Platelet-Rich Plasma Injection With Percutaneous Needling for Recalcitrant Lateral Epicondylitis

Comparison of Tenotomy and Fenestration Techniques

Michael P. Gaspar,*[†‡] MD, Michael A. Motto,[§] BS, Sarah Lewis,[†||] MD, DPT,
Sidney M. Jacoby,[†] MD, Randall W. Culp,[†] MD, A. Lee Osterman,[†] MD, and Patrick M. Kane,[†] MD
Investigation performed at the Philadelphia Hand to Shoulder Center, Department of Orthopaedic Surgery, Thomas Jefferson University, Philadelphia, Pennsylvania, USA

Background: Recalcitrant lateral epicondylitis (LE) is a common debilitating condition, with numerous treatment options of varying success. An injection of platelet-rich plasma (PRP) has been shown to improve LE, although it is unclear whether the method of needling used in conjunction with a PRP injection is of clinical importance.

Purpose: To determine whether percutaneous needle tenotomy is superior to percutaneous needle fenestration when each is combined with a PRP injection for the treatment of recalcitrant LE.

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 93 patients with recalcitrant LE were treated with a PRP injection and percutaneous needle fenestration (n = 45) or percutaneous needle tenotomy (n = 48) over a 5-year study interval. Preoperative patient data, including visual analog scale for pain (VAS-P), Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH), and Patient-Rated Tennis Elbow Evaluation (PRTEE) scores and grip strength, were obtained from a chart review and compared with postoperative values obtained prospectively. Secondary outcomes included the incidence of complications, need for additional interventions, return to work, and patient satisfaction.

Results: At a mean follow-up of 40 months, significant improvements in VAS-P (mean, –6.1; 95% CI, –6.8 to –5.5; $P < .0001$), QuickDASH (mean, –46; 95% CI, –52 to –40; $P < .0001$), and PRTEE (mean, –57; 95% CI, –64 to –50; $P < .0001$) scores and grip strength (mean, +6.1 kg; 95% CI, 4.9 to 7.3; $P < .0001$) were observed across the entire study cohort, with no significant differences noted between the fenestration and tenotomy groups. Nine of 45 patients (22%) underwent additional procedures to treat recurrent symptoms in the fenestration group compared with 5 of 48 patients (10%) in the tenotomy group ($P = .05$). No complications occurred in any patients, and no patients expressed dissatisfaction with their treatment course.

Conclusion: A PRP injection with concomitant percutaneous needling is an effective treatment for recalcitrant LE, with sustained improvements in pain, strength, and function demonstrated at a mean follow-up of longer than 3 years. Although the method of concomitant needling does not appear to have a significant effect on treatment outcomes, more aggressive needle tenotomy is less likely to require conversion to open tenotomy than needle fenestration in the short term to midterm.

Keywords: lateral epicondylitis; percutaneous needle tenotomy; platelet-rich plasma (PRP); tendinosis; tennis elbow; fenestration

Lateral epicondylitis (LE) is a commonly occurring condition that affects up to 3% of the adult population while accounting for significant costs related to medical care and lost wages.[14,30,43,53] Often referred to as *tennis elbow*, the underlying cause of LE involves noninflammatory processes of mucoid degeneration with neovascularization,

scarring, and microtearing at the extensor origin at the lateral elbow, collectively termed *angiofibroblastic hyperplasia* or *tendinosis*.[1,39] As LE is considered to be self-limiting in the majority of patients, first-line treatment options generally focus on addressing the primary symptom of pain and may include oral and/or topical anti-inflammatory drugs and analgesics, bracing, stretching, and other physical therapy measures.[6,30,40,45] Although for most patients, pain resolves within 1 year of onset with nonoperative treatment alone, a smaller but significant

population will continue to have persistent symptoms that are refractory to noninvasive treatment and will be deemed to have recalcitrant LE.[26]

Patients with recalcitrant LE are particularly difficult to treat, as outcomes are generally suboptimal, while the most favorable treatment regimens continue to be debated. The least invasive options involve injections of corticosteroids, platelet-rich plasma (PRP), or other autologous derivatives, such as whole blood and tenocyte concentrate.[2,37,41,51,54] However, these treatments are not without complications of their own; this is particularly true for corticosteroids, which carry the risks of tendon atrophy and blood glucose spikes.[8,13,49] Furthermore, while most evidence suggests that PRP is superior to corticosteroids in the long term, the superiority of one over the other has still not reached consensus.[2,11,12,22,27,28,37,45] This is important, given the fact that corticosteroid and PRP injections are thought to act in opposing pathways, as corticosteroids are known inhibitors of inflammation, while animal models suggest that PRP induces a transient inflammatory response to stimulate a repair response.[23]

