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Tenodesis with bone marrow venting under local anesthesia for recalcitrant lateral epicondylitis: results of 2 years of follow-up

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A R T I C L E I N F O

Keywords:
Recalcitrant lateral epicondylitis
Elbow pain
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Local anesthesia
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Level of evidence: Level IV; Case Series; Treatment Study

Hypothesis: We hypothesized that the treatment of recalcitrant lateral epicondylitis requires accurate identification of the painful area to promote remodeling of the degenerated extensor insertion and to stabilize the tendon origin during tendon healing. Thus, we performed tenodesis with bone marrow venting under local anesthesia for recalcitrant lateral epicondylitis.

Methods: Twenty patients (21 elbows) were treated with bone marrow venting at the painful area of the lateral epicondyle of the elbow and tenodesis using 2 soft anchors lateral to the capitellum (immediately distal to the painful area) and were followed up for ≥2 years. Patients were assessed using the numerical rating scale for pain and the Quick Disabilities of the Arm, Shoulder, and Hand questionnaire, and objective evaluation included active range of motion.

Results: The mean preoperative and postoperative pain scores were 7.5 and 0.5, respectively, indicating significant pain relief ($P < .001$). The mean preoperative and postoperative Quick Disabilities of the Arm, Shoulder, and Hand questionnaire scores were 44.2 and 1.0, respectively ($P < .001$). Two elbows had a slightly positive Thomsen test at the final visit. No recurrence of intra-articular symptoms induced by synovial fringe impingement was observed. Patients experienced more pain at the bone-tendon junction of extensors than at the tendon parenchyma.

Conclusion: Tenodesis with bone marrow venting under local anesthesia was effective for subjective patient satisfaction and positive clinical outcomes at ≥2 years of follow-up in patients with recalcitrant lateral epicondylitis. Intra-articular symptoms can be improved by stabilization of the lateral soft tissue without treatment for intra-articular lesions.

Lateral epicondylitis, which is commonly referred to as "tennis elbow," has a prevalence rate of 1%–3%.[9] This elbow disorder is most commonly observed in active individuals aged 45–54 years, regardless of sex. Although lateral epicondylitis can be managed with nonoperative treatment and most patients improve with conservative treatment, 5%–10% of patients require surgical intervention.[8,37,39] The standard surgical treatment for recalcitrant lateral epicondylitis involves the release or débridement of the extensor carpi radialis brevis (ECRB) tendon origin.[8,9,11,22,24,33] However, few reports exist on the anatomical repair of this disease.[40]

The pathology of recalcitrant lateral epicondylitis remains unclear; however, histopathological studies suggest that recalcitrant lateral epicondylitis is caused by failure of the inflammatory reparative mechanism of the ECRB due to overuse and repetitive stress activities.[13,21,33] The healing potential is considered poor because the degenerative tendon-to-bone insertion area is unstable, and the tendon origin is a hypovascular area.[6] Thus, for the surgical treatment for recalcitrant lateral epicondylitis, tendon release and débridement are recognized as more essential procedures than anatomical repair.[8,9,11,22,24,33,40]

We hypothesized that there are 3 requirements for the successful treatment of recalcitrant lateral epicondylitis: 1) accurate detection of the painful area, 2) promotion of tendon attachment

The experimental protocol was approved by the Institutional Review Board for Observation and Epidemiological Study, Kitasato University Medical Ethics Organization (approval number: KMEO B15-207).

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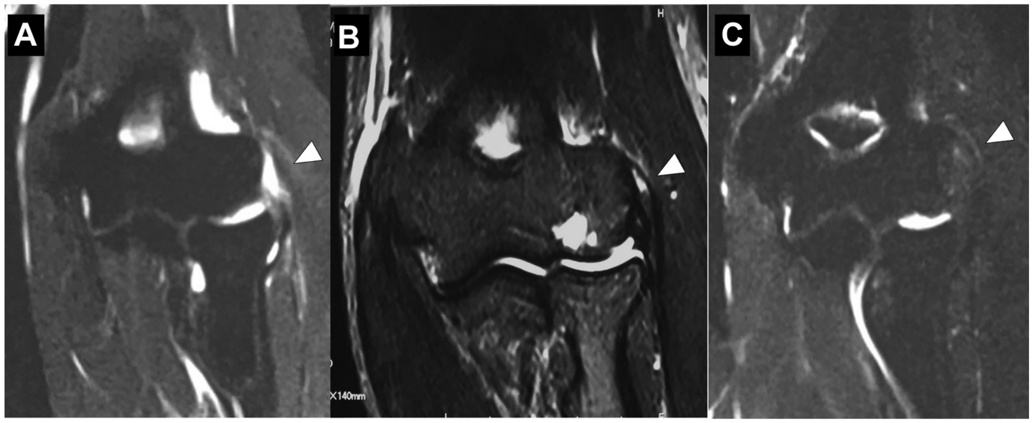

