasound-guidance, treatment of tendinopathy, and treatment with PNT, TENEX, or TENJET. Covidence Systematic Review Software used to screen for relevant studies. Only English-language studies were included.

Study Design: Systematic Review using PICO framework as defined and registered with the International Prospective Register of Systematic Reviews (PROSPERO ID CRD42022321307).

Level of Evidence: Level 4 (evidence from a systematic review graded to the lowest level of study included).

Data Extraction: Articles meeting the inclusion criteria were reviewed. Type and region of tendinopathy studied, outcome measures, and complications were recorded. Clinical and self-reported outcomes data were compared across studies.

Results: A total of 10 studies, representing 11 tendon sites, were included. The studies overall report improvements in pain, function, and quality of life after undergoing PNT or TENEX, with minimal adverse effects. Mean risk of bias assessment scores were 8.35 out of 10 assessing internal and external validity for included studies.

Conclusion: PNT and TENEX are safe, beneficial, and minimally invasive treatment option for patients, especially for conditions refractory to more conservative treatments options.

Keywords: fenestration; tendinopathy; TENEX; tenotomy; ultrasound-guided

Tendinopathy is defined as a disorder of a tendon associated with overuse that results in pain and decreased function.[16,17] Tendinopathy can be further subcategorized into the acute pathology of tendinitis and the chronic pathology of tendinosis. Tendinitis is characterized by inflammation, marked by a release of cytokines and immunomodulating factors that typically facilitate tendon repair.[18] However, tendinosis—the chronic stage of tendinopathy—often occurs without histologic signs of inflammation, which may be indicative of a failed healing response.[44] Unlike normal tendon, which appears white with a firm but elastic texture, tendinosis results in a thickened tendon that is gray or brown and has

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disorganized collagen, loose texture, and neovascularization.[44] These changes lead to activity-related pain, tenderness, and decreased strength and movement.[44]

Patients with tendinosis may respond well to conservative treatment consisting of relative rest with activity modification, pain medication, physical modalities, therapeutic exercise, and physical therapy.[14,32,42] However, up to 20% of patients with tendinosis fail to respond with conservative treatment, resulting in the need for more aggressive intervention.[3,27] Historically, corticosteroid injections have been used when conservative measures failed in an attempt to mitigate the inflammatory process assumed to be present in the tendon. However, histopathologic studies have found minimal inflammation present in tendinosis, and systematic reviews have failed to demonstrate long-term efficacy with corticosteroid injections.[2,24] In addition, corticosteroid injections, while generally well tolerated, carry the risk of adverse effects such as subcutaneous tissue atrophy, skin discoloration, and hyperglycemia. Repeated injections increase the chance of further tendon weakening and even rupture. More recently, orthobiologics such as platelet-rich plasma (PRP) have been introduced as alternative management and treatment modalities for tendonopathy.[21,29]

Percutaneous needle tenotomy (PNT), also known as tendon fenestration, has also been investigated for treatment of tendinosis, initially demonstrating to be effective for lateral elbow tendinosis and more recently showing promise in treating other tendinopathy regions.[40] PNT is typically performed under ultrasound guidance, where tendons with signs of chronic changes can be identified and fenestrated with an 18- to 22-gauge needle repeatedly, typically 20 to 40 times, to induce a healing response.[15,23] This is accomplished by creating local areas of acute inflammation and increased bloodflow, and upregulating growth factors that help to revitalize a stalled or compromised healing process in the diseased, fibrotic tissue of tendinosis.

Another form of PNT is percutaneous ultrasonic tenotomy. TENEX (Tenex Health Inc) has developed their own device that performs PNT in addition to removing diseased tendon via a suction and irrigation system connected to a handheld tool with an ultrasonic vibrating double-lumen needle.[6] The proposed mechanism is phacoemulsification of necrotic tendon and scar tissue, and promotion of normal healing with the resultant inflammatory response.[5] Whereas standard PNT does not incorporate the phacoemulsification technology of TENEX, the purpose of both PNT and TENEX is to induce an inflammatory response to facilitate healing.[5,24]

The TenJet system differs in that it utilizes high-pressure saline delivered through a 2-channel, 12-gauge needle with a 1.5 mm cutting window to selectively debride tendinopathic tissue. Finally, surgical debridement of the tendon has also been used after failing conservative options, but results have been varied and patients are often hesitant to undergo surgical intervention.[27]

The aim of this study is to provide a comprehensive review of the evidence published on the efficacy of PNT and TENEX for the treatment of tendinosis. Previous systematic reviews have been performed on this topic; however, new research published has advanced our knowledge on the utility of tendinopathy treated with PNT, and more recent studies include several additional body regions compared with the original review articles.[31,37]

METHODS

Search Strategy

A systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO ID CRD42022321307) and performed using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Guidelines. The PICO framework was defined in the PROSPERO registry as follows. Population: patients who underwent ≥1 ultrasound-guided percutaneous tenotomy; Intervention: percutaneous ultrasound-guided tenotomy; may also be known as a Tenex or TenJet procedure; Comparator: no intervention control group, summative dataset, or other control group; Outcome: change in pain, change in functional outcomes, tolerability, side effects or adverse effects. A comprehensive search was conducted from database inception to September 2023 in Ovid Medline, Ovid Embase, and Cochrane Library. Keywords and index terms related to tendon injury, ultrasound, and tenotomy were used in combination to identify relevant literature. The complete search strategies are defined in Appendix 1, available in the online version of this article.