Surgical treatment for recalcitrant LE, pioneered by Nirschl, included lateral release with debridement of the common extensor origin and has been shown to result in sustainable relief for over 1 decade.[10,16,17,39] Nirschl and Pettrone[39] suggested that the success of this procedure was secondary to the removal of diseased tissue, combined with bony decortication stimulating local blood flow. Since then, this concept has been modified to include arthroscopic and less invasive techniques, although the underlying method of tendon release or debridement has persisted.[3,16,29,47,50] Percutaneous tenotomy is favored by some, as it is reported to yield a lower severity and incidence of complications compared with open techniques.[4,31-36,38,42,44,52]

While positive outcomes after either a PRP injection or percutaneous needle tenotomy alone have been reported for the treatment of recalcitrant LE, to our knowledge, results after the two performed in conjunction have not been reported. Furthermore, it is not known if a PRP injection combined with more aggressive percutaneous needle tenotomy provides superior symptom relief than a PRP injection performed with a needle fenestration technique. Given the potential additive effects of PRP stimulating a repair response and decortication promoting increased blood flow, we hypothesized that a PRP injection performed in conjunction with needle tenotomy would result in superior outcomes compared with a PRP injection with needle fenestration. The purpose of this study was to determine if outcomes differed between patients with LE treated with a PRP injection plus percutaneous needle tenotomy and those treated with a PRP injection and percutaneous needle fenestration.

METHODS

This study was approved by our institutional review board. We queried our departmental electronic database to identify patients who received a PRP injection with percutaneous needling for LE from January 2010 through December 2014 by 1 of 2 senior, fellowship-trained orthopaedic hand and upper extremity surgeons. Per their personal preferences, one surgeon (R.W.C.) performed needling with the fenestration technique, while the other (A.L.O.) performed needle tenotomy. Both surgeons utilized the following patient selection criteria: minimum symptom duration of 6 months, physical examination and magnetic resonance imaging (MRI) findings consistent with LE, and failed nonoperative management including all of the following: at least 1 prior corticosteroid injection, supervised therapy, and trial of splinting and/or counterforce bracing. Patients were excluded if they met any of the following criteria: open lateral epicondyle tenotomy, prior surgery or PRP injection for LE of the same elbow, corticosteroid injection within 3 months before the PRP injection, history of inflammatory arthropathy, or history of significant trauma about the elbow. For patients with bilateral LE treated with a PRP injection, only the first injection was included in the analysis.

Procedure and Postoperative Rehabilitation

All procedures were performed under sterile conditions in the operating room. Approximately 30 mL of venous blood was drawn from each patient and processed using the ACP Double Syringe System (Arthrex Inc) to obtain PRP for an injection. Anesthesia was typically administered either via axillary nerve blockade or local anesthesia with sedation. For both techniques, after the surface anatomy was mapped with a surgical pen, an 18-gauge needle was introduced through the skin overlying the common extensor tendon. The procedure in the fenestration group was performed in a similar fashion to previously reported studies (often referred to as "peppering"), whereby the needle was used to perforate the common extensor origin 5 times through the single skin entry site.[22,28,37,41] For the tenotomy group, after needle entry through the skin, the beveled edge of the needle tip was used to abrade the footprint of the common extensor tendon until a change in feedback was felt by the surgeon, after which PRP was then injected at the site. The change in feedback indicated a softening of tendinotic, diseased tendon with smoothening of bony irregularities.[33,34] After both techniques, the elbow was then ranged to rule out iatrogenic injuries to the lateral stabilizers, and a sterile dressing was placed on the elbow. Postoperatively, the patient was permitted to use the arm

*Address correspondence to Michael P. Gaspar, MD, Philadelphia Hand to Shoulder Center, Department of Orthopaedic Surgery, Thomas Jefferson University, 834 Chestnut Street, Franklin Building, Suite G114, Philadelphia, PA 19107, USA (email: michaelpgaspar@gmail.com).
†Philadelphia Hand to Shoulder Center, Department of Orthopaedic Surgery, Thomas Jefferson University, Philadelphia, Pennsylvania, USA.
‡Darden School of Business, University of Virginia, Charlottesville, Virginia, USA.
§Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, USA.
‖Department of Orthopaedics, Southern California Permanente Medical Group, Fontana, California, USA.