Figure 1 MRI scans showing lateral epicondylitis. *White arrow head*, the common extensor origin defined based on the MRI classification by Walton et al (2011); (**A**) Severe. (**B**) Moderate. (**C**) Mild or None. *MRI*, magnetic resonance imaging.

remodeling on the lateral epicondyle of the elbow using bone marrow venting, and 3) stabilization of the tendon origin at the lateral side of the capitellum. Based on this concept, since 2015, we have been performing tenodesis using 2 soft anchors with bone marrow venting under local anesthesia for recalcitrant lateral epicondylitis.[29]

Herein, we report the results of tenodesis with bone marrow venting under local anesthesia for recalcitrant lateral epicondylitis after a 2-year follow-up period.

Patients and methods

Patients

This study was conducted in accordance with the guidelines of the ethics organization of our facility. All patients signed an informed consent form for surgery and participation in this study before the surgery. We retrospectively reviewed our database, which was collected prospectively.

Between May 2015 and May 2019, 23 patients with recalcitrant lateral epicondylitis (24 affected elbows) underwent repair of the ECRB tendon at the lateral epicondyle using 2 knotless suture anchors with bone marrow venting. Surgical treatment was proposed to the patients after they failed to show improvement following a minimum of 6 months of conservative treatment, which included administration of nonsteroidal anti-inflammatory medication and/or single or multiple local injections of corticosteroid and anesthetic, physical therapy, and forearm braces. All patients had well-localized lateral elbow pain and tenderness over the lateral epicondyle that limited their routine activities and sports activities. All patients underwent preoperative magnetic resonance imaging (MRI) of the affected elbow; all affected elbows revealed an intratendinous signal intensity change and morphologic alteration from the normal uniform hypointense signal in the coronal fat-suppressed T2-weighted images (Fig. 1). We excluded patients who also had medial epicondylitis at the affected elbow (n = 3) and patients allergic to local anesthesia (n = 0). All participants in this study were suitable for local anesthetic administration and were able to tolerate decortication with local analgesia. Thus, 20 patients (21 elbows; 9 men and 11 women; mean age, 48 years [range, 35–68 years]) were included in the analysis (Table I).

Surgical procedure (Video)

All procedures were performed under local anesthesia on an outpatient basis. One orthopedic surgeon performed all surgeries, and the same orthopedic surgeon confirmed the painful area on the lateral side of the affected elbow with forearm pronation and administered ~5 mL of 1% lidocaine mixed with 0.75% ropivacaine (1:1) subcutaneously. A linear incision of 3–5 cm in length was made, which extended from a point just proximal to the lateral epicondyle to the distal skin just posterior to the epicondyle, resulting in a sharp dissection of the fascia overlying the common extensor tendon origin. Subsequently, the lateral condyle was palpated, the painful area around the origin of the ECRB was determined using a 23-gauge needle, and the same local anesthesia was administered (Fig. 2, *A*). Thereafter, the blood circulation in the affected arm was blocked using a tourniquet. A longitudinal incision was made in line with the extensor carpi radialis longus (ECRL) fibers, and the origin of the ECRB was exposed by retracting the ECRL muscle fibers. Next, the painful area on the lateral epicondyle, which was previously confirmed using a 23-gauge needle, was drilled using the 1.4-mm step drill enclosed with the soft knotless anchor (JuggerKnot Soft Anchor 1.4 mm Short; Zimmer Biomet, Warsaw, IN, USA) after administering local anesthesia (Fig. 2, *B*). The number of drill times (range, 3–8) was based on the extent of the painful area, which was evaluated using a 23-gauge needle. The drilling depth was 16 mm up to the laser-printed line of the step drill. After drilling, we confirmed the humeroradial joint space by palpation, and we incised the extensor tendon longitudinally and exposed the lateral side of the capitellum of the humerus, which was the distal area of drilling. We inserted 2 soft anchors at the volar and dorsal sides of the lateral capitellum, where 2 anchors were positioned perpendicular to the common extensor tendon (Fig. 2, *C*). Both strings of the 2 anchors were firmly tied to the common extensor tendon. After knot-tying, we confirmed that the patients could independently extend and flex their wrist and elbow and finished the tourniquet (Fig. 2, *D* and *E*). The mean tourniquet time was 12 minutes (8–20 minutes). Detachment of the tendon origin or tendon release was not performed in any procedure. The fascia and subcutaneous tissues were approximated using 3-0 absorbable sutures (PDS Plus; Ethicon Inc., Piscataway, NJ, USA), and the skin was closed using 4-0 nylon sutures.

Postoperative rehabilitation protocol

Postoperatively, the arm extremity was placed in a sling; however, patients were allowed to take it off if they did not feel any pain. From the day of surgery onward, the patients were allowed to perform almost all routine activities, including writing, eating, and using a computer. However, the patients were instructed to use their treated elbow carefully and refrain from any lifting or carrying

Table I
Patients' demographic data.

