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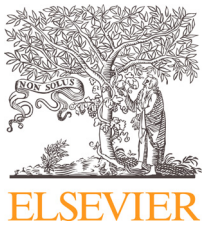

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Submuscular transposition of the ulnar nerve for persistent or recurrent cubital tunnel syndrome: Results of a prospective case series

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Summary *Background:* Submuscular transposition (SMT) of the ulnar nerve is frequently performed as secondary procedure in patients with persistent or recurrent cubital tunnel syndrome (CuTS) despite previous surgery. Good results have been reported for this surgical strategy, but mainly in small retrospective case series. The goal of the present study is therefore to analyze the results prospectively using a patient-reported outcome measure (PROM): patient-rated ulnar nerve evaluation (PRUNE).
Methods: SMT of the ulnar nerve was performed in 30 consecutive patients who were referred because of persistent or recurrent CuTS despite previous surgery. Objective outcome was measured in the outpatient clinic using the Likert scale. The PRUNE questionnaire was obtained pre-operatively, 6 weeks, 3 months, 6 months, and 12 months after the surgery. Simultaneously, 20 patients with primary surgery for CuTS, that underwent simple decompression, were followed.

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Results: Good outcome (Likert 1 or 2) was obtained in 67% after SMT for persistent/recurrent CuTS and 85% after decompression as primary surgical treatment. PRUNE scores were significantly decreased in both groups at all follow-up moments after surgery compared with preoperative for the total questionnaire and subscales "pain," "sensory/motor symptoms," and "specific activities."
In both groups, PRUNE score remained stable until 12 months of follow-up.
Conclusion: This prospective study confirms previous results from retrospective studies showing that SMT is an effective surgical option for persistent or recurrent CuTS. Prospective (randomized controlled) trials are needed to compare the effectiveness of SMT to the surgical alternative of subcutaneous transposition of the ulnar nerve.

Introduction

Cubital tunnel syndrome (CuTS) is the second most common entrapment neuropathy in the upper extremity after carpal tunnel syndrome.[1] Several surgical treatments for CuTS are available, including decompression or neurolysis and either subcutaneous transposition (SCT) or submuscular transposition (SMT).[2] Although surgery may be sufficient in the majority of patients, recurrence rates following cubital tunnel surgery range from 7% to 25%.[3] In these cases, either an SCT or SMT can be performed. Both procedures have their own advantages.[2,4] SCT is less invasive and has a shorter period of recovery, while in SMT, the nerve runs in a relatively straighter course and is partially protected by the overlying transposed muscle.

The literature is not conclusive regarding which technique has better post-operative outcomes in revision surgery,. Studies reporting these outcomes are mostly retrospective with only one prospective case series,[5] include heterogeneous patient groups with varying types of primary surgical procedures, [5,6] a varying overall severity due to referral bias and different grading systems, and a lack of a control groups.[4] To date, optimal management of failed primary surgery remains controversial, thus making the preference and/or experience of the treating surgeon the decisive factor for the type of surgery.

Therefore, we prospectively followed patients who received SMT in persistent or recurrent CuTS as well as patients with primary surgery receiving simple decompression (SD), as a reference group. The aim is to obtain more insight into the recovery of patients after different types of surgery using both an objective outcome and subjective patient-reported outcome and to add to the limited knowledge on effectiveness of revision surgery currently available in the literature.

Material and methods

Study population

All CuTS patients referred to our center between May 2014 and March 2017 and who had undergone SMT or SD were eligible for inclusion. The CuTS diagnosis was determined as a clinical diagnosis supported with a positive electromyography (EMG) (a nerve conduction block at the elbow) and/or ultrasonography (US) findings (swelling of the nerve at the elbow, determined as a cross-sectional area $\geq$ 10 mm^2). Symptoms consisted of pain, tingling, and/or progressive motor and/or sensory loss, and were classified as mild, moderate, or severe using the Dellon score (Appendix A), a modified version of the grading system described by McGowan in 1950.[7,8] Visits were planned until 3 months postoperative. Symptoms that were not relieved by the original surgery were classified as "persistent," while those that recurred after original improvement were classified as "recurrent." Patients were eligible for revision surgery in case of recurrent/persisting symptoms and signs of compression on EMG or US after a minimum of 3 months. If EMG and US were inconclusive, an magnetic resonance imaging (MRI) scan was made. All surgeries were performed by the last author (GdR).