TABLE 1
Custom Likert Scale to Assess Changes in Clinical Examination Findings and Final Patient Satisfaction With Treatment[a]

Outcome: Question	Point Tenderness: How Tender Are You at This Site Compared With Preoperatively?	Pain With Resisted Wrist Extension: How Is Your Pain With This Maneuver Compared With Preoperatively?	Satisfaction: At This Time, How Satisfied Are You With the End Results of Your Treatment?
1	Minimal to no tenderness; significantly improved	Minimal to no pain; significantly improved	Highest possible satisfaction; would definitely undergo this surgery again
2	Some mild tenderness; somewhat improved	Mild pain; somewhat improved	Satisfied; would likely undergo this surgery again
3	Tenderness is present; unchanged	Pain is unchanged	Neither satisfied nor dissatisfied; unsure if would undergo surgery again
4	Moderate but not severe tenderness; worsened	Moderate but not severe pain does not limit ability to fully extend wrist; worsened	Dissatisfied; unlikely to undergo this surgery again
5	Severe tenderness; significantly worsened	Extreme pain causing weakness or inability to fully extend wrist; significantly worsened	Lowest possible satisfaction; would definitely not undergo this surgery again

[a]Patients were asked to select the answer that best fit their self-assessment.

as tolerated. Rehabilitation protocols were identical between the groups and included range of motion exercises starting at 1 week and strengthening at 3 weeks.

Data Collection and Statistical Analysis

A retrospective chart review was performed to obtain patient demographic and disease-specific factors, including age, sex, handedness, medical comorbidities, work status, workers' compensation status, duration of symptoms, and prior treatment. Examination findings included preoperative grip strength, tenderness over the common extensor origin (yes or no), and pain with resisted wrist extension (yes or no). Per our institution's standard, documented grip strength was determined by the mean of 3 trials with the Jamar hand dynamometer (Sammons Preston Inc) on settings II and III for female and male patients, respectively. Preoperative visual analog scale for pain (VAS-P; 0 = no pain, 10 = worst pain imaginable) scores and Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Patient-Rated Tennis Elbow Evaluation (PRTEE) functional scores were also recorded. Patients were invited back to our center for a follow-up evaluation, which was performed by a study team member (M.P.G.) blinded to the original procedure. The follow-up evaluation included interval history taking; a repeat clinical examination; and postoperative VAS-P, QuickDASH, and PRTEE scores. Follow-up assessments of point tenderness and pain with resisted wrist extension were compared with preoperative findings using a custom Likert-type scale scored from 1 to 5 to maintain consistency with the format of the QuickDASH; in addition, patient satisfaction was assessed using a similar custom Likert-type scale (Table 1). Secondary data and qualitative outcomes that were recorded included patients' preoperative and postoperative work status, incidence of complications, and need for additional interventions.

Univariate analysis was utilized to obtain descriptive statistics of the entire cohort, and bivariate analysis was performed with the Fisher exact and independent *t* tests to compare baseline preoperative patient demographics between the tenotomy and fenestration groups. Preoperative and postoperative values within each treatment group were compared using paired *t* testing, while improvements between the 2 groups were compared using independent *t* testing. All statistical analyses were performed using Minitab for Windows (version 17.3.1; Minitab Inc). An a priori power analysis was performed using the QuickDASH in a manner analogous to the use of the PRTEE reported by Krogh and colleagues.[28] We elected to use the QuickDASH for power analysis, given the previously established minimal clinically important difference (MCID) for the QuickDASH of 14 ± 14 reported by Sorensen et al[48] and a more recent similar MCID of 15.8 reported that specifically pertained to LE.[46] Thus, for a 2-sided significance level $\alpha = .05$ to achieve 80% power ($\beta = .8$), a sample size of 17 patients in each group would be necessary to detect an effect size of 1.0.

RESULTS

Ninety-three patients (50 female, 43 male) satisfied the inclusion criteria for this study. The mean age across the entire cohort was 51.7 ± 8.1 years. The mean interval from the onset of symptoms to the PRP injection was 26.8 ± 23.6 months (range, 6.2-127.8 months), while the mean follow-up interval was 39.7 ± 19.3 months (range, 12.2-80.8 months). All patients had preoperative MRI findings consistent with LE, tenderness to palpation over the common extensor origin, and pain with resisted wrist extension. Additionally, all patients had failed a trial of conservative management including physical therapy (including stretching, splinting, and/or bracing) and corticosteroid injection(s); the mean number of corticosteroid injections before the PRP injection was 1.54 ± 0.83. Overall, 45 and 48 patients comprised the fenestration and tenotomy groups, respectively. There was no difference in the baseline demographics between the study groups, as outlined in Table 2.