Patient no.	Age (yr)	Sex	Affected side	Duration of symptoms, (mo)	Injection times	Follow-up terms (mo)
1	55	Male	Nondominant	6	5	40
2	49	Male	Dominant	8	3	60
3	46	Male	Dominant	11	2	69
4	44	Female	Nondominant	15	5	30
5	46	Female	Dominant	18	3	63
6	68	Male	Dominant	6	2	36
7	47	Female	Dominant	16	Uncountable	27
8	55	Male	Dominant	9	2	37
9	58	Female	Dominant	16	4	35
10	48	Female	Dominant	6	0	29
11	37	Male	Dominant	6	1	26
12	35	Male	Dominant	6	0	26
13	45	Male	Dominant	6	0	35
14	40	Female	Dominant	8	8	33
15	60	Male	Dominant	11	3	27
16	35	Female	Dominant	31	4	28
17	35	Female	Nondominant	11	3	28
18	51	Female	Dominant	48	15	26
19	48	Female	Dominant	9	3	25
20	49	Female	Dominant	15	4	24
21	48	Female	Dominant	6	3	24

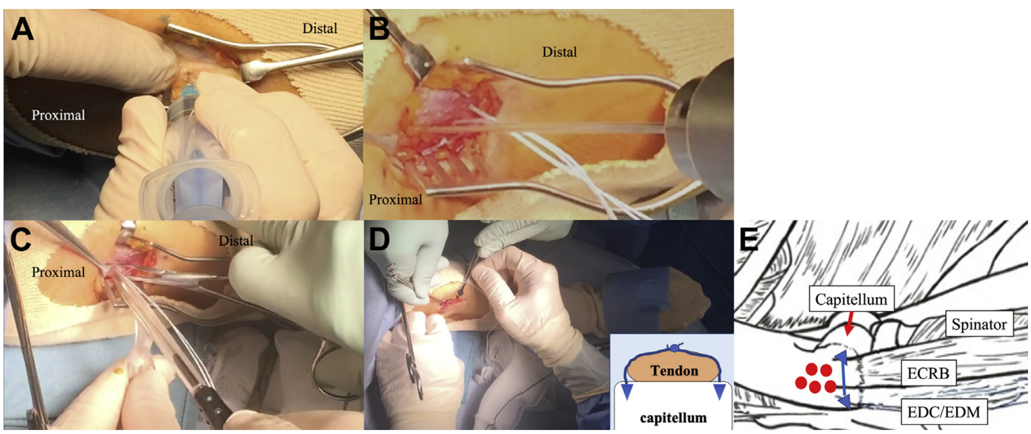

Figure 2 Intraoperative findings. (**A**) The painful area of the lateral epicondyle is confirmed using a 23-gauge needle. (**B**) Subsequent to local anesthesia administration, the confirmed painful area in the lateral epicondyle is drilled using the step drill enclosed with the soft knotless anchor (JuggerKnot Soft Anchor 1.4 mm Short; Zimmer Biomet, Warsaw, IN, USA). (**C**) Two soft anchors are secured at the lateral side of the capitellum where 2 anchors are positioned perpendicular to the ECRB tendon. (**D**) Both strings of the 2 anchors are tied to the ECRB tendon firmly; we confirmed that the patient could extend and flex their wrist and elbow. (**E**) Diagrammatic illustration of the procedure. Similar to compression using a counter force brace or band, the anchor strings compressed the tendon on the lateral capitellum. *Blue triangle*, soft anchor; *blue line*, strings of anchors; *red circle*, drilled hole. *ECRB*, extensor carpi radialis brevis; *EDC/EDM*, extensor digitorum communis/extensor digiti minimi.

using the treated extremity until 4 weeks postoperatively. The patients increased their activity levels under supervised physical therapy and were allowed to resume light sports activities or exercises at 6 weeks postoperatively. Return to normal sports activities using their treated arm was permitted at 12 weeks postoperatively, if full range of motion (ROM) had been achieved without severe or moderate pain. We set this protocol based on the significantly high rate of retear after rotator cuff repair within 12 weeks postoperatively.[1]

Intraoperative assessment

We assessed and confirmed the most painful point of the elbow (muscle belly of the ECRL and ECRB, tendon, bone-tendon junction of the ECRB, and the lateral side of the capitellum) by stimulation using a needle (Fig. 3). First, we touched the muscle belly of the ECRL and ECRB using a 23-gauge needle and confirmed whether the patient felt pain. We then confirmed the exposed tendon of the extensor and carefully pierced the needle without reaching the bone. At this point, we confirmed pain at the bone-tendon junction of the extensors. Subsequently, pain around the lateral side of the capitellum of the humerus was confirmed. The point at which the patient experienced the same intensity of pain as that before surgery was assessed to be the most painful area.

