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An Outcome Study for Ulnar Neuropathy at the Elbow: A Multicenter Study by the SUN study group

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Abstract

Background—Many instruments have been developed to measure upper extremity disability, but few have been applied to ulnar neuropathy at the elbow (UNE).

Objective—We measured patient outcomes following ulnar nerve decompression to 1) identify the most appropriate outcomes tools for UNE and 2) describe outcomes following ulnar nerve decompression.

Methods—Thirty-nine patients from 5 centers were followed prospectively after nerve decompression. Outcomes were measured preoperatively, 6-weeks, 3-months, 6-months, and 12-months postoperatively. Each patient completed the Michigan Hand Questionnaire (MHQ), Carpal Tunnel Questionnaire (CTQ), and Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaires. Grip, key-pinch strength, Semmes-Weinstein monofilament (SWM) and 2-point discrimination (2PD) were measured. Construct validity was calculated using Spearman correlation coefficients between questionnaire scores and physical and sensory measures. Responsiveness was assessed by standardized response means.

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Results—Key pinch ($p=0.008$) and SWM testing of the ulnar ring ($p<0.001$) and small finger (radial: $p=0.004$; ulnar: $p<0.001$) improved following decompression. 2PD improved significantly across the radial ($p=0.009$) and ulnar ($p=0.007$) small finger. Improved symptoms and function were noted by the CTQ (Preoperative CTQ symptom score 2.73 vs. 1.90 postoperatively, $p<0.001$), DASH ($p<0.001$), and MHQ: function ($p<0.001$), activities of daily living ($p=0.003$), work ($p=0.006$), pain ($p<0.001$), and satisfaction ($p<0.001$). All surveys demonstrated strong construct validity, defined by correlation with functional outcomes, but MHQ and CTQ symptom instruments demonstrated the highest responsiveness.

Conclusions—Patient-reported outcomes improve following ulnar nerve decompression, including pain, function and satisfaction. The MHQ and CTQ are more responsive than the DASH for isolated UNE treated with decompression.

Keywords

ulnar neuropathy at the elbow; simple decompression; outcomes; Carpal Tunnel Questionnaire; Michigan Hand Questionnaire

Ulnar neuropathy at the elbow (UNE) is the second most common peripheral compressive neuropathy in the upper extremity following carpal tunnel syndrome (CTS), and affects approximately 1% of individuals in the United States.¹ Patients with UNE commonly complain of debilitating numbness, pain, and, in severe cases, weakness in the affected regions. Although functional measures such as sensory testing, grip and pinch strength have been used to measure treatment effectiveness, patient-reported outcomes following UNE treatment have not been systematically assessed, and the optimal treatment remains controversial.²

Surgical treatments for UNE include simple decompression, decompression and medial epicondylectomy, subcutaneous anterior transposition, intramuscular anterior transposition, and submuscular anterior transposition. Several meta-analyses report no significant differences in effectiveness among these techniques. However, these studies are limited by heterogeneous measures of UNE outcomes, and it is therefore difficult to compare treatment effectiveness across studies.^{3,4} For example, a recent systematic review identified 21 different health outcomes measures used to evaluate UNE, none of which has yet been shown to be reliable, reproducible or valid.⁵ However, capturing patient-reported outcomes is essential to identify effective treatments and measure surgical quality. For upper extremity disability, traditional indicators, such as mortality or hospital readmission rates, are exceedingly rare and not sensitive enough to distinguish variations in patient outcomes.⁶ Therefore, measures of patient satisfaction and disability are important endpoints to explore patient outcomes following treatment.

Many instruments have been introduced to measure outcomes for hand and upper extremity conditions.⁷ Before developing a new questionnaire specifically for UNE, it is prudent to investigate the application of existing questionnaires for UNE. For example, in the 1990s, the Carpal Tunnel Questionnaire (CTQ) was developed to measure self-reported outcomes among CTS patients, and resulted in a greater understanding of the effectiveness of operative and non-operative treatments for CTS.^{8–10} Additionally, the Michigan Hand

Questionnaire (MHQ) and the Disabilities of the Arm, Shoulder and Hand (DASH) have also been extensively investigated and shown to demonstrate validity and responsiveness for CTS.¹¹ These self-reported instruments were found to be more responsive, or able to detect clinically significant improvement, than traditional physical and sensory measures.¹² Because of the similarity of CTS and UNE sequelae and disability, it is feasible that these self-reported outcomes questionnaires could be applied to UNE.

Advances in the treatment of UNE depend on identifying a responsive outcomes tool to measure patient symptoms and functional changes after treatment. Therefore, we established a multicenter collaborative study group, the Surgery of the Ulnar Nerve (SUN) study group, consisting of 5 different centers to prospectively follow a cohort of UNE patients treated with simple decompression surgery for 1 year. To identify the best outcomes instrument, we examined the psychometric performance of three popular questionnaires, the CTQ, DASH, and MHQ in this cohort. Therefore, the specific aims of this study are to 1) identify the most appropriate outcomes tool for UNE and 2) describe patient-reported outcomes following simple decompression of the ulnar nerve at the elbow.