Outcomes

Postoperatively, mean grip strength (+6.1 kg; 95% CI, 4.9 to 7.3; $P < .0001$) and mean VAS-P (−6.1; 95% CI, −6.8 to −5.5;

TABLE 2
Comparison of Baseline Demographic Data
Between the Groups[a]

Variable	Fenestration (n = 45)	Tenotomy (n = 48)	P Value
Age, y	50.3 ± 8.1	52.9 ± 8.0	.13
Interval from symptom onset to injection, mo	24.7 ± 20.9	28.5 ± 26.1	.48
Follow-up duration, mo	39.4 ± 21.6	40.0 ± 17.2	.87
Female sex	23 (51)	27 (56)	.68
Dominant side	29 (64)	27 (56)	.55
Work status			.75
Full-time	18 (40)	18 (38)	
Modified duty	16 (36)	11 (23)	
Out of work	8 (18)	14 (29)	
Retired	3 (6)	5 (10)	
Workers' compensation	15 (33)	19 (40)	.53
Diabetes	12 (27)	11 (23)	.81
No. of prior steroid injections	1.53 ± 0.82	1.54 ± 0.85	.96

[a]Values are shown as mean ± SD or n (%).

TABLE 3
Comparison of Treatment Outcomes Between the Groups[a]

Variable	Fenestration (n = 45)	Tenotomy (n = 48)	P Value
Grip strength improvement, kg	7.1 ± 5.4	5.2 ± 4.7	.12
VAS-P score improvement	5.8 ± 2.4	6.5 ± 2.4	.28
QuickDASH score improvement	47.5 ± 21.5	44.2 ± 22.0	.56
PRTEE score improvement	52.0 ± 24.1	61.6 ± 25.2	.18
Second procedure	10 (22)	5 (10)	.16
PRP re-injection	3 (30)	3 (60)	>.99
Open tenotomy	7 (70)	2 (40)	.05
Improved work status	17/24 (71)	16/25 (64)	.61
Modified duty to full-time	15/16 (94)	9/11 (82)	
Out of work to modified duty	2/8 (25)	7/14 (50)	
Patient satisfaction	1.27 ± 0.58	1.17 ± 0.43	.35
Postoperative tenderness	1.71 ± 0.71	1.79 ± 0.73	.59
Postoperative pain with resisted wrist extension	2.02 ± 0.81	1.94 ± 0.86	.63

[a]Values are shown as mean ± SD or n (%). PRP, platelet-rich plasma; PRTEE, Patient-Rated Tennis Elbow Evaluation; Quick-DASH, Quick Disabilities of the Arm, Shoulder and Hand; VAS-P, visual analog scale for pain.

$P < .0001$), QuickDASH (–46; 95% CI, –52 to –40; $P < .0001$), and PRTEE (–57; 95% CI, –64 to –50; $P < .0001$) scores were significantly improved across the entire study cohort compared with preoperative values. Mean postoperative pain with resisted wrist extension and tenderness values across the cohort were 1.98 ± 0.84 and 1.75 ± 0.71, respectively. A comparison of outcomes between the fenestration and tenotomy groups is depicted in Table 3.

When comparing the final postoperative VAS-P score between the groups, the tenotomy group had a significantly lower VAS-P score than the fenestration group (Table 4),

although the absolute preoperative versus postoperative difference was not significant (Table 3). Similarly, while the difference in final postoperative grip strength approached statistical significance (higher for the fenestration group), the preoperative versus postoperative difference between the groups was again nonsignificant. No other significant differences were found between the fenestration and tenotomy groups for any of the aforementioned variables (Tables 3 and 4).

Excluding those patients who were retired or already working full-time at the point of their initial procedure, 33 of 49 (67%) patients with preoperative work restrictions, that is, those either out of work or working a modified time/light duty, increased their work capacity by final follow-up. All 16 of those patients whose work capacity did not improve were workers' compensation patients. No patients in either group were working in a lesser capacity than preoperatively. The mean satisfaction score across the full study cohort was 1.22 ± 0.51, with no patients scoring worse than 3.

Additional Procedures

Of the 93 patients, 14 (15%) underwent a second procedure. Three patients in each group received a second PRP injection for recurrent symptoms; 5 of those patients subsequently did well and required no further interventions. One patient who received a second PRP injection in the fenestration group had minimal symptom relief after the second injection and was subsequently converted to open tenotomy. Six additional patients in the fenestration group were converted to open tenotomy versus 2 patients in the tenotomy group ($P = .05$). The mean interval from the initial PRP injection to the second procedure was 9.7 ± 7.6 months (range, 2.6-30.1 months). No complications occurred in any patients.