Clinical assessments

The patients completed a subjective assessment using the numerical rating scale (NRS) for pain at rest, wrist motion pain, and pain at night, as well as the Quick Disabilities of the Arm, Shoulder, and Hand questionnaire (Q-DASH). The assessment was performed preoperatively; again at 1, 3, 6, and 12 months postoperatively; and at the last postoperative visit. Objective evaluation of clinical outcomes, including the ROM of the elbow, and physical examination (Thomsen test,[2,26] middle finger extension test [Maudsley's test],[2,26] and fringe impingement test) were also performed at 1, 3, 6, and 12 months postoperatively and at the last postoperative visit.

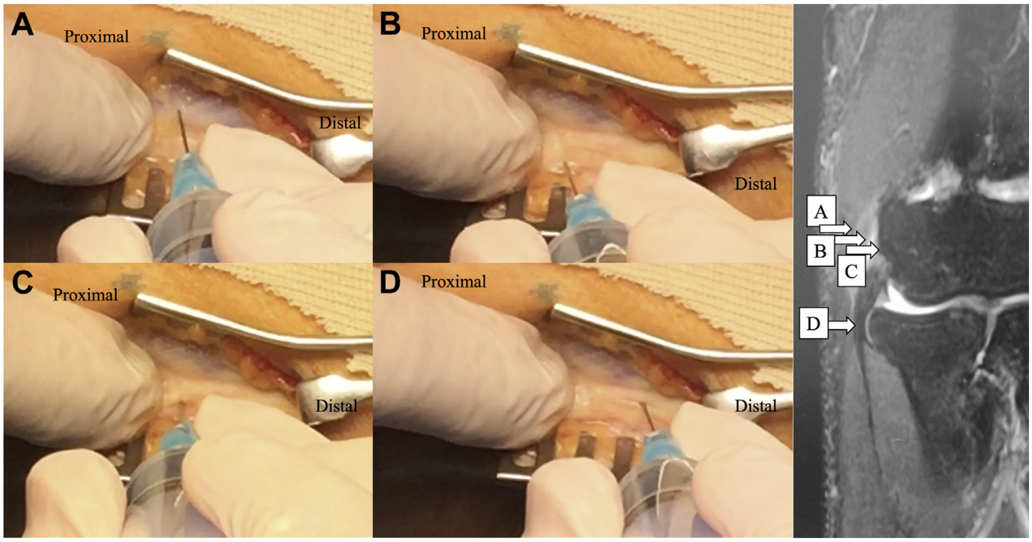

Figure 3 Painful area assessment. (**A**) Muscle belly. (**B**) Tendon. (**C**) Tendon-bone junction at the tendon origin (the tip of needle reached the bone). (**D**) Lateral site of the capitellum (the tip of needle reached the bone). (**E**) Depth of the needle at locations A, B, C, and D; the *white arrows* show the depth attained by the point of each needle.

The Thomsen test was performed based on previous reports.[2,26] Patients fully extended their elbow, with the forearm pronated and wrist extended. An examiner stressed the patients' wrist in the direction of flexion. The Maudsley's test was performed with the elbow extended and the forearm pronated. In this position, pressure was applied to the dorsal side of the middle finger in a volar direction.[2,26] Pain was considered a positive finding in each test. Intra-articular lesions have been recognized as one of the causes for recalcitrant lateral epicondyle.[3,10,25,35] Therefore, evaluation of intra-articular lesions was performed using the synovial fringe impingement maneuver in the humeroradial joint according to previous reports (Fringe impingement test).[3,35] The fringe impingement test was performed by extending the patient's elbow with the forearm fully supinated or pronated, and pain indicated a positive result. Active ROM of the elbow was measured with a standard goniometer. Forearm rotation was recorded as the degree of pronation and supination from the neutral position with the elbow at 90° flexion. Based on objective data, the Mayo elbow performance score (MEPS) was determined to evaluate the patients' clinical result.[14] The patients were divided into groups based on their pain NRS; scores of 1–3, 4–7, and >8 indicated mild, moderate, and severe pain, respectively.[19]

Magnetic resonance imaging

We obtained preoperative and follow-up MRI scans at 3 and 6 months postoperatively. Based on the MRI scoring system by Walton et al, we assessed the condition of the extensor origin at the lateral epicondyle using coronal fat-suppressed T2-weighted images at 3 and 6 months postoperatively (Fig. 1).[41] We also confirmed whether the drilling site matched the tendon area with an increased signal intensity on the coronal and axial fat-suppressed T2-weighted images (Fig. 4).

Statistical analysis

Statistical analysis was performed using a commercial software program (JMP Pro, version 14.3; SAS Institute Inc., Cary, NC, USA). Results are presented as mean ± standard deviation. The Kruskal-Wallis test was used to compare the follow-up scores in the MEPS and Q-DASH, which was followed by the Dwass-Steel-Critchlow-Fligner post hoc test. For all statistical analyses, significance was defined as $P < .05$.