MATERIALS AND METHODS

Study sample

Consecutive patients were prospectively recruited from 5 centers to participate in this study. Inclusion criteria for eligibility included being 18 years of age or older, ability to read, understand and complete the questionnaires in English, electrodiagnostic confirmation of UNE (ulnar nerve conduction velocity of less than 50m/sec across the elbow), symptoms consistent with UNE based on surgeon assessment, and treatment with simple decompression surgery. Exclusion criteria included a history of trauma to the injured elbow, recurrent UNE or prior ulnar nerve surgery on the same elbow, history of dementia, Alzheimer's disease, traumatic brain injury or other serious psychiatric disorders, and history of substance abuse. Additionally, patients with concomitant neuropathic conditions, such as carpal tunnel syndrome in the affected extremity, were excluded as these can influence outcomes assessment. All centers acquired appropriate Institutional Review Board approvals for this study.

Ulnar nerve decompression at the elbow

Because the current evidence reports no significant differences in effectiveness among the available types of surgeries for UNE, only patients who underwent simple ulnar nerve decompression were included in the cohort.^{3,4} At the study inception, to decompress the ulnar nerve at the elbow, a 3-centimeter incision was made posterior to the medial epicondyle, taking care to preserve the medial antebrachial cutaneous nerve. The ulnar nerve was identified proximally, and Osborne's ligament was divided. The elbow was then flexed to determine if the ulnar nerve subluxed anteriorly. If the ulnar nerve subluxed over the medial epicondyle, an anterior transposition procedure was performed. All patients who underwent anterior transposition were subsequently excluded from the study (n=1). Postoperatively, patients were fitted with a soft dressing and no formal therapy was prescribed. Patients were advised to refrain from strenuous activity for 6 weeks following

the operation, but no specific restrictions regarding elbow flexion or extension were included. All participating surgeons in this multicenter study have received formal training in peripheral nerve surgery or hand surgery and have the certificate of added qualification in hand surgery. All surgeons agreed upon the standard operative technique established by the senior author to standardize the approach to ulnar nerve decompression at the elbow.¹³ The length of the incision was adjusted based on surgeon preference and patient body habitus.

Measurements

Physical assessment—Physical assessments were performed preoperatively, at 6-weeks, 3-months, 6-months, and 12-months postoperatively. Dellon scores were estimated preoperatively.¹⁴ Perception of touch with the Semmes-Weinstein monofilament (SWM) (Smith & Nephew Roylan, Inc., Germantown, WI) was performed on the radial and ulnar sides of the ring and small finger of the affected hand. Tactile gnosis with the static 2-point discrimination (2PD) (MacKinnon-Dellon Discriminator; Lafayette Instruments, Lafayette, IN) test was conducted on the radial and ulnar side of the ring and small fingers of the injured hand. Grip strength and key-pinch strengths were measured bilaterally with a Jamar dynamometer (Jamar, Bolingbrook, IL) and a pinch gauge (B & L Engineering, Tustin, CA), respectively. Three grip strength and key-pinch strength measurements were recorded, and an average value noted for analysis. For grip strength calculations, a 10% strength increase in the right hand was accounted for if the patient was right-hand dominant but did not compensate if the left hand was dominant.¹⁵ Key-pinch strengths were recorded for the injured side only.

Questionnaires—The Michigan Hand Questionnaire (MHQ), Disabilities of Hand and Shoulder (DASH) questionnaire, and the Carpal Tunnel Questionnaire (CTQ) were administered at each of the five different time points. The MHQ is a 37-item hand specific outcomes instrument with 6 domains: (1) overall hand function, (2) activities of daily living (ADLs), (3) pain, (4) work performance, (5) aesthetics, and (6) patient satisfaction. The work domain considers both the left and right hands in the score. The other 5 domains assess the left and right hands separately, and only the injured side was scored. Incorporating all 6 domain scores, a total overall MHQ score was also calculated.^{16,17} The DASH questionnaire is a 30-item questionnaire assessing the disability and symptoms in patients with upper extremity conditions. When more than 3 questions were missing, the DASH disability/symptom score for that time-point was deemed invalid and not used in the analysis.¹⁸ Finally, the CTQ is a 19-item condition-specific questionnaire with two separate domains that yield a symptom severity and functional status score for the affected hand.^{8,10}

Statistical analysis

Power analysis—Descriptive statistics were used to calculate means and standard deviations, and all statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics, Version 19 (2010); Amonk, New York). The minimal clinically important difference (MCID) of each survey among UNE patients was used to calculate sample size. For example, at 12 months, the MCID of the DASH is 7 points, the CTQ symptom score is 0.4 points, and the CTQ function score is 0.7 points. The MHQ MCID is highest for the pain domain at 13 points. Therefore, assuming a 2-sided test with an alpha of 0.05, 14 patients

are needed to detect a significant difference in the CTQ function score, 33 to detect a significant difference in the CTQ symptom score, 39 patient to detect a significant difference in the MHQ pain score with 90% power. For the DASH, assuming a 2-sided test with an alpha of 0.05, 52 patients are needed to detect a significant difference with 80% power.