DISCUSSION

Despite a wealth of treatments available for patients with recalcitrant LE, an effective consensus or gold-standard option remains elusive. Nirschl and Pettrone[39] first reported histopathological findings confirming the condition to be a degenerative process rather than one of an inflammatory cause. In their series of 88 elbows treated with open debridement and repair at the common extensor origin, over 97% demonstrated improvement compared with preoperative symptoms.[39] Less invasive variations of the now-eponymous Nirschl procedure have since been described to include arthroscopic or percutaneous tenotomy and debridement of the common extensor origin, while repair of the tendon is no longer considered to be critical.[||] Needle tenotomy in particular has been shown to yield positive outcomes, although comparative data relative to other options are lacking.[32-34,55] Furthermore, we found that there was a substantial variability between studies as to the true definition of tenotomy, ranging from needle

---

[||]References 4, 16, 29, 31, 38, 42, 44, 47, 50, 52.

TABLE 4
Comparison of Preoperative and Postoperative Quantitative Outcomes Between the Groups[a]

Outcome Measure	Preoperative			Postoperative		
	Fenestration	Tenotomy	P Value	Fenestration	Tenotomy	P Value
Grip strength, kg	24.9 ± 11.7	22.8 ± 8.8	.33	32.0 ± 12.7	28.0 ± 10.0	.09
VAS-P score	8.1 ± 1.5	7.8 ± 1.7	.46	2.3 ± 2.1	1.3 ± 1.6	.05
QuickDASH score	58.7 ± 18.9	61.6 ± 22.0	.63	11.2 ± 17.9	17.4 ± 16.4	.21
PRTEE score	72.1 ± 22.8	75.2 ± 19.6	.61	20.1 ± 17.7	13.6 ± 17.8	.20

[a]Data are shown as mean ± SD. PRTEE, Patient-Rated Tennis Elbow Evaluation; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; VAS-P, visual analog scale for pain.

fenestration of the diseased tendon to debridement of the underlying bone.[18,32-34,55] McShane and colleagues[33] reported on a prospective series of 58 patients treated with needle tenotomy under ultrasound guidance, which they described as "repeatedly fenestrat[ing] the tendinotic tendon," followed by abrading the periosteum of the lateral epicondyle with the beveled needle edge, and finally, injecting a corticosteroid. In that report, 80% of patients reported excellent or good outcomes, although no objective measures or validated outcome instruments were used.[33] In a follow-up study by the same authors, 57 patients were treated in an identical fashion but without a corticosteroid injection, resulting in over 92% of patients with good or excellent outcomes.[34] In a similar study, Zhu et al[55] reported on 76 patients treated with ultrasound-guided needle "puncture" (without periosteal abrading), yielding 87% good or excellent outcomes. None of the 3 aforementioned studies included a comparison group or validated outcome measures.

As interest in more cost-efficient, nonsurgical methods has increased, definitive treatment with injectable therapies has also garnered more attention.[¶] PRP in particular has gained increasing popularity as an autologous therapeutic agent targeting a range of tendinopathies, including LE.[18,19] The exact mechanism by which PRP improves the symptoms of tendinopathy is still not entirely understood, although recent genomic work suggests that PRP incites a transient but substantial inflammatory process in fibroblasts within the diseased tendon, subsequently inducing signaling pathways involved in tendon regeneration.[23] This is supported by clinical reports demonstrating the positive effects of PRP to generally outlast those of corticosteroid injections.[2,22,28,41]

Based on the potential individual benefits of tenotomy and PRP injections, we hypothesized that a PRP injection and percutaneous needle tenotomy would have an additive effect on outcomes, with superior results in patients with recalcitrant LE as compared with a PRP injection with the needle fenestration technique. We found that outcomes were largely similar between the groups, with the exception of final pain scores and grip strength. However, this difference was not observed when comparing the mean difference between the groups from preoperatively to postoperatively.

Despite a potentially synergistic effect against recalcitrant LE, we found that needle tenotomy offered no significant additional benefit to needle fenestration regarding outcomes when both were combined with a PRP injection. We suspect that this is more reflective of a largely positive effect of the PRP injection rather than a marginal effect from tenotomy. From a pathophysiological standpoint, this may be explained by a large inflammatory effect of PRP, as described by Hudgens et al,[23] surpassing the combined mechanical effect of tenotomy on the degenerative tendon and its own mild incitation of inflammatory processes.

In addition to differences in symptomatic and functional outcomes, a key question that we aimed to answer was the relative complication and failure rates and the need for additional interventions. We found that the need for revision open tenotomy was significantly higher in the fenestration group than in the tenotomy group. One possible explanation for this difference is that the tenotomy procedure involves more aggressive abrading of tendinotic tissue than fenestration, with the latter process not adequately stimulate a repair response in the diseased tissue, thus allowing for symptoms to recur. Despite this difference, the overall revision rate of 15% across all patients lends further credence to the argument that a single PRP injection may serve as an alternative to surgery for the definitive treatment of recalcitrant LE.[20,21,24]