Study Selection

Four authors screened the studies using Covidence software (Covidence systematic review software, Veritas Health Innovation), beginning with a title and abstract review, followed by a full-text review for those articles that could not be excluded by title and abstract. Each article was screened by 2 authors. Conflicts were resolved via discussion among all authors. The following inclusion criteria were used for study selection: (1) ultrasound-guidance; (2) treatment of tendinopathy; and (3) treatment with PNT, TENEX, or TENJET. The following exclusion criteria were used: (1) case reports, surgical techniques; (2) non-English studies; and (3) cadaver studies.

Data Extraction

After study screening, full-text articles were reviewed by 6 authors and the following data were extracted: study design, level of evidence, number of patients, patient age, patient sex, tendinopathy region treated, and tenotomy method. In addition, the following outcomes data were extracted at baseline and each follow-up timepoint: visual analog score (VAS), Disabilities of the Arm, Shoulder, and Hand (DASH), Quick DASH (QDASH), Harris Hip Score, Patient Rated Tennis Elbow Evaluation Score (PRTEE), Oxford Elbow Scale, American Orthopedic Foot and Ankle Score, the Lower Extremity Function Scale (LEFS), and the Physical Component Score (PCS) of the Short-Form 12 (SF-12).

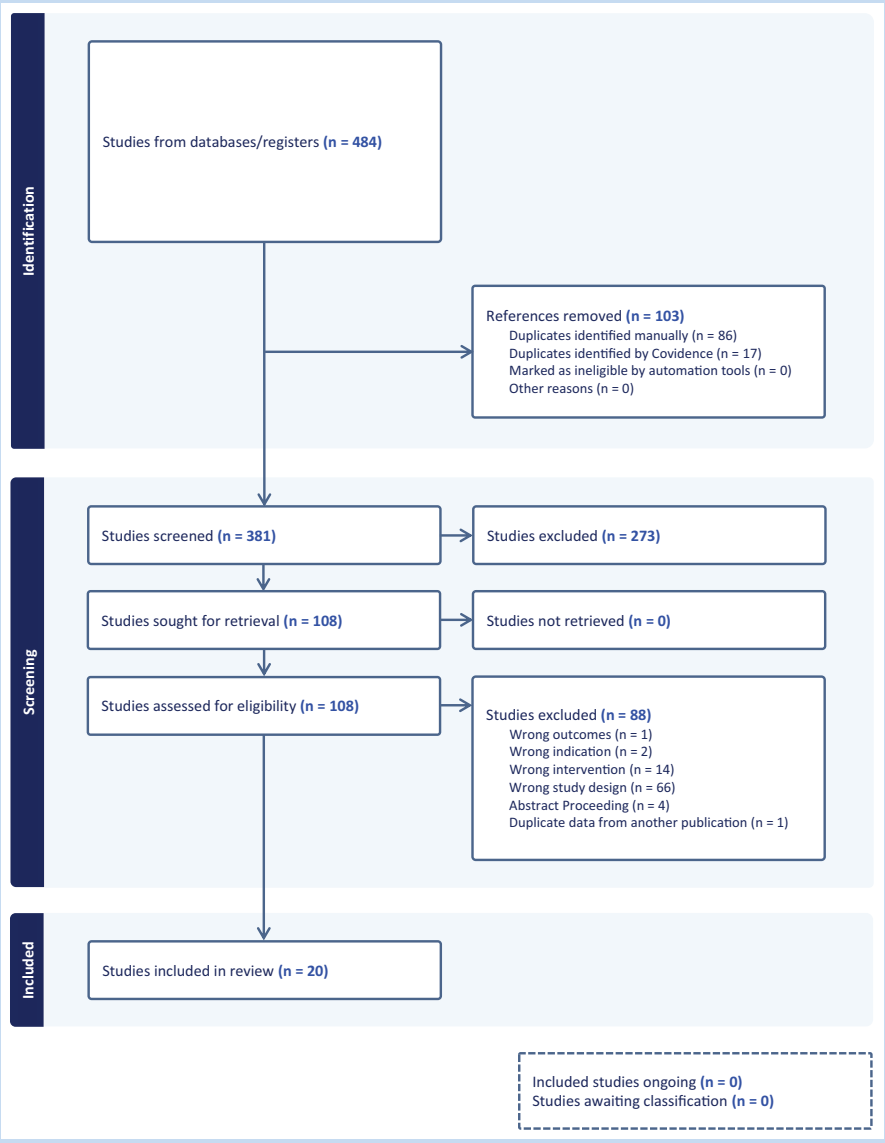

Figure 1. PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Quality Appraisal

The methodological quality and the internal and external validity of the studies were assessed using specific criteria guided by Vajapey et al,[41] the Centre for Evidence-Based Medicine, and the University of York Centre for Reviews and Dissemination.[34,39] Independent risk of bias was performed by 3 authors. Any discrepancies were resolved through consensus discussion by these authors.