Assessment of outcomes—Mean and standard deviation of each outcome were compared using ANOVA, stratified by severity. In order to examine longitudinal differences in objective measurements and patient-reported outcomes over time, general linear mixed regression models were used to examine the difference among mean outcomes at distinct time points, controlling for the clustering of patients within each time period. Each model was adjusted for preoperative Dellon score (mild, moderate, or severe neuropathy) in order to control for preoperative severity of symptoms.¹⁴

Psychometric outcomes: Validity and Responsiveness—Validity is the ability of an instrument to correctly measure a concept. For example, patients who score poorly on the MHQ, indicating worse hand function, would be expected to also have poor performance in other aspects of hand functioning, such as grip strength and dexterity with specific tasks. Although specific types of validity exist, construct validity is most often used to establish the validity of outcomes questionnaires.¹⁹ Construct validity describes the extent to which the scales in the survey instrument behave as expected. For example, patients who report high pain scores would be expected to endorse difficulty with functioning, ADLs and work performance. Spearman's correlation coefficients were used to examine the relationships between the MHQ, CTQ, and DASH and functional outcomes at 12 months and quantify construct validity.

Responsiveness is defined as the ability of an instrument to detect relevant changes in an outcome of interest over time.¹⁷ Responsiveness to clinical change following ulnar nerve decompression was measured at each postoperative time point for the MHQ, DASH, and CTQ using standardized response means (SRM). The SRM is calculated as the mean difference between the preoperative and follow-up scores divided by the standard deviation of the difference. Ideally, a more sensitive instrument should have a higher SRM.²⁰ Using Cohen's effect size definition, we assumed that an SRM of 0.2 corresponds with a small effect size, 0.5 corresponds with a medium effect size, and 0.8 corresponds with a large effect size.²¹

RESULTS

Study sample

Ninety-four met the inclusion and exclusion criteria and were eligible to participate in the study. (Figure 1) Thirty-four patients declined due to the required time commitment (n=27), lack of interest (n=6), and logistical constraints (n=1). Sixty patients were consented to participate. Seventeen patients were excluded, withdrew from the study, or did not have complete follow-up leaving 39 patients who were followed for 12-months. The demographic characteristics of the 39 enrolled patients are shown in Table 1. In this sample, 18 (46.2%) were female, and 21 were male (53.8%). The mean age of the patients was 50.6 years (SD

± 11.7 years) with a range of 28 to 79 years. Finally, 81.6% of patients were white, 94.9% had completed high school or received higher education (94.9%), and 41% reported annual incomes greater than \$70,000.

Functional outcomes following ulnar nerve decompression

Table 2 displays the functional outcomes of UNE patients following nerve decompression. Key pinch ($p=0.008$) strength improved significantly following decompression, but not grip strength ($p=0.08$). SWM testing was performed for the ring and small finger to determine changes in sensation threshold. Following decompression, a significant decline in filament size to trigger sensation was identified along the ulnar aspect of the ring ($p<0.001$) and the radial ($p=0.004$) and ulnar ($p<0.001$) aspect of the small finger. Two-point discrimination improved significantly across the radial ($p=0.009$) and ulnar ($p=0.007$) aspect of the small finger.

Table 3 displays the pre- and postoperative functional outcomes stratified by preoperative severity. There were no significant differences in grip or pinch strength over the time period when stratified by Dellon score. For SWM testing, sensation was slightly poorer among patients with severe ulnar neuropathy for small finger preoperatively (radial: $p=0.02$; ulnar: $p=0.001$) and significantly worse at 6 weeks (radial: $p=0.003$; ulnar: $p=0.004$). Patients with greater severity also had poorer 2PD preoperatively (radial: $p=0.02$; ulnar: $p=0.04$). At 6 weeks, 2PD remained poorer for patients with severe ulnar neuropathy (radial: $p=0.001$; ulnar: $p<0.001$). After 3 months, for both SWM and 2PD testing, sensation among patients with severe ulnar neuropathy did not show difference from patients with milder neuropathy.

Figure 2 displays the number of patients who experienced improvement or worsening in 2PD by the end of the study period. The majority of patients experienced minimal or no change in 2PD following decompression for the ulnar aspect of the ring finger (slight worsening: 18 patients, no change: 6 patients), radial aspect of the small finger (slight worsening: 19 patients, no change: 6 patients), and ulnar aspect of the small finger (slight worsening: 19 patients, no change: 2 patients). Eight patients experienced improved 2PD along the ulnar aspect of the ring finger, 7 along the radial aspect of the small finger, and 10 along the ulnar aspect of the small finger.