The protocol was approved by the Ethical Medical Committee (MEC-2014–479) and informed consent was obtained from all participants before inclusion.

Surgical procedure

SMT was performed using the Z-lengthening technique, as described previously by Dellon and Coert.[9] Patients were positioned in a supine position with a tourniquet. First, the nerve was decompressed, with specific attention to potential residual compression, compression by scar tissue, and potential (sub)luxation of the nerve.

Second, muscle fibers were coagulated, a Z-lengthening incision was made through the attachment of the flexor pronator mass to the medial epicondyle,[9] the nerve was transposed, and the long end of the flexor pronator mass was attached to the remnant of the tendon on the medial epicondyle. If one or more motor branches to the flexor carpi ulnaris muscle caused tethering after transposition, an intraneural dissection was performed. In addition, the septum between the biceps and triceps was incised, resecting a v-shaped 2 cm segment up until the vessels at the base of the septum. At the end of the procedure, it was ensured that there was no residual or novel compression of the nerve proximal, distal and at the site of transposition. If present, medial antebrachial cutaneous nerve (MABCN) neuromas were surgically excised, and subsequently, the proxi-

Table 1 Patient characteristics for both groups: patients who underwent primary SD group and patients who underwent SMT for persistent or recurrent CuTS.

Patients		*Revision SMT(N = 30)*	*Primary SD(N = 20)*
Mean age in years (SD)		54.1 (14.4)	57.4 (10.8)
Men: women, N		18: 12	9: 11
Affected side left: right, N		20: 10	11: 9
Dominant side affected, N (%)		12 (40%)	5 (25%)
Dellon score, N (%)	*Mild*	11 (37%)	6 (30%)
	Moderate	2 (7%)	2 (10%)
	Severe	17 (57%)	12 (60%)
Luxation, N (%)		8 (27%)	3 (15%)
Confirmation of diagnosis, N (%)	*Ultrasound*	21 (70%)	12 (60%)
	EMG	30 (100%)	8 (40%)
	Both	21 (70%)	8 (40%)
Persistent: recurrent, N		10: 20	
Median interval between prior surgery and revision in months (range)		15 (3–366)	
One previous surgery: two previous surgeries, N		27: 3	
Type of (last performed) previous surgical technique, N (%)	*Decompression*	24 (80%)	
	SCT	6 (20%)	

SD: simple decompression; SCT: subcutaneous transposition; SMT: submuscular transposition.

mal end of the MABCN was buried in the triceps muscle without tension and secured with two or three nylon sutures to prevent dislocation.

Post-operative care consisted of 1 week of immobilization of the arm in 90° flexion. Subsequently, patients underwent 2 weeks of passive mobilization in a sling, followed by 3 weeks of active mobilization without lifting objects weighing more than 1 kg.

SD was performed using the same procedure as described in the first part of the SMT. Only difference was that the procedure was performed under local anesthesia, without tourniquet, in 80% of the patients.

Data collection

All clinical data were prospectively collected. Outcomes included the 5-point Likert score, ranging from 1 to 5 with 1 being "complete recovery" and 5 being "worsening of symptoms" of which Likert score 1 or 2, complete and almost complete recovery, were considered as good outcome (Appendix B). The Likert scale has been reported to have good reliability[10] and was determined by the surgeon in the outpatient clinic 6 weeks after surgery for the recovery of pain symptoms. Motor and sensory functions were not systematically evaluated as this is not standard of care. Data on complications were collected until 8 weeks after surgery.