RESULTS

Study Characteristics

A total of 20 studies met criteria for inclusion: 10 were retrospective case series, 3 were prospective cohort studies, 5 were retrospective cohort studies, and 2 were double-blind randomized controlled trials. The PRISMA flow diagram is shown in Figure 1. The mean risk of bias score for the 20 studies included in this review was 8.35 on a 0 to 10 ordinal scale. The range of scores was 5 to 10, with the majority scoring 8 or 9. The detailed risk of bias assessment for each study is provided in Appendix 2, available online.

Study Details

Tendinopathy regions treated included: lateral elbow, medial elbow, gluteal, tensor fascia lata, insertional and midportion Achilles, patella, rotator cuff, hamstring, plantar fascia, iliotibial band, and triceps. A total of 14 of the studies used TENEX under ultrasound guidance and 6 used PNT under ultrasound guidance. No studies using the TenJet device met criteria for inclusion. Patient demographics for each study are provided in

Table 1 while detailed outcomes are provided in Appendix 3, available online. The VAS was the most commonly used outcome across studies. Line plots of VAS scores for elbow tenotomy are shown in Figure 2a and all other regions combined are shown in Figure 2b. Several articles by the same author group included subjects from other publications. Subjects in which overlap was definitively identified (typically by region studied) were removed to prevent duplication of data as appropriate. Overlap in patient samples was evident in articles by Fick et al[19] and Stover et al,[38] specific to the medial and lateral elbow populations studied; however, both were included due to inability to differentiate the samples of patients without losing data. Several studies reported outcome data as an aggregate of all included body regions, thereby limiting detailed results by specific body regions.[25,30] Finally, Ang et al,[4] Koh et al,[26] and Seng et al[36] followed the lateral elbow outcomes of the same cohort of subjects to different timepoints. Cumulative data are reported for these 3 articles.

Lateral Elbow Tendinopathy

Of the 20 studies, 16 included lateral elbow tendinopathy treated with tenotomy under ultrasound guidance. Of these 16 studies, 9 included VAS data that demonstrated clinically significant improvement of pain, 4 of which reported decreases of ≥5 points on the VAS score sustained to ≥1 year.[4,6,7,33] Two of the studies demonstrated sustained improvement at 2 years[7] and another at 7.5 years.[4] In addition, studies by Kirschner et al[25] and Lavallee et al[28] demonstrated global improvement of VAS in PNT subjects, which included lateral elbow tendinopathy reported in aggregate alongside other body regions. Various versions of the DASH were the most common patient reported outcome. The minimal clinically important difference (MCID) values have been reported as 15.91 points for the QDASH and 10.83 points for the DASH[20]; 9 of the studies met the MCID for the QDASH.[1,4,6,8,11,12,26,28,30,36] Koh et al[26] examined 20 patients and noted that 100% of patients were either "satisfied" or "very satisfied" at 7.5 years. Chalian et al[12] demonstrated improvements in PRTEE, from 56.8 preprocedure to 17.0 at a mean duration follow-up of 15 months, reporting a statistically significant improvement in pain and function after treatment with TENEX.

Fick et al[19] studied both the medial and lateral elbow and showed that after TENEX treatment, aggregated elbow pain had statistically significant improvement from "moderate/daily" to "no pain" at long-term follow-up with the Mayo Performance Scale. In addition, significant improvement at both short- and long-term follow-up were reported on functional and quality of life measures captured with the PCS of SF-12 compared with baseline.[19]

Martin et al[30] performed a study of lateral elbow tendinopathy that was treated under ultrasound guidance with PNT+lidocaine vs PNT+PRP. The VAS changed from 5.87 at baseline to 1.73 after 20 months in the lidocaine group, which was similar to the PRP group (5.97-1.39). Both groups achieved the MCID threshold for the DASH.[30]

Rupe et al[35] compared PNT with PRP in a retrospective study finding significant reduction in pain at the 12-week follow-up, with no difference between groups. When examining characteristics of failed cases of PNT, common extensor tendon tears on ultrasound and worker's compensation cases were significant predictors.[35]

Medial Elbow Tendinopathy

Of the 20 studies, 7 included medial elbow tendinopathy treated with PNT under ultrasound guidance.[6,8,19,25,28,30,38] Of the 7 studies, 6 demonstrated clinically significant improvement in pain, as measured by a VAS improvement of >2, or a statistically significant change in the study-specific pain outcome measure.[6,8,19,25,28,30] Four of these studies included DASH scores that met MCID thresholds for improvement.[6,8,28,30] As mentioned, Fick et al[19] demonstrated statistically significant improvement of aggregated medial and lateral elbow tendinopathy pain, and significant improvement of functional and quality of life measures.

As referenced earlier, Martin et al[30] examined medial and lateral elbow tendinopathy treated under ultrasound guidance with PNT+lidocaine vs PNT+PRP. These outcomes were similar to the lateral elbow tendinopathy group in both VAS and DASH score improvements. No statistically significant difference was seen between the 2 groups.