Patient-reported outcomes following ulnar nerve decompression

Table 4 displays the change in patient reported outcomes over time following ulnar nerve decompression. As measured by the CTQ, patients reported significant improvement in symptoms (Preoperative CTQ symptom score: 2.73 vs. 1.90 postoperatively, $p<0.001$) and function (Preoperative CTQ function score: 2.10 vs. 1.72 postoperatively, $p=0.01$). DASH disability scores improved from 30.4 preoperatively to 19.8 at 1 year following decompression ($p<0.001$). The MHQ measures hand performance along 6 domains, and all were significantly improved at 1 year including function ($p<0.001$), activities of daily living ($p=0.002$), work ($p=0.004$), pain ($p=0.01$), aesthetic appearance ($p=0.03$) and satisfaction ($p<0.001$). Finally, overall MHQ score improved significantly, from 55.5 preoperatively to 70.7 at 1-year follow-up ($p<0.001$). Table 5 displays pre- and post-operative patient reported outcomes stratified by severity. MHQ function of severe UNE patients was significant

poorer than milder cases preoperatively (32.2 vs. 57.9, $p=0.03$) and at 6 weeks (48.3 vs. 68.8, $p=0.03$). Satisfaction among severe patients was also worse preoperatively (18.5 vs. 40.4, $p=0.02$). However, there were no significant differences in patient-reported outcomes after 6 weeks following ulnar nerve decompression by preoperative ulnar nerve severity.

Complications

Four patients experienced complications post-operatively. One patient experienced substantial scar tenderness. Two patients developed superficial wound dehiscence, and one patient developed a subsequent superficial wound infection. Finally, one patient required re-operation with anterior subcutaneous transposition for persistent symptoms, and was thus excluded from the study.

Psychometric properties of patient-reported outcome instruments

Validity—To compare the validity of the CTQ, the MHQ and DASH, Spearman's correlation coefficients were calculated between the scores at 3 months and objective functional measurements. (Table 6) All correlations between the objective measures and outcomes scores were in the expected direction. The CTQ Symptom Score was significantly correlated with grip strength ($r=-0.37$, $p<0.05$), SWM measures of the ring ($r=0.37$, $p<0.05$) and small ($r=0.42$, $p<0.05$), and 2PD of the small finger ($r=0.35$, $p<0.05$). The CTQ function score was correlated with grip strength ($r=-0.39$, $p<0.05$), SWM measures of the ring ($r=0.36$, $p<0.05$) and small ($r=0.38$, $p<0.05$) fingers, and 2PD of the ring ($r=0.44$, $p<0.05$) and small ($r=0.47$, $p<0.05$) fingers. The DASH score was correlated with grip strength ($r=-0.44$, $p<0.05$), SW measures of the ring ($r=0.45$, $p<0.05$) and small ($r=0.44$, $p<0.05$) fingers, and 2PD of the ring ($r=0.38$, $p<0.05$) and small ($r=0.37$, $p<0.05$) fingers. All domains of the MHQ were correlated with functional measures with the exception of aesthetics. The function domain of the MHQ was correlated with grip strength ($r=0.34$, $p<0.05$), and the activities of daily living domain correlated with 2PD of the ring finger ($r=-0.35$, $p<0.05$). The work domain was correlated with both SWM values of the ring finger ($r=-0.37$, $p<0.05$), and 2PD of the ring ($r=-0.47$, $p<0.05$) and small ($r=-0.49$, $p<0.05$) fingers. Satisfaction was correlated with SWM values of the ring finger ($r=-0.38$, $p<0.05$), and 2PD of the ring finger ($r=-0.47$, $p<0.05$). Finally, overall MHQ score was correlated with SWM values of the ring ($r=-0.38$, $p<0.05$) and small ($r=-0.35$, $p<0.05$) fingers, and 2PD of the ring ($r=-0.43$, $p<0.05$) and small ($r=0.37$, $p<0.05$) fingers.

Responsiveness—Figure 3 illustrates the responsiveness of the MHQ, measured by SRM, following ulnar nerve decompression at each time point. An SRM of 0.8 or greater is considered strong effect, 0.5 or greater moderate effect, and 0.2 or greater a mild effect. The satisfaction domain of the MHQ demonstrated strongest responsiveness to clinical change at each time point (6 weeks: 0.81; 3 months: 0.97; 6 months: 1.26, and 1 year: 0.95). In addition, the overall MHQ score demonstrated moderate responsiveness at each time point (6 weeks: 0.79; 3 months: 0.77; 6 months: 1.10, and 1 year: 0.78). The function domain was also moderately responsive at each time point (6 weeks: 0.68; 3 months: 0.69; 6 months: 0.84, and 1 year: 0.73), as well as the pain domain (6 weeks: 0.75; 3 months: 0.62; 6 months: 0.65, and 1 year: 0.67). The activities of daily living domain were also moderately responsive (6 weeks: 0.62, 3 months 0.53, 6 months: 0.88, 1 year: 0.56. However, aesthetic

and work domains of the MHQ were overall the least responsive to clinical change over time.