Results

Intraoperative findings and complications

In one case (case #10), the tourniquet time took 20 minutes. Therefore, for the last 11 cases, we applied the tourniquet after confirmation of the painful area; the tourniquet time was within 10 minutes in all these cases. Thus, 15 patients were each finished within 10 minutes.

In all patients with recalcitrant lateral epicondylitis in this study, the most painful area during surgery was not the tendon but the bone-tendon junction of the extensor. Moreover, the painful area was localized. All patients felt more intensive pain around the insertion of the extensor than at the side of the capitellum where the anchors were inserted. Only 1 patient felt the same intensity of pain at the side of the capitellum as that at the extensor insertion. In this study, we only performed tenodesis with bone marrow venting; intra-articular lesions were not directly treated for any patient. No infection was observed at the surgical site.

Clinical outcomes

The mean follow-up period was 34.7 months (range, 24–69 months). The changes in pain and clinical outcomes are presented in Tables II, III, and IV. Eight elbows could not be fully extended preoperatively, and 7 elbows could not be fully extended at 1 month postoperatively. However, no elbow extension limitation was noted at 3 months postoperatively. Two patients experienced pain at the final visit although the NRS score for wrist motion pain was significantly decreased. In addition, the fringe impingement test, which indicated intra-articular pain, was positive in 11 of 21 elbows, and 1 of 11 elbows with a positive fringe impingement test had a popping sound with pain during extension. However, the fringe impingement test showed improvement within 3 months postoperatively in all patients (Table III).

Compared with the preoperative score, the MEPS score from 1 month after surgery to that at the last follow-up significantly improved (*P* value in the Dwass-Steel-Critchlow-Fligner post hoc

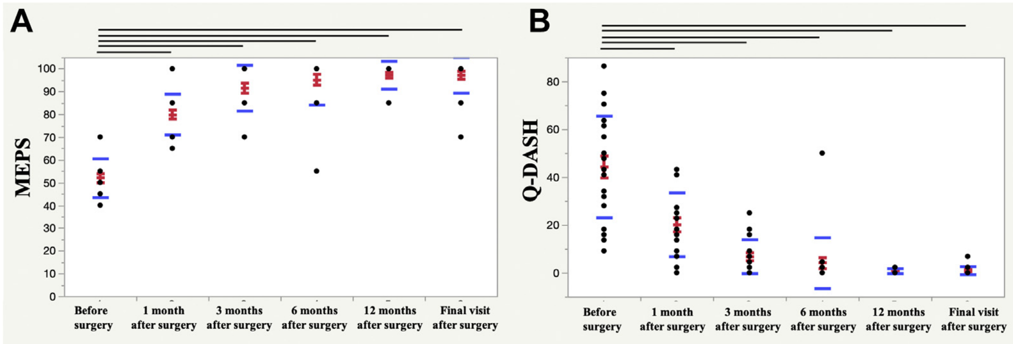

Figure 4 Changes in clinical scores. (**A**) Mayo elbow performance score (MEPS). (**B**) Quick Disabilities of the Arm, Shoulder, and Hand questionnaire (Q-DASH). Both scores significantly improved 1 month after surgery ($P < .001$). *Blue bar*, standard deviation; *red bar*, mean and standard error; *black bar*, significant difference between preoperative score and score at each measured timepoint.

Table II
Pain changes in patients' data.

Patient no.	Rest pain						Motion pain						Night pain						MRI findings[*]		
	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m
1	5	1	0	0	0	0	10	1	0	0	0	0	10	0	0	0	0	0	Severe	Mild	No
2	1	0	0	0	0	0	8	5	0	1	0	0	6	1	0	0	0	0	Severe	Mild	No
3	6	0	0	0	0	0	5	2	0	1	1	1	2	0	0	0	0	0	Severe	Mild	No
4	6	0	0	0	0	0	7	4	1	0	0	0	6	0	0	0	0	0	Severe[†]	Mild	No
5	1	1	0	4	0	0	8	5	3	8	1	1	1	5	1	5	0	0	Severe	Moderate	Moderate
6	2	0	0	0	0	0	10	1	0	0	0	0	4	0	0	0	0	0	Severe	Mild	Mild
7	9	2	0	0	0	0	9	2	0	0	0	0	9	0	0	0	0	0	Severe	Mild	No
8	8	0	0	0	0	0	8	3	3	1	0	0	0	0	0	0	0	0	Severe	Severe	Mild
9	6	0	0	0	0	0	9	6	6	2	0	0	9	0	0	0	0	0	Severe	Moderate	No
10	2	2	0	0	0	0	8	5	2	0	0	0	5	3	0	0	0	0	Severe	Mild	No
11	5	2	0	0	0	0	6	6	1	1	1	0	0	0	0	0	0	0	Moderate	No	No
12	3	0	0	0	0	0	5	3	0	2	1	2	0	0	0	0	0	0	Severe	Mild	Mild
13	0	0	0	0	0	0	3	1	1	1	0	1	0	0	0	0	0	0	Severe	No	No
14	0	0	0	0	0	0	7	3	0	0	0	0	0	0	0	0	0	0	Severe[†]	Mild	No
15	0	0	0	0	0	0	9	3	3	1	1	1	9	0	5	0	0	0	Severe	Moderate	Mild
16	0	0	0	0	0	0	8	0	0	0	0	0	10	0	0	0	0	0	Severe[†]	No	No
17	0	0	0	0	0	1	6	4	7	2	1	4	6	0	0	0	0	0	Moderate	Mild	Mild
18	2	6	0	0	0	0	6	5	0	0	0	0	8	3	0	0	0	0	Severe[†]	Mild	Moderate
19	5	0	0	0	0	0	8	1	0	0	0	0	3	1	0	0	0	0	Moderate	No	No
20	8	5	1	0	0	0	8	7	3	0	0	0	8	0	0	0	0	0	Severe	Mild	No
21	4	0	0	0	0	0	9	3	1	0	0	0	2	1	0	0	0	0	Severe	Mild	No