Achilles Tendinopathy

Two of the studies included Achilles tendinopathy treated with TENEX under ultrasound guidance.[19,28] Fick et al[19] included 23 patients with midportion Achilles tendinopathy and 34 patients with insertional Achilles tendinopathy, demonstrating an improvement in pain from "moderate/daily" to "mild/occasional" at short- and long-term follow-up.[19] Quality of life and functional outcomes measured by the PCS of the SF-12 showed significant improvements at short-term follow-up for the insertional Achilles group and at long-term follow-up for the midportion Achilles tendinopathy group. Out of the 43 patients who responded to long-term surveys, 35 rated their satisfaction as either "very satisfied" or "somewhat satisfied."

Lavallee and Bush[28] included 27 patients with Achilles tendinopathy and demonstrated mean VAS improvement from 7.3 at baseline to 1.37 at 1 year. Lower extremity function measured using the LEFS improved from 42.5 to 65.8 at 1 year, indicative of a change from mild-to-moderate functional limitations, to none-to-minimal functional limitations.[28]

Gluteal Tendinopathy

Three studies included patients that were treated with PNT under ultrasound guidance for gluteal tendinopathy.[5,23,25] Jacobson et al[23] conducted a prospective study with a comparator group of 15 patients with either gluteus medius or gluteus minimus tendinopathy treated with PNT. Improvement in mean pain scores from 32.4 to 15.2 at 17.6 days was reported, which was clinically significant but not significantly different than 15 patients treated with PRP.[23]

Table 1. Study and baseline patient characteristics

Author (Year)	Body Region	Sample Size, n	Age, Years (Mean)	Male/ Female	Symptom Duration, Months	BMI, kg/m^2
Altahawi et al[1] (2020)	Lateral elbow	23	53.5±8.3	12/11	23±18.5	NR
Baker and Mahoney[5] (2020)	Gluteal	29	62±11.7	3/26	41±60.5	28
Barnes et al[6] (2015)	Lateral and medial elbow	19	55.3±7.3	10/9	>6	NR
Battista et al[7] (2018)	Lateral elbow	7	NR	NR	21.4±13.5	NR
Boden et al[8] (2019)	Lateral and medial elbow	30	51±8	18/12	25±21	NR
Bradberry et al[9] (2018)	Tensor fascia lata	2	52±1	0/2	3.5±0.25	NR
Bureau et al[11] (2022)	Lateral elbow	31	46.7±8.0	8/11	23.3±22.5	NR
Chalian et al[12] (2021)	Lateral elbow	37	51.3±8.9	15/22	>6	NR
Fick et al[19] (2021)	Lateral and medial elbow	87	48.8±9.0	47/40	22	31.3±10.0
	Patellar	38	27.1±12.9	29/9	15	26.2±7.6
	Midportion Achilles	23	50.6±15.4	8/15	38.9	30.0±7.8
	Insertional Achilles	34	52.2±11.6	13/21	26	32.9±7.5
	Plantar fascia	80	47.2±12.2	19/61	31	30.4±6.4
Jacobson et al[23] (2016)	Gluteal	15	60±13.1	5/10	NR	NR
Kirschner et al[25] (2021)	Lateral and medial elbow	19	47.1±15.5	11/8	25.4±30.5	26.3±4.7
Koh et al[26] (2013)[a] Seng et al[36] (2016) Ang et al[4] (2021)	Lateral elbow	20	45.5±7.1	7/13	12.5±11.5	NR
Lavallee and Bush[28] (2021)	Lateral and medial elbow, Achilles, patellar, plantar fascia	103	49.1±12.4	42/61	>3	30.8±6.07
Martin et al[30] (2019)	Lateral elbow	35	48.3±7.6	19/16	>3	26.05±3.15
Nakagawa et al[33] (2023)	Lateral elbow	15	51±6.0	6/9	30±25.5	NR
Rupe et al[35] (2023)	Lateral elbow	52 (57 procedures)	46.9±8.5	28/29	24.3	27.7±4.5
Stover et al[38] (2019)	Lateral and medial elbow	131 (144 procedures)	48.1±9.8	77/54	14 [10, 24]	32.2±7.7
Wahezi et al[43] (2023)	Iliotibial band	48 (56 procedures)	67±13.3	4/44	>6	28±5

BMI, body mass index; NR, not reported.
[a]Articles by Seng et al[36] and Ang et al[4] were longitudinal follow-up studies of the original research article by Koh et al[26]; thus, baseline demographic data were the same for all 3 articles.