The patient-reported outcome measure (PROM) included the validated and translated patient-rated ulnar nerve evaluation (PRUNE) questionnaire[11,12], focusing on ulnar nerve-related sensory/motor deficits and associated functional disability (Appendix C). This included 20 items with scores from 0 to 10, with 0 being "no pain/no difficulty" and 10 being "worst pain/completely unable." Patients received the questionnaires by mail at home pre-operatively and 6 weeks, 3 months, 6 months, and 12 months after surgery. PRUNE scores were determined for the subscales[11]: Pain (six items), sensory/motor symptoms (four items), specific activities (six items), and usual activities (four items), and the total score: equally weighs the 10 symptom items and the 10 functional items by dividing the total by 2.

Statistical analysis

Statistical analysis was performed with IBM SPSS (25th version). Pearson's correlation was used to determine whether there was a correlation between Dellon grade and pre-operative PRUNE score. A dependent *t*-test was used for analyzing difference in PRUNE scores pre- and post-operatively. The significance level was set at $P = 0.05$. An independent *t*-test was used to determine whether type of symptoms (persistent versus recurrent) and type of surgery (SD or SCT) before revision surgery influenced PRUNE outcomes pre- and post-operatively.

Results

Patient characteristics

Between May 2014 and March 2017, 30 consecutive patients with recurrent or persistent CuTS and 20 consecutive patients without previous surgery for CuTS received SMT and primary decompression, respectively. Table 1 presents patient characteristics. The median interval between prior surgery and revision surgery was 15 months (range 3 months-24 years) in the SMT group, where two surgeries were performed before 6 months (3 and 5 months) against common practice due to continuous complaints and patient's preference. Five patients (16.7%) had an interval of more than