The DASH demonstrated moderate responsiveness over the study period (6 weeks: 0.49; 3 months: 0.74; 6 months: 0.63, and 1 year: 0.64) (Figure 4). Finally, the CTQ symptom score demonstrated strong responsiveness over the study period (6 weeks: 0.99; 3 months: 0.97; 6 months: 1.13, and 1 year: 1.05) (Figure 5). However, the CTQ function domain demonstrated only moderate responsiveness (6 weeks: 0.82; 3 months: 0.66; 6 months: 0.59, and 1 year: 0.53).

DISCUSSION

Patient reported outcomes, such as self-reported disability, pain, and function, are essential endpoints to measure to identify optimal treatment strategies for hand-related conditions.^{7,8,16–18} Self-reported outcomes questionnaires must be reliable, valid, and responsive to identify change over time, and selecting an instrument requires a rigorous examination of its psychometric properties. In this study of UNE patients, three commonly used surveys, the CTQ, MHQ, and DASH, were able to adequately detect postoperative improvement following simple ulnar nerve decompression. Each survey demonstrated strong construct validity, as defined by correlation with functional outcomes, as well as responsiveness over time.²² Functional testing identified improvement in grip and pinch strength, as well as improvement in sensory threshold and density. Preoperative severity did not significantly influence postoperative outcomes. Finally, marked differences were noted in patient-reported outcomes following decompression as measured by all three surveys.

To date, only 2 studies have examined the performance of self-reported outcomes instruments designed specifically for UNE patients. Mondelli and colleagues developed a new questionnaire for UNE, the Ulnar Neuropathy at the Elbow Questionnaire (UNEQ).²³ Similar to the CTQ, the UNEQ is a disease-specific questionnaire composed of 9 questions emphasizing symptoms in the ring and small fingers related to elbow bending. Compared with the CTQ, the UNEQ is moderately responsive for assessing conservative treatments for UNE, and the CTQ was poorly responsive in this relatively small sample. Similarly, Zimmerman and colleagues compared the DASH and CTQ among UNE patients.²⁴ The study assessed criterion validity for DASH and CTQ, using the DASH as the “gold standard.” In this sample, the CTQ symptom and function scores were strongly correlated with DASH scores. However, criterion validity is a challenging psychometric property to assess because typically no “gold standard” exists. In fact, the only exception of the existence of a “gold standard” for assessing criterion validity is when a shortened instrument is compared to the original long instrument, in which case the latter is considered the gold standard.^{25,26} In our study, we relied on comparison with functional measures to establish validity given a lack of accepted gold standard by which UNE outcomes can be measured.

Limitations

There are several limitations to this study. First, 28% of the originally enrolled study subjects were unable to be followed despite efforts to encourage continued participation with repeated calls and mailings (Figure 1). Losses to follow-up decrease the sample size

and may have introduced attrition bias if these individuals were systematically different than our study population. We did not include a control group cohort of patients who were managed expectantly, and we cannot comment on the effectiveness of surgical intervention compared with conservative management. Additionally, we did not specifically exclude patients with diabetes, which may have confounded our results. The possibility of worker's compensation or litigation was not explored in this analysis, which may have influenced our findings. Electrodiagnostic and nerve conduction studies were performed according to the protocols at each institution, and imaging techniques were not specifically employed. Therefore, we may have failed to capture some patients with more subtle presentations of UNE. There was little socioeconomic diversity in this sample, and our results may not be generalizable to patients with different ethnic or educational backgrounds. However, this sample does represent patients drawn from five centers including both academic centers and specialty practices from the Midwest and east coast, as well as patients who were recruited from a range of specialties that included neurosurgery, orthopedic surgery, and plastic surgery patients. Furthermore, continued changes in ulnar nerve function may have occurred beyond 1 year, which was not captured in our analysis. Although 4 patients in this study experienced complications, this rate is not significantly different than previously reported in the literature.^{27,28} Finally, we began our assessment of outcomes at 6 weeks following surgery, and the majority of patients experienced only modest gains in functional outcomes such as 2PD. Future studies that assess patients with varying degrees of neuropathy at earlier, more frequent intervals may better define the rate and amount of improvement following decompression in order to provide a better estimate of recovery for patients undergoing this common procedure.

Implications

The need for reliable and valid instruments of health outcomes is two-fold. First, it is difficult to combine results of many studies meaningfully when different outcomes measures are used by different investigators.⁵ Second, instruments previously unpublished or not validated may result in biased results. In a review of schizophrenia clinical trials, authors who used unpublished measurement instruments were more likely than validated instruments to report that a treatment intervention was more effective and superior to a control group.¹⁵ Thus, careful examination of the measurement properties of an outcomes questionnaire for a specific target condition is important for objectively evaluating treatment outcomes. Finally, patient-reported outcomes are an important component of treatment effectiveness. Empiric endpoints for nerve compression syndromes, such as grip strength and sensation, can be measured efficiently in a standardized fashion and easily compared across centers. Conversely, patient-reported outcomes such as satisfaction may have more inherent noise due to modifying factors and confounding effects, but provide information that cannot be captured well objectively, such as postoperative pain and aesthetic outcome. Our findings are consistent with previous studies in which patient-reported outcomes are much more responsive as measured by validated outcomes questionnaires such as the MHQ and the CTQ than physical measures such as grip strength and 2-point discrimination.^{11,12} Therefore, both complement each other and should be taken together when considering the effectiveness of surgical treatment.