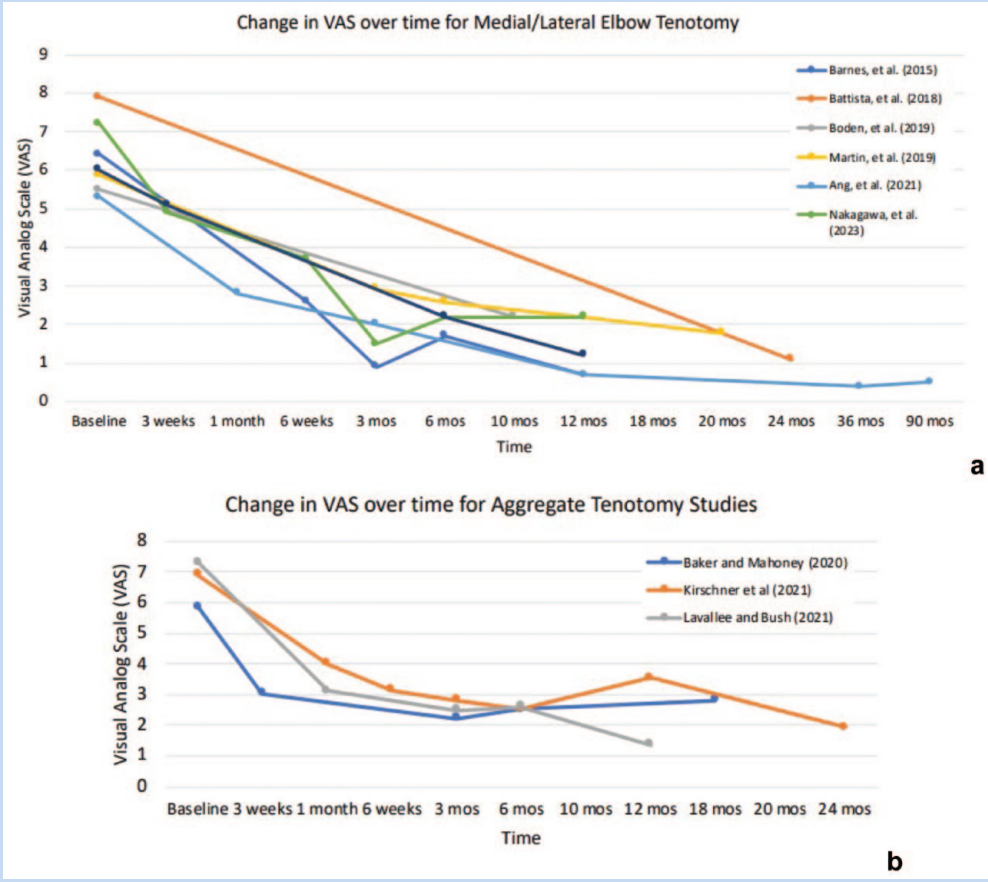

Figure 2. Line plots depicting change in VAS pain scores from baseline through all follow-up visits for studies involving (a) medial or lateral elbow tendinopathy and (b) all other body regions. mos, months; VAS, visual analog scale.

Kirschner et al[25] conducted a randomized controlled trial that included 6 patients with gluteus medius tendinopathy treated with PNT and 2 patients treated with PNT+PRP. Clinically significant decreases in pain were reported at 2 years with no difference between PNT vs PNT+PRP.

Baker and Mahoney studied 29 patients with either or both gluteus medius and/or gluteus minimus tendinopathy treated with TENEX under ultrasound guidance, demonstrating an improvement in mean VAS scores from 5.86 at baseline to 2.82 at 18 months.[5] Clinically significant improvements on the Harris Hip Score and the SF-12 were also reported at each timepoint.

Patellar Tendinopathy

Three studies included patients who were treated with PNT under ultrasound guidance for patellar tendinopathy.[19,25,28] Fick et al[19] included 38 patients who were treated for patellar tendinopathy, reporting a significant improvement of pain on the Kujala scale, from "moderate/daily" at baseline to "mild/occasional" at long-term follow-up. Kirschner et al[25] included 2 patients who were treated with PNT under ultrasound guidance resulting in clinically significant pain reduction via VAS.

Triceps Tendinopathy

Stover et al[38] included 8 patients with distal triceps tendinopathy who were treated with TENEX under ultrasound guidance. There were 5 patients who responded to follow-up at 6 weeks. All 5 reported baseline pain of "moderate/daily" and at 6-week follow-up, 3 reported "mild/occasional" pain and 2 reported "none." At 12-week follow-up, only 1 person responded and reported a "moderate/daily" pain level. At both short- and long-term follow-up, there were quality of life and functional improvements as noted by the PCS from SF-12 scores.

Plantar Fascia

Two studies included patients who were treated with TENEX under ultrasound guidance for plantar fascia pain.[19,28] Fick et al[19] included 80 patients who showed clinically significant mean pain improvement from "moderate/daily" to "mild/occasional." This study also reported statistically significant improvements in the PCS from SF-12 scores for these patients at short- and long-term follow-up.[19] Lavallee and Bush included 41 patients treated with TENEX for plantar fascia pain, demonstrating an overall improvement in mean VAS from 7.3 to 1.37 at 1 year.[28] LEFS

score for lower extremity function improved from 42.5 to 65.8 at 1 year.[28] Of note, these results were for the entire cohort of patients included in this study and were not parsed out by region treated.

Rotator Cuff Tendinopathy

Kirschner et al[25] included 3 supraspinatus tendinopathy patients treated with PNT under ultrasound guidance and 4 patients treated with PNT+PRP. Overall, this study reported clinically significant pain reduction that was comparable between PNT and PNT+PRP groups. Outcomes reported were not specific to supraspinatus tendinopathy; rather, data were reported in aggregate for all regions treated.