MRI, magnetic resonance imaging; *Pre*, preoperative data; *3 m*, clinical data after 3 mo; *6 m*, clinical data after 6 mo; *12 m*, clinical data after 12 mo; *24 m*, clinical data after 24 mo; last, clinical data at the last visits (mean follow-up term, 34.7 mo).
[*]MRI, findings were assessed using the MRI, classification by Walton et al.[41]
[†]Patient felt apprehension during daily activities.

test between the preoperative and every measured timepoint, $P < .001$). The Q-DASH score also improved significantly from 1 month after surgery to the last follow-up visit (*P* value between the preoperative and 1-month postoperative timepoint, $P = .003$; between preoperative and other measured timepoints, $P < .001$) (Fig. 5, Table IV).

MRI findings

Based on the MRI classification by Walton et al,[41] preoperatively and at 3 and 6 months postoperatively, severe, moderate, and mild or no epicondylitis were observed in 19, 2, and 0; 1, 3, and 17; and 0, 2, and 19 elbows, respectively, (Fig. 4, Table II). In all elbows, traces of drilling were noted at the tendon origin with an increased signal intensity on the MRI at 3 months postoperatively (Fig. 4, *B*).

Discussion

This investigation presented excellent clinical results for tenodesis with bone marrow venting under local anesthesia for the treatment of recalcitrant lateral epicondylitis. For orthopedic surgeons, a degenerative tendon is often difficult to distinguish from healthy or nonpainful ones during open surgery for recalcitrant lateral epicondylitis. This can result in excess or insufficient débridement or release, thereby causing poor clinical outcomes.[28] With our method, the painful area can be detected accurately since surgery is performed under local anesthesia. In addition, the procedure does not require débridement or detachment of the tendon origin. Moreover, 2 soft anchors can stabilize the tendon origin during wrist motion, much like the mechanism of a counterforce brace or band. Accurate detection of the painful area and stabilization of the tendon origin may lead to excellent clinical results. Hence, our simple procedure can serve as a useful treatment strategy before débridement or release for recalcitrant lateral epicondylitis.

The chief complaint of patients with recalcitrant lateral epicondylitis is localized pain over the lateral epicondyle.[6,32,33] In terms of intraoperative findings, all patients with recalcitrant lateral epicondylitis reported that the most painful area was the bone at the extensor origins rather than that at the tendon, and the

Table III
Clinical changes in patients' data.

Patient no.	Thomsen test						Middle finger test						Fringe impingement test					
	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m	12 m	24 m	Last
1	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
2	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
3	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
4	+	+	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
5	+	+	+	+	–	+	+	+	–	+	–	–	–	+	–	–	–	–
6	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
7	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
8	+	–	–	–	–	–	+	+	–	–	–	–	+	+	+	–	–	–
9	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
10	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
11	+	+	+	+	+	–	–	+	–	–	–	–	–	–	–	–	–	–
12	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
13	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
14	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
15	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
16	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
17	+	–	+	–	–	+	+	–	–	–	–	+	+	–	–	–	–	–
18	+	+	–	–	–	–	+	+	–	–	–	–	+	–	–	–	–	–
19	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
20	+	–	–	–	–	–	+	–	–	–	–	–	+	+	–	–	–	–
21	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–

Pre, preoperative data; *3 m*, clinical data after 3 mo; *6 m*, clinical data after 6 mo; *12 m*, clinical data after 12 mo; *24 m*, clinical data after 24 mo; *last*, clinical data at the last visits (mean follow-up term, 34.7 mo).