CONCLUSION

Given the extensive repertoire of outcomes instruments for the upper extremity, it is reasonable to explore the use of dominant outcomes questionnaires in hand surgery, such as the MHQ, CTQ and DASH, to assess UNE outcomes. This study demonstrates that patient-reported hand function improves following ulnar nerve decompression, and can be reliably measured with existing questionnaires. Furthermore, these instruments appear to measure different dimensions of clinical outcomes compared with traditional physical and sensory measures of neuromuscular impairment. In this study, the MHQ and the CTQ-Symptom demonstrated the greatest responsiveness to clinical change during this study period. We advocate that these instruments may be most useful to clinicians and researchers who are attempting to characterize improvement in ulnar nerve function following decompression at the elbow. Currently, an abbreviated version of the CTQ does not exist, but the MHQ has undergone item reduction to create a shortened version.²⁹ This version has been examined among patients with carpal tunnel syndrome, but not for patients with UNE, and further study is warranted to describe its responsiveness for this population. Future studies using these instruments that compare all surgical options over a longer period of time may identify predictors of outcomes, examine trends in recovery, and elucidate best treatment practices for this compression neuropathy of the ulnar nerve.

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REFERENCES

1. Shin R, Ring D. The ulnar nerve in elbow trauma. *The Journal of bone and joint surgery. American volume*. 2007 May; 89(5):1108–1116. [PubMed: 17473151]
2. Chung KC. Treatment of ulnar nerve compression at the elbow. *The Journal of hand surgery*. 2008 Nov; 33(9):1625–1627. [PubMed: 18984348]
3. Macadam SA, Gandhi R, Bezuhly M, Lefaivre KA. Simple decompression versus anterior subcutaneous and submuscular transposition of the ulnar nerve for cubital tunnel syndrome: a meta-analysis. *The Journal of hand surgery*. 2008 Oct.33(8) 1314 e1311-1312.
4. Caliendo P, La Torre G, Padua R, Giannini F, Padua L. Treatment for ulnar neuropathy at the elbow. *Cochrane database of systematic reviews*. 2011; (2):CD006839. [PubMed: 21328287]
5. Macadam SA, Bezuhly M, Lefaivre KA. Outcomes measures used to assess results after surgery for cubital tunnel syndrome: a systematic review of the literature. *The Journal of hand surgery*. 2009 Oct; 34(8):1482–1491. e1485. [PubMed: 19801108]
6. Birkmeyer JD, Dimick JB, Birkmeyer NJ. Measuring the quality of surgical care: structure, process, or outcomes? *J Am Coll Surg*. 2004 Apr; 198(4):626–632. [PubMed: 15051016]
7. Alderman AK, Chung KC. Measuring outcomes in hand surgery. *Clin Plast Surg*. 2008 Apr; 35(2): 239–250. [PubMed: 18298996]