Hamstring Tendinopathy

Kirschner et al[25] included 2 patients with proximal hamstring tendinopathy treated with PNT under ultrasound guidance and 6 patients treated with PNT+PRP under ultrasound guidance with hamstring tendinopathy. Overall, this study reported clinically significant pain reductions across all regions studied that were comparable between PNT and PNT+PRP groups.

Tensor Fascia Lata Tendinopathy

Bradberry et al[9] included 2 patients treated with PNT under ultrasound guidance for tensor fascia lata tendinopathy. One patient had complete resolution of pain 8 weeks after PNT. The other patient had minimal improvement at 6 weeks after first PNT. This patient then had a repeat PNT at 6 weeks with complete resolution of pain 2 weeks later.

Iliotibial Band Tendinopathy

Wahezi et al[43] demonstrated clinically and statistically significant improvements in median pain in 48 patients treated with TENEX for iliotibial band tendinopathy. A total of 56 procedures were performed as 8 subjects had the intervention performed bilaterally. At 1 year, 70% of patients endorsed pain relief. In addition, there were statistically significant improvements in side-lying and walking tolerance and an increase in patients able to tolerate sit-to-stand movement. Satisfaction with the procedure was reported by 81% of patients at 1-year follow-up.

DISCUSSION

The effectiveness of TENEX and PNT as treatments for tendinopathy was assessed by this systematic review. TENEX and PNT appear to be effective treatments for lateral elbow tendinopathy, medial elbow tendinopathy, and gluteal tendinopathy. TENEX appears to be an effective treatment option for Achilles, patellar, triceps, iliotibial band tendinopathy, and plantar fascia pain. TENEX and PNT may provide some improvement in symptoms for patients with hamstring tendinopathy and tensor fascia lata tendinopathy.

While there have been case reports of significant adverse events due to PNT/TENEX, the studies in this systematic review had a low rate of adverse events that were limited primarily to procedure related pain and skin infection after the procedure. Several studies reported no adverse events related to PNT or TENEX. With the number of patients considered, PNT and TENEX appear to be safe procedures with low rates of adverse events and minimal complications.

Treatment of tendinopathy continues to evolve as new treatment options are developed and studies evaluate their efficacy. While we found no studies that directly compared the effectiveness of TENEX versus PNT, both appear to be useful tools for the treatment of tendinopathy that is resistant to conservative measures such as rest, physical therapy, nonsteroidal anti-inflammatory drugs, and corticosteroid injections. Corticosteroid and PRP injections have mixed results in treatment of tendinopathy, which leaves a gap between conservative treatment and surgery. Several studies have evaluated the treatment of tendinopathy with surgical debridement and tendon repair, but these have shown inconsistent results as well.[10,13,22] In the majority of included studies, few patients progressed to further surgical intervention after PNT or TENEX treatment, which may imply that they improved sufficiently to not pursue more invasive options. In addition, studies have tried to evaluate the effectiveness of the addition of PRP to PNT. While the current data do not seem to demonstrate additional benefit, future studies investigating the efficacy of PRP combined with PNT/TENEX compared with either PNT/TENEX or PRP alone may be of interest.

Another consideration is that symptoms tend to improve with time as a natural course of tendinopathy. When that does not occur, PNT/TENEX can be used to facilitate this recovery process. While the healing factors affecting tendon repair and remodeling are multifactorial, it is important to acknowledge that there is no definitive consensus that PNT consistently provides that impetus for recovery or accelerated improvement. PNT should be compared against a control group undergoing conservative management or sham PNT, to demonstrate its comparative effectiveness in promoting healing.

In addition, there is no standard time of when to intervene. Often, it is when symptoms are refractory to conservative management. Some of the studies noted mean durations of symptoms of >1 year, and inclusion criteria of "failing conservative treatments", which suggests that there may be a role for PNT intervention as the natural course of tendinopathy healing became stagnant.

Study Limitations

There are limitations of this systematic review. Due to the heterogeneity of outcome measures, it was difficult to make direct comparisons between individual studies; therefore, a meta-analysis was not feasible. In addition, the majority of the studies were of lower-level evidence due to nonrandomized patient selection, small sample sizes, and primarily use of patient-reported outcome measures. Several studies had incomplete information due to limited patient follow-up. Finally, several published studies with the same author group reported outcomes from overlapping patients which could not be

distinguished or separated. Full datasets using common data elements are needed to conduct a well-designed meta-analysis to fully understand the effectiveness of PNT or TENEX in the treatment of tendinopathy.

CONCLUSION

Both PNT and TENEX are safe and effective treatment options for tendinopathy refractory to conservative treatment. Currently, most studies involve treatment of the lateral elbow, medial elbow, and gluteal tendons. Patients and practitioners would benefit from higher quality studies in a greater number of body regions to assess the effectiveness of PNT and TENEX more accurately for different types of tendinopathy.

REGISTRATION AND PROTOCOL

This review is registered with PROSPERO (CRD 42022321307).

DATA AVAILABILITY

Data collected for this review are available upon request.