This study is not without limitations, most notably the retrospective nature of preoperative data collection. This was especially likely to introduce bias with subjective assessments such as pain with resisted wrist extension or point tenderness. Although it would have been ideal to use the VAS-P or a Likert-type scale for these preoperative values, the lack of such details from clinical documentation precluded us from doing so. Thus, we elected to use the binary yes/no format and rely on our postoperative scales, which are of course subject to their own inherent recall bias. Another limitation is regarding the surgical technique itself. We did not use ultrasound for guidance to localize needle placement or for the evaluation of tendon quality postoperatively. This should be noted in light of recent findings by Keijsers et al,[25] who reported that the majority of injections were intra-articular rather than intratendinous. However, with the combined experience of the 2 senior authors (R.W.C., A.L.O.) who performed the procedure at more than 60 years in practice, we feel that this risk was likely minimal. Another noteworthy limitation was the

¶References 2, 5, 7, 9, 11, 15, 21, 22, 27, 28, 37, 41, 51, 54.

absence of a true control group, such as a cohort treated with tenotomy and saline.

Despite these limitations, we feel that this study further supports the utility of PRP injections for the treatment of recalcitrant LE, with significant improvements observed in pain, function, and strength, for a mean duration of longer than 3 years and, in some patients, up to 6 years. Outcomes of a PRP injection combined with percutaneous needle tenotomy were not significantly different than those of a PRP injection and percutaneous needle fenestration, although more aggressive abrading with needle tenotomy resulted in a significantly lower rate of conversion to open tenotomy compared with needle fenestration. Future prospective randomized studies could further test this finding, and the addition of needle tenotomy and needle fenestration arms without a PRP injection would be warranted in such a study.

REFERENCES

1. Ahmad Z, Siddiqui N, Malik S, Abdus-Samee M, Tytherleigh-Strong G, Rushton N. Lateral epicondylitis: a review of pathology and management. *Bone Joint J*. 2013;95:1158-1164.
2. Arirachakaran A, Sukthuayat A, Sisayanarane T, Laoratanavoraphong S, Kanchanatawan W, Kongtharvonskul J. Platelet-rich plasma versus autologous blood versus steroid injection in lateral epicondylitis: systematic review and network meta-analysis. *J Orthop Traumatol*. 2016; 17(2):101-112.
3. Baker CL Jr, Baker CL 3rd. Long-term follow-up of arthroscopic treatment of lateral epicondylitis. *Am J Sports Med*. 2008;36(2):254-260.
4. 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.
5. Brkljac M, Kumar S, Kalloo D, Hirehal K. The effect of platelet-rich plasma injection on lateral epicondylitis following failed conservative management. *J Orthop*. 2015;12(suppl 2):S166-S170.
6. Burnham R, Gregg R, Healy P, Steadward R. The effectiveness of topical diclofenac for lateral epicondylitis. *Clin J Sport Med*. 1998;8: 78-81.
7. Chaudhury S, de La Lama M, Adler RS, et al. Platelet-rich plasma for the treatment of lateral epicondylitis: sonographic assessment of tendon morphology and vascularity (pilot study). *Skeletal Radiol*. 2013; 42(1):91-97.
8. Cheng J, Abdi S. Complications of joint, tendon and muscle injections. *Tech Reg Anesth Pain Manag*. 2007;11(3):141-147.
9. Claessen FM, Heesters BA, Chan JJ, Kachooei AR, Ring D. A meta-analysis of the effect of corticosteroid injection for enthesopathy of the extensor carpi radialis brevis origin. *J Hand Surg Am*. 2016;41(10): 988-998.e2.
10. Coleman B, Quinlan JF, Matheson JA. Surgical treatment for lateral epicondylitis: a long-term follow-up of results. *J Shoulder Elbow Surg*. 2010;19(3):363-367.
11. Coombes BK, Bisset L, Vicenzino B. Efficacy and safety of corticosteroid injections and other injections for management of tendinopathy: a systematic review of randomised controlled trials. *Lancet*. 2010; 376(9754):1751-1767.
12. de Vos RJ, Windt J, Weir A. Strong evidence against platelet-rich plasma injections for chronic lateral epicondylar tendinopathy: a systematic review. *Br J Sports Med*. 2014;48(12):952-956.
13. Dean BJF, Lostis E, Oakley T, Rombach I, Morrey ME, Carr AJ. The risks and benefits of glucocorticoid treatment for tendinopathy: a systematic review of the effects of local glucocorticoid on tendon. *Semin Arthritis Rheum*. 2014;43(4):570-576.
14. Descatha A, Albo F, Leclerc A, et al. Lateral epicondylitis and physical exposure at work? A review of prospective studies and meta-analysis. *Arthritis Care Res (Hoboken)*. 2016;68(11):1681-1687.