8. Katz JN, Gelberman RH, Wright EA, Lew RA, Liang MH. Responsiveness of self-reported and objective measures of disease severity in carpal tunnel syndrome. *Medical care*. 1994 Nov; 32(11): 1127–1133. [PubMed: 7967853]
9. Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability, and responsiveness of the Disabilities of the Arm, Shoulder and Hand outcome measure in different regions of the upper extremity. *J Hand Ther*. 2001 Apr-Jun;14(2): 128–146. [PubMed: 11382253]
10. Levine DW, Simmons BP, Koris MJ, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *The Journal of bone and joint surgery. American volume*. 1993 Nov; 75(11):1585–1592. [PubMed: 8245050]
11. Kotsis SV, Chung KC. Responsiveness of the Michigan Hand Outcomes Questionnaire and the Disabilities of the Arm, Shoulder and Hand questionnaire in carpal tunnel surgery. *The Journal of hand surgery*. 2005 Jan; 30(1):81–86. [PubMed: 15680560]
12. Kotsis SV, Lau FH, Chung KC. Responsiveness of the Michigan Hand Outcomes Questionnaire and physical measurements in outcome studies of distal radius fracture treatment. *The Journal of hand surgery*. 2007 Jan; 32(1):84–90. [PubMed: 17218180]
13. Lin, PY.; Sebastin, SJ.; Chung, KC. In Situ Cubital Tunnel Decompression. In: Chung, KC., editor. *Operative Techniques: Hand and Wrist Surgery*. 2nd. 2011.
14. Lee Dellon A. Review of treatment results for ulnar nerve entrapment at the elbow. *The Journal of hand surgery*. 1989; 14(4):688–700. [PubMed: 2666496]
15. Crosby CA, Wehbe MA, Mawr B. Hand strength: normative values. *The Journal of hand surgery*. 1994 Jul; 19(4):665–670. [PubMed: 7963331]
16. Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. *J Hand Surg Am*. 1998 Jul; 23(4):575–587. [PubMed: 9708370]
17. Chung KC, Hamill JB, Walters MR, Hayward RA. The Michigan Hand Outcomes Questionnaire (MHQ): assessment of responsiveness to clinical change. *Ann Plast Surg*. 1999 Jun; 42(6):619–622. [PubMed: 10382797]
18. Health IfW. The DASH Outcome Measure. 2010.
19. Trochim, W.; Donnelly, JP. *The Research Methods Knowledge Base*. 2nd. Cincinnati, Ohio: 2007.
20. Liang MH, Lew RA, Stucki G, Fortin PR, Daltroy L. Measuring clinically important changes with patient-oriented questionnaires. *Medical care*. 2002 Apr; 40(4 Suppl):II45–II51. [PubMed: 12064581]
21. Cohen, J., editor. *Statistical power analysis for the behavioral sciences*. 2nd. Hillsdale, N.J.: Lawrence Erlbaum Associates; 1988.
22. Shauver MJ, Chung KC. The minimal clinically important difference of the Michigan hand outcomes questionnaire. *J Hand Surg Am*. 2009 Mar; 34(3):509–514. [PubMed: 19258150]
23. Mondelli M, Padua L, Giannini F, Bibbo G, Aprile I, Rossi S. A self-administered questionnaire of ulnar neuropathy at the elbow. *Neurological sciences : official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology*. 2006 Dec; 27(6):402–411.
24. Zimmerman NB, Kaye MB, Wilgis EF, Zimmerman RM, Dubin NH. Are standardized patient self-reporting instruments applicable to the evaluation of ulnar neuropathy at the elbow? *Journal of shoulder and elbow surgery / American Shoulder and Elbow Surgeons ... [et al.]*. 2009 May-Jun; 18(3):463–468.
25. Mokkink LB, Terwee CB, Patrick DL, et al. The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation*. 2010 May; 19(4):539–549.
26. Mokkink LB, Terwee CB, Knol DL, et al. The COSMIN checklist for evaluating the methodological quality of studies on measurement properties: a clarification of its content. *BMC medical research methodology*. 2010; 10:22. [PubMed: 20298572]
27. Bartels RH, Verhagen WI, van der Wilt GJ, Meulstee J, van Rossum LG, Grotenhuis JA. Prospective randomized controlled study comparing simple decompression versus anterior

- subcutaneous transposition for idiopathic neuropathy of the ulnar nerve at the elbow: Part 1. *Neurosurgery*. 2005 Mar; 56(3):522–530. discussion 522–530. [PubMed: 15730578]
28. Biggs M, Curtis JA. Randomized, prospective study comparing ulnar neurolysis in situ with submuscular transposition. *Neurosurgery*. 2006 Feb; 58(2):296–304. discussion 296–304. [PubMed: 16462483]
29. Waljee JF, Kim HM, Burns PB, Chung KC. Development of a brief, 12-item version of the Michigan Hand Questionnaire. *Plastic and reconstructive surgery*. 2011 Jul; 128(1):208–220. [PubMed: 21701336]

Figure 1.
SUN study enrollment and final patient sample.

Figure 2.
Change in 2-point discrimination during the study period.

Figure 3.
Responsiveness of the MHQ at each time interval.

Figure 4.
Responsiveness of the DASH at each time interval.

Figure 5.
Responsiveness of the CTQ at each time interval.

Table 1

Demographic and clinical characteristics of the study sample. (n=39)

Characteristics		Number of subjects (%) [‡]
Gender	Men	21 (53.8%)
	Women	18 (46.2%)
Race	Asian	1 (2.3%)
	Black or African-American	6 (15.8%)
	White	31 (81.6%)
Education Level	Some high school	2 (5.1%)
	High school graduate	8 (20.5%)
	Some college	10 (25.6%)
	College graduate	10 (25.6%)
	Professional or graduate school	9 (23.1%)
Income level	Less than \$10,000	2 (5.1%)
	\$10,000–\$19,999	4 (10.3%)
	\$20,000–\$29,999	3 (7.7%)
	\$30,000–\$39,999	5 (12.8%)
	\$40,000–\$49,999	3 (7.7%)
	\$50,000–\$59,999	1 (2.6%)
	\$60,000–\$69,999	3 (7.7%)
	More than \$70,000	16 (41.0%)
Preoperative nerve conduction studies		Mean ± SD
Above elbow → hypothenar amplitude (mV)		6.6 ± 4.8
Above elbow → hypothenar latency (ms)		10.0 ± 3.7
Above elbow → wrist velocity (m/s)		38.7 ± 10.8
Preoperative Dellon Score		
Mild		13 (39.4%)
Moderate		12 (36.4%)
Severe		8 (24.2%)

[‡]Values may not sum to 100% because some respondents chose not to answer all demographic questions.