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REFERENCES

1. Altahawi F, Li X, Demarest B, Forney MC. Percutaneous ultrasonic tenotomy with the TX-1 device versus surgical tenotomy for the treatment of common extensor tendinosis. *Skeletal Radiol*. 2021;50(1):115-124.
2. Andres BM, Murrell GA. Treatment of tendinopathy: what works, what does not, and what is on the horizon. *Clin Orthop Relat Res*. 2008;466(7):1539-1554.
3. Andriolo L, Altamura SA, Reale D, Candrian C, Zaffagnini S, Filardo G. Nonsurgical treatments of patellar tendinopathy: multiple injections of platelet-rich plasma are a suitable option: a systematic review and meta-analysis. *Am J Sports Med*. 2019;47(4):1001-1018.
4. Ang BFH, Mohan PC, Png MA, et al. Ultrasonic percutaneous tenotomy for recalcitrant lateral elbow tendinopathy: clinical and sonographic results at 90 months. *Am J Sports Med*. 2021;49(7):1854-1860.
5. Baker CL Jr, Mahoney JR. Ultrasound-guided percutaneous tenotomy for gluteal tendinopathy. *Orthop J Sports Med*. 2020;8(3):2325967120907868.
6. Barnes DE, Beckley JM, Smith J. Percutaneous ultrasonic tenotomy for chronic elbow tendinosis: a prospective study. *J Shoulder Elbow Surg*. 2015;24(1):67-73.
7. Battista CT, Dorweiler MA, Fisher ML, Morrey BF, Noyes MP. Ultrasonic percutaneous tenotomy of common extensor tendons for recalcitrant lateral epicondylitis. *Tech Hand Up Extrem Surg*. 2018;22(1):15-18.
8. Boden AL, Scott MT, Dalwadi PP, Mautner K, Mason RA, Gottschalk MB. Platelet-rich plasma versus Tenex in the treatment of medial and lateral epicondylitis. *J Shoulder Elbow Surg*. 2019;28(1):112-119.
9. Bradberry DM, Sussman WI, Mautner KR. Ultrasound-guided percutaneous needle tenotomy for chronic tensor fascia lata tendinopathy: a case series and description of sonographic findings. *PM R*. 2018;10(9):979-983.
10. Buchbinder R, Johnston RV, Barnsley L, Assendelft WJ, Bell SN, Smidt N. Surgery for lateral elbow pain. *Cochrane Database Syst Rev*. 2011;2011(3):CD003525.
11. Bureau NJ, Tetreault P, Grondin P, et al. Treatment of chronic lateral epicondylosis: a randomized trial comparing the efficacy of ultrasound-guided tendon dry needling and open-release surgery. *Eur Radiol*. 2022;32(11):7612-7622.
12. Chalian M, Nacey NC, Rawat U, et al. Ultrasound-guided percutaneous needle tenotomy using Tenex system for refractory lateral epicondylitis; short and long-term effectiveness and contributing factors. *Skeletal Radiol*. 2021;50(10):2049-2057.
13. Challoumas D, Clifford C, Kirwan P, Millar NL. How does surgery compare to sham surgery or physiotherapy as a treatment for tendinopathy? A systematic review of randomised trials. *BMJ Open Sport Exerc Med*. 2019;5(1):e000528.
14. Chianca V, Albano D, Messina C, et al. Rotator cuff calcific tendinopathy: from diagnosis to treatment. *Acta Biomed*. 2018;89(1-S):186-196.
15. Chiavaras MM, Jacobson JA. Ultrasound-guided tendon fenestration. *Semin Musculoskelet Radiol*. 2013;17(1):85-90.
16. Cook JL, Purdam CR. Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. *Br J Sports Med*. 2009;43(6):409-416.
17. Cook JL, Rio E, Purdam CR, Docking SI. Revisiting the continuum model of tendon pathology: what is its merit in clinical practice and research? *Br J Sports Med*. 2016;50(19):1187-1191.
18. D'Addona A, Maffulli N, Formisano S, Rosa D. Inflammation in tendinopathy. *Surgeon*. 2017;15(5):297-302.
19. Fick B, Stover DW, Chimenti RL, Hall MM. The safety of ultrasound guided tenotomy and debridement for upper and lower extremity tendinopathies: a retrospective study. *Iowa Orthop J*. 2021;41(2):82-90.
20. Franchignoni F, Vercelli S, Giordano A, Sartorio F, Bravini E, Ferriero G. Minimal clinically important difference of the disabilities of the arm, shoulder and hand outcome measure (DASH) and its shortened version (QuickDASH). *J Orthop Sports Phys Ther*. 2014;44(1):30-39.
21. Hudgens JL, Sugg KB, Grekin JA, Gumucio JP, Bedi A, Mendias CL. Platelet-rich plasma activates proinflammatory signaling pathways and induces oxidative stress in tendon fibroblasts. *Am J Sports Med*. 2016;44(8):1931-1940.
22. Irby A, Gutierrez J, Chamberlin C, Thomas SJ, Rosen AB. Clinical management of tendinopathy: a systematic review of systematic reviews evaluating the effectiveness of tendinopathy treatments. *Scand J Med Sci Sports*. 2020;30(10):1810-1826.
23. Jacobson JA, Yablon CM, Henning PT, et al. Greater trochanteric pain syndrome: percutaneous tendon fenestration versus platelet-rich plasma injection for treatment of gluteal tendinosis. *J Ultrasound Med*. 2016;35(11):2413-2420.
24. Khan KM, Cook JL, Bonar F, Harcourt P, Astrom M. Histopathology of common tendinopathies. Update and implications for clinical management. *Sports Med*. 1999;27(6):393-408.
25. Kirschner JS, Cheng J, Hurwitz N, et al. Ultrasound-guided percutaneous needle tenotomy (PNT) alone versus PNT plus platelet-rich plasma injection for the treatment of chronic tendinosis: a randomized controlled trial. *PM R*. 2021;13(12):1340-1349.
26. Koh JS, Mohan PC, Howe TS, et al. Fasciotomy and surgical tenotomy for recalcitrant lateral elbow tendinopathy: early clinical experience with a novel device for minimally invasive percutaneous microresection. *Am J Sports Med*. 2013;41(3):636-644.
27. Kongsgaard M, Kovanen V, Aagaard P, et al. Corticosteroid injections, eccentric decline squat training and heavy slow resistance training in patellar tendinopathy. *Scand J Med Sci Sports*. 2009;19(6):790-802.
28. Lavallee M, Bush C. Ultrasound-guided percutaneous tenotomy and its associated pain reduction and functionality outcomes in nonelite active adults. *Am J Phys Med Rehabil*. 2021;100(4):349-353.
29. Lu J, Li H, Zhang Z, Xu R, Wang J, Jin H. Platelet-rich plasma in the pathologic processes of tendinopathy: a review of basic science studies. *Front Bioeng Biotechnol*. 2023;11:1187974.
30. Martin JI, Atilano L, Bully P, et al. Needle tenotomy with PRP versus lidocaine in epicondylopathy: clinical and ultrasonographic outcomes over twenty months. *Skeletal Radiol*. 2019;48(9):1399-1409.