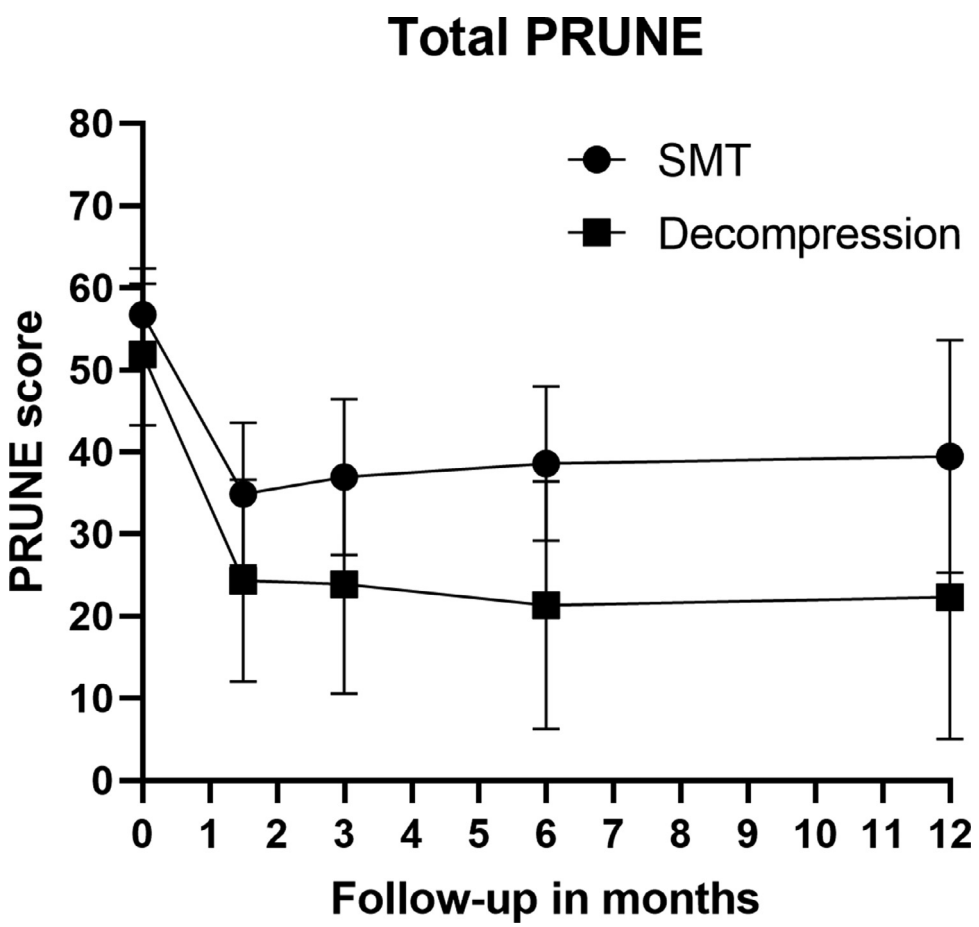

Figure 1 Scores of the PRUNE questionnaire, pre-operatively and 6 weeks, 3 months, 6 months, and 1 year after surgery. All scores are given with the 95% CI. The number of patients at each time point was 28, 28, 26, 27, and 19 for SMT, and 20, 19, 16, 14, and 10 for decompression.

5 years (5, 9.5, 11, 11.5, and 24 years). Three patients had two previous surgeries, including primary decompression followed by SCT in all three cases.

Perioperative findings

Of three patients, perioperative data were missing. All other patients had obvious pathology at the time of revision surgery. Signs of residual compression of the ulnar nerve (i.e. nerve hyperemia, incomplete release or compression at its new position) were found in 13 patients (43%). Dense scar tissue around the nerve as cause for compression was observed in 18 patients (60%). Both residual compression and new compression caused by scar tissue were observed in seven patients (23%). (Sub)luxation of the ulnar nerve was found in four patients (13%). MABCN neuromas were found and resected in patients (13%).

Post-operative outcomes

Good outcome (Likert score 1 or 2) was achieved in 20 out of 30 patients (67%) and 17 out of 20 patients (85%) at 6 weeks after SMT and decompression, respectively.

Response rates for the PRUNE in the SMT group were 28/30 patients (93%) at 6 weeks (93%), 22 (73%) at 3 months, 27 (90%) at 6 months, and 17 (57%) at 12 months after surgery. In the decompression group, the response rates were 18 (90%), 14 (70%), 13 (65%), and 10 (50%), respectively. Pre-operative PRUNE scores did not correlate with Dellon score. No differences were found in gender, age at surgery, and Dellon score between responders and non-responders.

PRUNE scores were significantly lower at all follow-up moments after surgery compared with pre-operative scores in both groups (SMT $P = 0.001$–0.025; decompression $P = 0.000$–0.002). After both surgical procedures, PRUNE scores dropped at 6 weeks, then went up from 6 weeks to 6 months before stabilizing. Differences between follow-up moments were not significant. For three out of four subscales (pain, sensory/motor symptoms, and specific activities), a similar trend was shown in which PRUNE scores did not differ between follow-up moments, but were significantly lower at all follow-up moments after surgery compared with pre-operative scores in both groups, except for specific activities at 12 months of follow-up in the SMT group (SMT, $P = 0.000$–0.019; decompression, $P = 0.000$–0.004 for pain; SMT, $P = 0.000$–0.011; decompression, $P = 0.000$–0.003 for sensory–motor symptoms; SMT, $P = 0.006$–0.051; de-