15. Dogramaci Y, Kalaci A, Savaş N, Duman IG, Yanat AN. Treatment of lateral epicondilitis using three different local injection modalities: a randomized prospective clinical trial. *Arch Orthop Trauma Surg*. 2009; 129(10):1409-1414.
16. Dunkow PD, Jatti M, Muddu BN. A comparison of open and percutaneous techniques in the surgical treatment of tennis elbow. *J Bone Joint Surg Br*. 2004;86(5):701-704.
17. Dunn JH, Kim JJ, Davis L, Nirschl RP. Ten- to 14-year follow-up of the Nirschl surgical technique for lateral epicondylitis. *Am J Sports Med*. 2008;36(2):261-266.
18. Finnoff JT, Fowler SP, Lai JK, et al. Treatment of chronic tendinopathy with ultrasound-guided needle tenotomy and platelet-rich plasma injection. *PM R*. 2011;3(10):900-911.
19. Fitzpatrick J, Bulsara M, Zheng MH. The effectiveness of platelet-rich plasma in the treatment of tendinopathy: a meta-analysis of randomized controlled clinical trials. *Am J Sports Med*. 2017;45(1):226-233.
20. Ford RD, Schmitt WP, Lineberry K, Luce P. A retrospective comparison of the management of recalcitrant lateral elbow tendinosis: platelet-rich plasma injections versus surgery. *Hand (N Y)*. 2015; 10(2):285-291.
21. Glanzmann MC, Audigé L. Platelet-rich plasma for chronic lateral epicondylitis: is one injection sufficient? *Arch Orthop Trauma Surg*. 2015;135(12):1637-1645.
22. Gosens T, Peerbooms JC, van Laar W, den Oudsten BL. Ongoing positive effect of platelet-rich plasma versus corticosteroid injection in lateral epicondylitis: a double-blind randomized controlled trial with 2-year follow-up. *Am J Sports Med*. 2011;39(6):1200-1208.
23. 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.
24. Karaduman M, Okkaoglu MC, Sesen H, Taskesen A, Ozdemir M, Altay M. Platelet-rich plasma versus open surgical release in chronic tennis elbow: a retrospective comparative study. *J Orthop*. 2016; 13(1):10-14.
25. Keijsers R, van den Bekerom MP, Koenraadt KL, Bleys RL, van Dijk CN, Eygendaal D; Elbow Study Collaborative. Injection of tennis elbow: hit and miss? A cadaveric study of injection accuracy. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(7):2289-2292.
26. Knutsen EJ, Calfee RP, Chen RE, Goldfarb CA, Park KW, Osei DA. Factors associated with failure of nonoperative treatment in lateral epicondylitis. *Am J Sports Med*. 2015;43(9):2133-2137.
27. Krogh TP, Bartels EM, Ellingsen T, et al. Comparative effectiveness of injection therapies in lateral epicondylitis: a systematic review and network meta-analysis of randomized controlled trials. *Am J Sports Med*. 2013;41(6):1435-1446.
28. Krogh TP, Fredberg U, Stengaard-Pedersen K, Christensen R, Jensen P, Ellingsen T. Treatment of lateral epicondylitis with platelet-rich plasma, glucocorticoid, or saline: a randomized, double-blind, placebo-controlled trial. *Am J Sports Med*. 2013;41(3):625-635.
29. Kwon BC, Kim JY, Park KT. The Nirschl procedure versus arthroscopic extensor carpi radialis brevis debridement for lateral epicondylitis. *J Shoulder Elbow Surg*. 2017;26(1):118-124.
30. Lewis M, Chesterton LS, Sim J, Mallen CD, Hay EM, van der Windt DA. An economic evaluation of TENS in addition to usual primary care management for the treatment of tennis elbow: results from the TATE randomized controlled trial. *PLoS One*. 2015;10(8):e0135460.
31. Lin CL, Lee JS, Su WR, et al. Clinical and ultrasonographic results of ultrasonographically guided percutaneous radiofrequency lesioning in the treatment of recalcitrant lateral epicondylitis. *Am J Sports Med*. 2011;39(11):2429-2435.
32. 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.
33. McShane JM, Nazarian LN, Harwood MI. Sonographically guided percutaneous needle tenotomy for treatment of common extensor tendinosis in the elbow. *J Ultrasound Med*. 2006;25(10):1281-1289.
34. McShane JM, Shah VN, Nazarian LN. Sonographically guided percutaneous needle tenotomy for treatment of common extensor

tendinosis in the elbow: is a corticosteroid necessary? *J Ultrasound Med*. 2008;27(8):1137-1144.