31. Mattie R, Wong J, McCormick Z, Yu S, Saltychev M, Laimi K. Percutaneous needle tenotomy for the treatment of lateral epicondylitis: a systematic review of the literature. *PM R*. 2017;9(6):603-611.
32. Millar NL, Silbernagel KG, Thorborg K, et al. Tendinopathy. *Nat Rev Dis Primers*. 2021;7(1):1.
33. Nakagawa H, Sung K, Mautner K, May T, Sussman WI. Lateral epicondylitis: comparing ultrasound-guided tenotomy with or without amniotic membrane allograft injection. *Regen Med*. 2023;18(5):399-411.
34. OCEBM Levels of Evidence Working Group. The Oxford Levels of Evidence 2. Oxford Centre for Evidence-Based Medicine. https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence. Accessed September 15, 2023.
35. Rupe MW, Fleury IG, Glass N, Kruse R, Buckwalter JA V. Efficacy of ultrasonic tenotomy and debridement and platelet-rich plasma injections for lateral elbow tendinopathy. *J Hand Surg Glob Online*. 2023;5(5):667-672.
36. Seng C, Mohan PC, Koh SB, et al. Ultrasonic percutaneous tenotomy for recalcitrant lateral elbow tendinopathy: sustainability and sonographic progression at 3 years. *Am J Sports Med*. 2016;44(2):504-510.
37. Shomal Zadeh F, Shafiei M, Hosseini N, Alipour E, Cheung H, Chalian M. The effectiveness of percutaneous ultrasound-guided needle tenotomy compared to alternative treatments for chronic tendinopathy: a systematic review. *Skeletal Radiol*. 2023;52(5):875-888.
38. Stover D, Fick B, Chimenti RL, Hall MM. Ultrasound-guided tenotomy improves physical function and decreases pain for tendinopathies of the elbow: a retrospective review. *J Shoulder Elbow Surg*. 2019;28(12):2386-2393.
39. University of York Centre for Reviews and Dissemination. Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews. https://www.crd.york.ac.uk/CRDWeb/ShowRecord.asp?AccessionNumber=32001000984. Accessed September 15, 2023.
40. Vajapey S, Ghenbot S, Baria MR, Magnussen RA, Vasileff WK. Utility of percutaneous ultrasonic tenotomy for tendinopathies: a systematic review. *Sports Health*. 2021;13(3):258-264.
41. Vajapey SP, Blackwell RE, Maki AJ, Miller TL. Treatment of extensor tendon disruption after total knee arthroplasty: a systematic review. *J Arthroplasty*. 2019;34(6):1279-1286.
42. Vander Doelen T, Jelley W. Non-surgical treatment of patellar tendinopathy: a systematic review of randomized controlled trials. *J Sci Med Sport*. 2020;23(2):118-124.
43. Wahezi SE, Patel A, Yerra S, et al. Percutaneous ultrasound-guided tenotomy of the iliotibial band for trochanteric pain syndrome: a longitudinal observational study with one-year durability results. *Pain Physician*. 2023;26(4):393-401.
44. Xu Y, Murrell GA. The basic science of tendinopathy. *Clin Orthop Relat Res*. 2008;466(7):1528-1538.