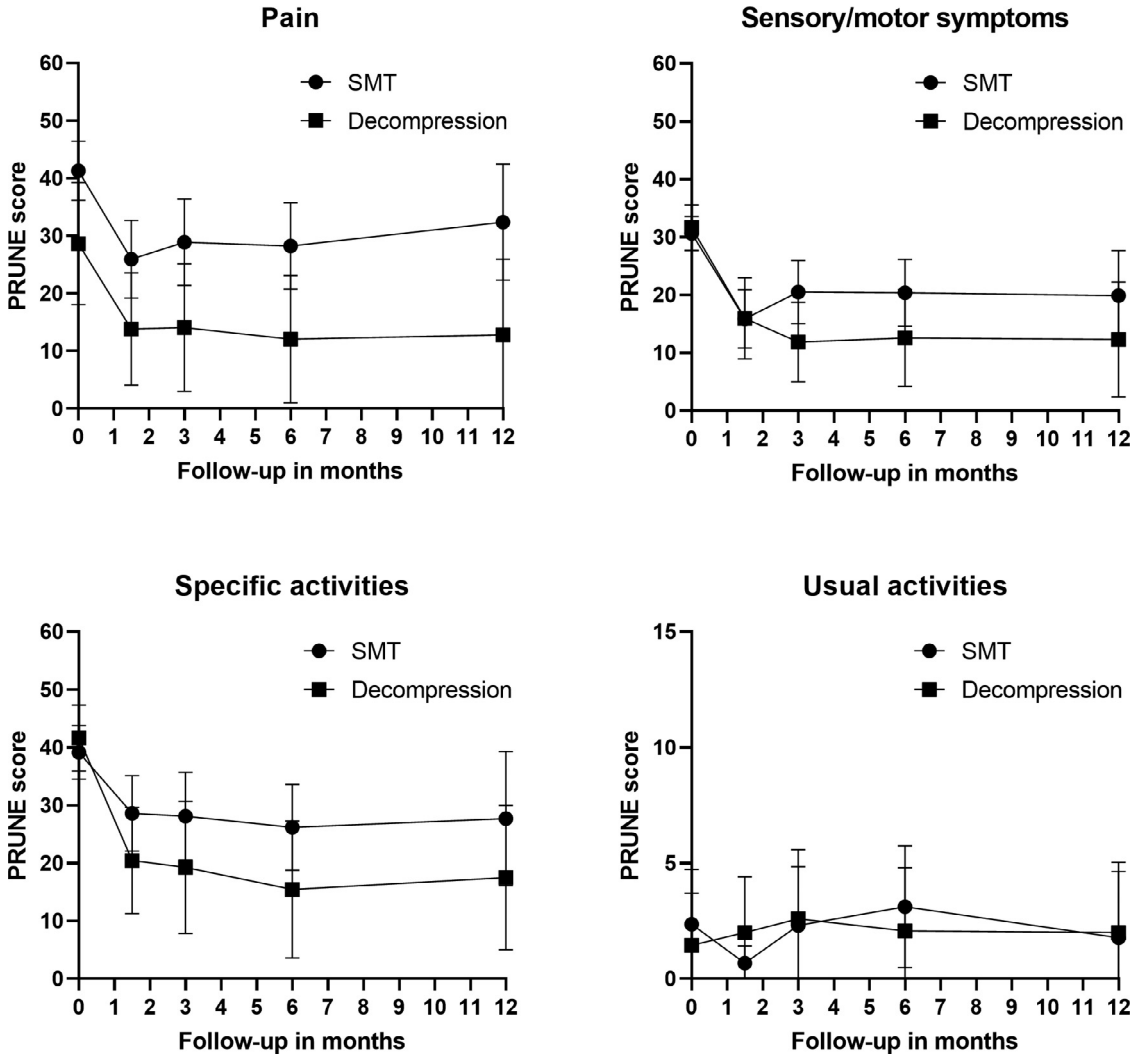

Figure 2 Scores of the four separate PRUNE subscales, pre-operatively and 6 weeks, 3 months, 6 months, and 1 year after surgery. All scores are given with the 95% CI. The number of patients at each time point was 28, 28, 26, 27, and 19 for SMT, and 20, 19, 16, 14, and 10 for decompression.

compression, $P = 0.000$–0.010 for specific activities). Other than the above-mentioned subscales, subscale usual activities, remained the same during follow-up compared with pre-operative scores (SMT, $P = 0.152$–1.000; decompression, $P = 0.332$–0.513). Figures 1 and 2 show PRUNE scores at different time points during follow-up for the total PRUNE questionnaire and the four separate subscales, respectively.

Pre- and post-operative PRUNE scores were not different in subgroups regarding type of symptoms (persistent versus recurrent; P-values = 0.107–0.785) and type of surgery (SD or SCT; P-values = 0.370–0.914) before revision surgery.

Post-operative complications

Three complications occurred after SMT: a direct post-operative hematoma, which required revision surgery, a wound infection treated with oral antibiotics, and a late intramuscular hematoma that was discovered with US imaging during follow-up. After primary decompression, instability of the ulnar nerve was found in one patient. The prevalence of complications is shown in Table 2.