Table IV
Clinical changes in patients' data.

Patient no.	Mayo elbow performance scale						Q-DASH					
	Pre	3 m	6 m	12 m	24 m	Last	Pre	3 m	6 m	12 m	24 m	Last
1	45	85	100	100	100	100	75	40.91	2.27	2.27	0	0
2	50	65	100	100	100	100	28	15.91	2.27	4.55	0	0
3	50	85	100	100	100	100	43.18	27.27	6.82	4.55	2.27	2.27
4	40	85	85	100	100	100	61.4	27.27	15.9	2.27	0	0
5	50	70	85	55	85	85	40.91	40.91	25	50	2.27	2.27
6	45	85	100	100	100	100	50	9.1	2.27	0	0	0
7	50	85	100	100	100	100	43.18	18.18	0	0	0	0
8	55	70	85	100	100	100	18.18	2.27	2.27	2.27	0	0
9	40	85	70	85	100	100	63.64	25	6.82	2.27	0	0
10	55	70	85	100	100	100	56.8	25	9.1	0	0	0
11	70	70	85	85	85	100	13.64	40.91	6.82	4.55	2.27	0
12	70	70	100	85	85	100	15.9	15.9	2.27	2.27	2.27	2.27
13	70	70	85	100	100	85	9.1	9.1	2.27	0	0	2.27
14	50	85	100	100	100	100	31.82	6.82	4.5	2.27	2.27	2.27
15	50	85	85	100	85	100	86.36	18.18	18.18	4.55	2.27	2.27
16	50	100	100	100	100	100	34.09	0	0	0	0	0
17	50	85	70	85	100	70	34.09	9.09	9.09	2.27	0	6.82
18	50	70	100	100	100	100	47.73	22.73	2.27	2.27	0	0
19	50	85	100	100	100	100	70.45	13.64	2.27	0	0	0
20	50	85	85	100	100	100	63.64	43.18	18.18	0	0	0
21	50	85	100	100	100	100	40.91	6.82	2.27	0	0	0

Q-DASH, Quick Disabilities of the Arm, Shoulder, and Hand questionnaire; *Pre*, preoperative data; *3 m*, clinical data after 3 mo; *6 m*, clinical data after 6 mo; *12 m*, clinical data after 12 mo; *24 m*, clinical data after 24 mo; *last*, clinical data at the last visits (mean follow-up term, 34.7 mo).

painful area was localized. In all cases, we were able to retrospectively confirm, using MRI, that the drilling area where the patients felt pain matched the area of the extensor origin with an increased signal on the preoperative fat-suppressed T2-weighted images. In previous reports, tendon degeneration and the degree of tear, based on MRI, correlated well with histologic findings, such as neovascularization and collagen disruption.[21,34] In addition, histologic analysis revealed increased perivascular sympathetic innervation with loss of sensory innervation at the undersurface of the ECRB tendon.[38] Similar to previous reports,[6,32–34,38] our findings demonstrated that patients with recalcitrant lateral epicondylitis felt pain at the attachment site of the common extensor origin. Therefore, the treatment target for recalcitrant lateral epicondylitis is the bone-tendon junction of the extensor, mainly the area with higher signal intensity observed on MRI. Recently, we performed an MRI at 2 months postoperatively, wherein the drilled area could be observed with higher signal than that at 3 months after surgery (Supplementary Figure S1). We are planning on undertaking further research to elucidate the association between pain and the increased signal intensity observed on MRI performed at 2 months postoperatively.

Anatomical repair of recalcitrant lateral epicondylitis requires sufficient tendon remodeling. Herein, the reported MRI grade based on the classification of Walton et al improved after the procedure was performed in all cases; this grade worsened at 6 months compared to that at 3 months from diagnosis in only 1 case.[41] The