35. Meknas K, Al Hassoni TN, Odden-Miland Å, Castillejo M, Kartus J. Medium-term results after treatment of recalcitrant lateral epicondylitis: a prospective, randomized study comparing open release and radiofrequency microtenotomy. *Orthop J Sports Med*. 2013;1(4): 2325967113505433.

36. Meknas K, Odden-Miland A, Mercer JB, Castillejo M, Johansen O. Radiofrequency microtenotomy: a promising method for treatment of recalcitrant lateral epicondylitis. *Am J Sports Med*. 2008;36(10): 1960-1965.

37. Mishra AK, Skrepnik NV, Edwards SG, et al. Efficacy of platelet-rich plasma for chronic tennis elbow: a double-blind, prospective, multi-center, randomized controlled trial of 230 patients. *Am J Sports Med*. 2014;42(2):463-471.

38. Nazar M, Lipscombe S, Morapudi S, et al. Percutaneous tennis elbow release under local anaesthesia. *Open Orthop J*. 2012;6:129-132.

39. Nirschl RP, Pettrone FA. The surgical treatment of lateral epicondylitis. *J Bone Joint Surg Am*. 1979;61(6A):832-839.

40. Paoloni JA, Murrell GAC, Burch RM, Ang RY. Randomised, double-blind, placebo-controlled clinical trial of a new topical glyceryl trinitrate patch for chronic lateral epicondylosis. *Br J Sports Med*. 2009; 43:299-302.

41. Peerbooms JC, Sluimer J, Bruijn DJ, Gosens T. Positive effect of an autologous platelet concentrate in lateral epicondylitis in a double-blind randomized controlled trial: platelet-rich plasma versus corticosteroid injection with a 1-year follow-up. *Am J Sports Med*. 2010; 38(2):255-262.

42. Pomerantz ML. Complications of lateral epicondylar release. *Orthop Clin North Am*. 2016;47(2):445-469.

43. Sanders TL, Maradit Kremers H, Bryan AJ, Ransom JE, Smith J, Morrey BF. The epidemiology and health care burden of tennis elbow: a population-based study. *Am J Sports Med*. 2015;43(5):1066-1071.

44. 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.

45. Sims SEG, Miller K, Elfar JC, Hammert WC. Non-surgical treatment of lateral epicondylitis: a systematic review of randomized controlled trials. *Hand (N Y)*. 2014;9(4):419-446.

46. Smith-Forbes EV, Howell DM, Willoughby J, Pitts DG, Uhl TL. Specificity of the minimal clinically important difference of the quick Disabilities of the Arm Shoulder and Hand (QDASH) for distal upper extremity conditions. *J Hand Ther*. 2016;29(1): 81-88, quiz 88.

47. Solheim E, Hegna J, Øyen J, Inderhaug E. Arthroscopic treatment of lateral epicondylitis: tenotomy versus debridement. *Arthroscopy*. 2016;32(4):578-585.

48. Sorensen AA, Howard D, Tan WH, Ketchersid J, Calfee RP. Minimal clinically important differences of 3 patient-rated outcomes instruments. *J Hand Surg Am*. 2013;38(4):641-649.

49. Stepan JG, London D, Boyer MI, Calfee RP. Blood glucose levels in diabetic patients following corticosteroid injections into the hand and wrist. *J Hand Surg Am*. 2014;39(4):706-712.

50. Szabo SJ, Savoie FH 3rd, Field LD, Ramsey JR, Hosemann CD. Tendinosis of the extensor carpi radialis brevis: an evaluation of three methods of operative treatment. *J Shoulder Elbow Surg*. 2006;15(6): 721-727.

51. Tan XX, Ju HY, Yan W, et al. Autologous platelet lysate local injections for the treatment of refractory lateral epicondylitis. *J Orthop Surg Res*. 2016;11(1):17.

52. Tasto JP, Cummings J, Medlock V, Hardesty R, Amiel D. Microtenotomy using a radiofrequency probe to treat lateral epicondylitis. *Arthroscopy*. 2005;21(7):851-860.

53. Walker-Bone K, Palmer KT, Reading I, Coggon D, Cooper C. Prevalence and impact of musculoskeletal disorders of the upper limb in the general population. *Arthritis Rheum*. 2004;51(4):642-651.

54. Wang A, Mackie K, Breidahl W, Wang T, Zheng MH. Evidence for the durability of autologous tenocyte injection for treatment of chronic resistant lateral epicondylitis: mean 4.5-year clinical follow-up. *Am J Sports Med*. 2015;43(7):1775-1783.

55. Zhu J, Hu B, Xing C, Li J. Ultrasound-guided, minimally invasive, percutaneous needle puncture treatment for tennis elbow. *Adv Ther*. 2008;25(10):1031-1036.