Failure of improvement

Failure of improvement was present in three out of 20 patients (15%) who received SD and nine out of 30 patients who received SMT (30%). Of the latter group, almost all patients had persistent symptoms and only one patient had recurrent symptoms before revision surgery. Of the nine failures after SMT, seven and two patients had persistent and recurrent symptoms after revision surgery, respectively. Three of nine patients had signs of residual compression on US imaging/MRI (Figure 3) and received revision surgery 1 year after they received the SMT procedure. Notably, no intra-operative findings of a secondary compression of the ulnar were found under the transposed muscle. However, a

Table 2 Post-operative complications.

Type of complication	SMT(N = 30)	Primary SD (N = 20)
Wound infection	1	0
Direct hematoma	1	0
Late hematoma	1	0
Instability of the ulnar nerve	0	1
Pain following an MABCN neuroma	0	0
Numbness in the ulnar distribution	0	0
Weakening of the wrist flexion or pronation	0	0

MABCN: medial antebrachial cutaneous nerve; n: number of patients; SD: simple decompression; SMT: submuscular transposition.

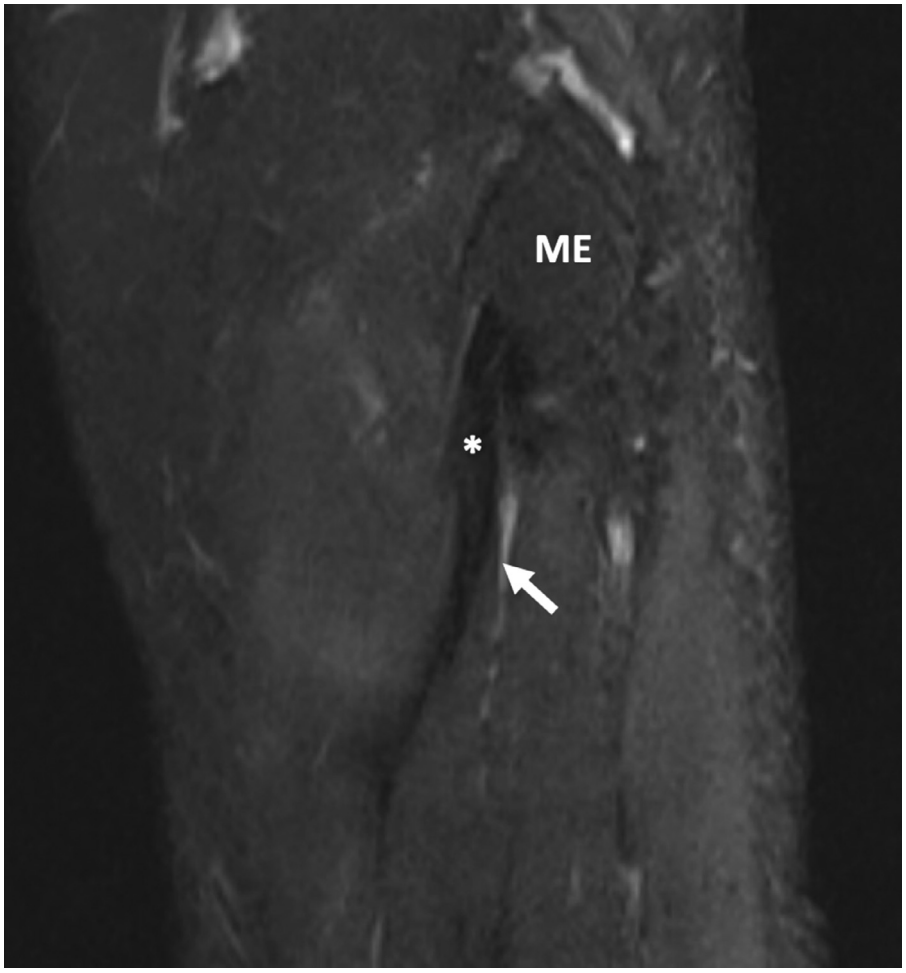

Figure 3 MRI of the elbow shows thickening of the ulnar nerve (asterisk) after submuscular transposition, just proximal to the remnant of the distal intermuscular septum (indicated by the arrow). ME stands for medial epicondyle (of the elbow).