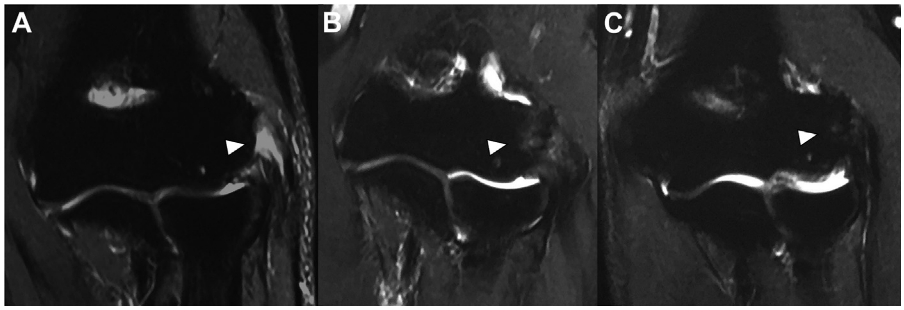

Figure 5 Changes observed on MRI before and after surgery. A case of a 44-year-old male painter who was referred to our hospital after 18 conservative treatments. Steroid was administered 3 times before surgery. MEPS and Q-DASH scores before surgery were 40 and 61.4, respectively. Based on the MR images of the common extensor origin, the condition is severe (**A**). MEPS and Q-DASH score at 3 months postoperatively were 85 and 15.9, respectively. Based on the MR images of the common extensor origin, the condition improved and is mild; drilling traces are confirmed in the same area just beneath the tendon with an increased signal before surgery (**B**). MEPS and Q-DASH scores at 6 months postoperatively were 100 and 2.3, respectively. MR images of the common extensor origin show improvement and the condition is classified as mild/none (**C**). MEPS and Q-DASH scores of this patient at the final visits (69 months postoperatively) were 100 and 0, respectively. *White triangle*, lateral epicondyle of the extensor tendon origin. *MRI*, magnetic resonance imaging; *MEPS*, Mayo elbow performance score; *Q-DASH*, Quick Disabilities of the Arm, Shoulder, and Hand questionnaire.

efficacy of drilling at the site of insertion of ECRB for the recalcitrant lateral epicondylitis has been reported.[42] An in vivo study reported that the mechanism for promoting tendon-bone healing includes infiltration of bone marrow cells into the tendon from the drilling holes.[17,18,20,30] Drilling into the tendon origin and preserving the fibrocartilage helps improve tissue repair and the biomechanical strength at the bone-tendon junction.[30] In our procedure, we stabilized the tendon origin using 2 soft anchors, which were similar to a counterforce brace or band, without the need for débridement or release of tendon origin to support tendon healing after the operation. In addition, based on the clinical evidence for tendon healing, we provided clear instructions to the patients regarding their activities, specifically those that involved their treated elbow, and emphasized the importance of compliance until 12 weeks postoperatively,[1] which resulted in excellent outcomes in terms of tendon healing. In addition, in previous studies, regenerated soft tissue was confirmed at the footprint where bone marrow venting was performed after rotator cuff repair.[15] We suspected that this regeneration of soft tissue would occur after our procedure, and this supported the excellent outcomes shown in the MRI results.

Recently, intra-articular lesions such as a synovial fringe and synovitis have also been considered as causes of chronic pain in lateral epicondylitis.[3,4,12,16,35] However, the incidence rate of intra-articular symptoms ranges from 20% to 58% in recalcitrant lateral epicondylitis.[16] Based on anatomical findings, the elbow capsule, ligament, and the ECRB origin are attached to the lateral epicondyle.[7,27,31] Compared to the lateral ligament, the elbow capsule plays a more important role in stabilizing the elbow[36]; subtle instability may result in intra-articular symptoms in recalcitrant lateral epicondylitis.[5,23] The 2 soft anchors in our treatment method help stabilize the tendon without the need for débridement of the elbow capsule. In this study, we did not directly treat intra-articular lesions. Our procedure may have caused improvements in the results of the fringe impingement test even without treatment for intra-articular lesions. Moreover, the clinical results of this study support the relationship between intra-articular lesions in recalcitrant lateral epicondylitis and minor instability due to degeneration of the origin of the common extensors, mainly the ECRB.[5,23]

Minor instability at the lateral component of the elbow can induce lateral elbow pain.[4,5] In addition, in 41% of patients who underwent plication of the lateral component, elbow ROM restriction persisted even though the lateral elbow pain improved.[4] Since the limitation of the elbow ROM after surgery was a concern, we ensured that our procedure did not restrict the anatomic elbow ROM immediately after tendon fixation by using the 2 anchors. No restriction in elbow ROM was observed during surgery, and elbow ROM fully recovered within 3 months postoperatively in all cases. In this series, the moderate instability observed in 4 of 21 cases improved after surgery. Thus, our procedure stabilizes the lateral component of the extensor insertion and does not induce the anatomical limitation of the elbow ROM.

Limitations

This study has some limitations. First, the number of cases was small. Second, we could not accurately identify the presence of intra-articular lesions in every patient with a positive fringe impingement test. Nevertheless, we confirmed that none of the patients felt pain during elbow extension with forearm pronation or supination that might have suggested intra-articular symptoms.[3,35] Third, the number of drill times differed among the patients, which was because the extent of painful areas on the bone surface was different for each patient. Hence, further investigation is required to clarify the appropriate number of drill times for tendon healing.

Conclusion

Tenodesis with bone marrow venting under local anesthesia resulted in substantial improvement in subjective patient satisfaction and positive clinical outcomes at $\geq$2 years of follow-up in patients with recalcitrant lateral epicondylitis. Moreover, patients with recalcitrant lateral epicondylitis felt more pain at the bone-tendon junction of extensors than at the tendon parenchyma. Intra-articular symptoms can be improved by stabilization of the lateral soft tissue even without treatment for intra-articular lesions.

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Supplementary Data

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