remnant of the distal intermuscular septum was found and removed in all three patients after which two patients improved (Likert 1 and Likert 2) and one patient remained to have numbness (no paresthesias), which worsened after revision surgery (Likert 5). One patient had normal conduction of the ulnar nerve across the elbow after SMT, despite unchanged symptoms (Likert 4). In one patient, who had only slightly improved after SMT (Likert 3), residual complaints were caused by radiculopathy of C7 which completely recovered after an anterior discectomy. In one patient, who had persistent symptoms for over 20 years, extensive neurolysis with a free muscle transfer of the gracilis was performed as a last resort treatment to create a scar-free, traction-free, well-padded, and well-vascularized environment (by J.H.C.) which led to a decrease in symptoms (Likert 3).[13] One patient had a late complication of an intramuscular hematoma detected with US 4 months after surgery. Drainage did not improve symptoms. In the remaining two failures, no other causes that could explain the residual symptoms were detected.

In the primary decompression group, one of three patients had improvement of EMG and US, and was therefore not re-operated. One patient had developed a luxation of the ulnar nerve with flexion of elbow detected with dynamic US imaging. SMT performed 8 months after the first surgery resulted in complete recovery. One patient, who had worsening on EMG, was re-operated 4 months after the first surgery. Intraoperatively, there was extensive scarring around the nerve. Subsequent SMT resulted in complete relief and also recovery of weakness.

Discussion

The results of this prospective study confirm the results from our previous retrospective study in that SMT is an effective option for the surgical treatment of persistent or recurrent CuTS[4]. After decompression, PRUNE scores dropped significantly and remained the same up to 1 year after surgery. After SMT, scores for the PRUNE dropped significantly, but slightly tend to increase again and stabilized after 6 months. Possible explanation for the significant decrease at 6 weeks, and the slight worsening between 6 weeks and 6 months could be that patients were advised not to lift heavy objects up to 6 weeks after SMT and that afterwards residual pain symptoms slightly intensified due to an increased load on the affected arm. Nevertheless, total PRUNE scores at all follow-up moments were significantly decreased compared with pre-operatively in both groups.

Our mean improvement in PRUNE score after SMT was in line with earlier studies in which PRUNE was determined in patients receiving either SMT or SCT.[14,15] The proportion of recovery after revision surgery (Likert 1 and Likert 2) in the present study was slightly higher (67%) compared with our previous study (62%) and other recent studies (57% [16] and 42% [17]), possibly explained by the homogenous patient group and the limited amount of patients with more than one previous surgery (10%) compared with our previous study (30%) and other studies, performed in tertiary and quaternary care centers.[4] A meta-analyses of Natroshvili et al. found a pooled overall improvement (also including slightly improved patients) of 85% and a complete recovery (only Likert 1) of 23%.[5] The rate of complications was higher after SMT compared with decompression, which is also found by a recent meta-analyses of Said et al.[18]

Another notable finding was the severity of CuTS, which was comparable in both groups. More than half of the patients had severe CuTS in both groups. As described by Dellon before, the severity of CuTS indicates the risk of revision surgery in the follow-up years (21% in 6 years, 33% in 3 years, and 62% in 3 years after primary surgery in mild, moderate, and severe CuTS, respectively).[7] We did not find a correlation between severity, expressed by the Dellon grade, and pre-operative PRUNE score. A study comparing grip strength, pinch strength, and sensory threshold found that only grip strength had a moderate, significant correlation with PRUNE score ($R = -0.38$). Better correlations with PRUNE score were found at 2 years following surgery. Overall, changes in grip strength, pinch strength, and sensation accounted for 20% of the variance in PRUNE changes.[15]

The prospective design of this study made it possible to analyze failed surgeries in detail. Out of the nine failures of SMT, a potential explanation was found in five cases. Three cases had residual compression at the distal intermuscular septum. Two patients improved after revision surgery, stressing the importance of substantial release of this septum, as previously reported by Felder et al.[19] Other important findings were the double crush injury (CuTS and cervical root compression) and a late hematoma. Those cases illustrate the importance of careful clinical examination and usefulness of additional imaging in case of doubt or persistence of symptoms after SMT, as mentioned by Giostad et al.[16]. In comparison with SCT, SMT obviously poses a higher risk for the development of a post-operative hematoma due to transection of a highly vascularized muscle.[20]

Also, in the case of luxation, preference may be SMT or decompression, depending on the surgeon. In our study, three patients with luxation of the ulnar nerve were treated with SD of which two improved (Likert 2) and one did not improve (Likert 4) as a result of a double crush injury (cervical root compression, as described in the results section).

This study had some important advantages. The prospective design of this study made it possible to evaluate PROMs at several standardized time points during the first year after surgery, which is increasingly important since objective measures might not adequately reflect success of a surgical procedure. Modern medicine is shifting toward feedback of patients and having a better understanding of patients' experience. Given the lack of use of PROMs in current literature, we used patients undergoing primary decompression as a reference group. Though outcomes cannot be compared due to different indications and surgical techniques, data on both groups give a better insight in PRUNE outcomes in CuTS surgery. This cohort is also more homogeneous than most previous performed studies,[21-24] due to the single-center and single-surgeon design, and since sampling bias, referral bias, selection bias, and were kept minimal, since all eligible patients were included, patients were referred from surrounding local hospitals and SMT was the only procedure performed by recurrent/persisting symptoms.

The present study also has several potential limitations. The PRUNE is shown to be a reliable and valid tool for the assessment of symptoms of CuTS and functional complaints[11], also compared with other scales (the SF-36 and Bishop)[25]. However, in our population, the second part of the PRUNE was sometimes found difficult to answer, especially if the affected arm was not that of their dominant hand. This was the case in 40% of patients in which PRUNE scores may be underestimated. This underestimation may cause the low pre-operative score for the subscale "usual activities" and, therefore, no difference pre- and post-operative. This potential impact of handedness on outcome has recently been investigated by Philip et al.[26] They found that impairment of the dominant hand is associated with reduced ability to perform specific activities, although this reduced ability is not reflected in standardized measures of disability and health status. In line with this, there was no statistically significant difference in PRUNE scores between patients with and without their dominant hand affected, and total PRUNE score was still significantly lowered at follow-up moments. However, this shortcoming should be considered in future stud-

ies using PROMs including questions on specific/daily activities. Furthermore, in the present study, we did not measure the recovery of sensation and strength after surgery. Main reason for this was that it requires close monitoring of all patients in a standardized manner for the entire follow-up, which is difficult for a prospective study and potentially also lowers the willingness of patients to participate. Finally, only 57% and 50% of patients with SMT and decompression completed PRUNE questionnaires at all follow-up moments up to 12 months of follow-up, which may underestimate the long-term change in PRUNE score. Finally, in this study, we did not report the potential side effects that surgery may have on functioning of the elbow due to contractures[21] or pain due to transection of the flexor pronator mass. Although these side effects, in our experience, are not frequently observed, the potential of occurrence should be considered and weighted against the alternative option of SCT.

Conclusion

The results of this prospective study confirm that SMT is an effective option for persistent or recurrent CuTS. Success rates in this study were higher than found in our previous retrospective study, possibly due to a decrease in referral bias with only three patients (10%) who had undergone more than one previous surgery. Results for the PRUNE score after decompression and SMT provided interesting insights in the course of recovery after surgery. These results can serve as baseline for future prospective (randomized controlled) trials on the comparison of different surgical techniques for persistent or recurrent CuTS, as for example SMT versus SCT, as more (long-term) follow-up of both objective and subjective patient-reported outcomes are necessary.

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Conflict of Interest

All authors declare no conflicts of interest.

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Ethical approval

The protocol was approved by the Ethical Medical Committee (MEC-2014-479) and informed consent was obtained from all participants before inclusion.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2022.04.045.

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