Table 2
Change in functional and sensory measures over time following ulnar nerve decompression.*

	Preop ($\pm$ SD)	6-week ($\pm$ SD)	3-month ($\pm$ SD)	6-month ($\pm$ SD)	1-year ($\pm$ SD)	p-value
Grip strength (kg)	28.6 $\pm$ 15.1	30.8 $\pm$ 15.4	33.3 $\pm$ 15.4	32.3 $\pm$ 16.6	34.4 $\pm$ 16.4	0.08
Key pinch strength (kg)	7.0 $\pm$ 2.9	7.5 $\pm$ 2.9	7.7 $\pm$ 3.4	8.7 $\pm$ 5.1	8.3 $\pm$ 3.1	0.008
Semmes Weinstein Monofilament	3.8 $\pm$ 0.8	3.6 $\pm$ 0.8	3.5 $\pm$ 0.8	3.6 $\pm$ 0.8	3.4 $\pm$ 0.7	0.08
Ring finger - radial	4.1 $\pm$ 0.9	3.7 $\pm$ 0.8	3.6 $\pm$ 0.8	3.6 $\pm$ 0.8	3.6 $\pm$ 0.8	<0.001
Ring finger - ulnar	4.1 $\pm$ 1.0	3.9 $\pm$ 1.1	3.8 $\pm$ 1.0	3.6 $\pm$ 0.8	3.5 $\pm$ 0.8	0.004
Small finger - radial	4.3 $\pm$ 1.0	3.9 $\pm$ 1.1	3.7 $\pm$ 0.9	3.6 $\pm$ 0.8	3.5 $\pm$ 0.8	<0.001
Small finger - ulnar	0.5 $\pm$ 0.2	0.6 $\pm$ 0.3	0.5 $\pm$ 0.2	0.5 $\pm$ 0.3	0.6 $\pm$ 0.4	0.61
2 point discrimination	0.6 $\pm$ 0.3	0.7 $\pm$ 0.3	0.5 $\pm$ 0.2	0.6 $\pm$ 0.3	0.6 $\pm$ 0.3	0.26
Ring finger - radial	0.7 $\pm$ 0.4	0.8 $\pm$ 0.6	0.6 $\pm$ 0.3	0.6 $\pm$ 0.4	0.5 $\pm$ 0.3	0.009
Ring finger - ulnar	0.8 $\pm$ 0.5	0.8 $\pm$ 0.6	0.6 $\pm$ 0.4	0.6 $\pm$ 0.4	0.6 $\pm$ 0.3	0.007
Small finger - radial						
Small finger - ulnar						

* Adjusted for Dellon Score.

Table 3

Change in functional and sensory measures over time following ulnar nerve decompression by Dellon Sore

	Preop Dellon Score	Preop (±SD)	6-week (±SD)	3-month (±SD)	6-month (±SD)	1-year (±SD)
Grip strength (kg)						
	Mild	32.9(15.4)	36.1(16.8)	35.9(18.1)	33.9(17.4)	36.6(17.4)
	Moderate	26.6(15.7)	31.1(14.9)	33.3(14.7)	29.2(15.8)	31.2(16.5)
	Severe	27.3(16.1)	23.4(12.2)	30.8(14.9)	35.7(19.2)	37.1(18.6)
	P-value	0.56	0.21	0.79	0.66	0.68
Key pinch strength (kg)						
	Mild	8.1(3.1)	8.1(3.4)	8.8(4.0)	9.8(7.5)	8.8(3.3)
	Moderate	6.5(3.1)	8.0(2.9)	7.6(3.4)	7.6(2.4)	8.9(3.4)
	Severe	6.1(2.2)	5.7(1.9)	6.0(2.2)	7.3(1.4)	6.7(2.0)
	P-value	0.26	0.17	0.21	0.42	0.34
Sennnes Weinstein Monofilament						
Ring finger - radial						
	Mild	3.7(1.1)	3.4(0.6)	3.3(0.6)	3.4(0.6)	3.3(0.6)
	Moderate	3.9(0.6)	3.8(0.6)	3.7(1.0)	3.8(0.9)	3.8(0.9)
	Severe	3.8(0.6)	3.9(1.3)	3.6(0.8)	3.5(0.6)	3.2(0.3)
	P-value	0.85	0.33	0.41	0.36	0.17
Ring finger - ulnar						
	Mild	3.9(1.0)	3.4(0.6)	3.3(0.6)	3.4(0.5)	3.3(0.7)
	Moderate	4.3(1.0)	3.8(0.6)	3.8(1.0)	3.8(0.9)	4.0(0.9)
	Severe	4.1(0.5)	4.2(1.1)	3.6(0.8)	3.7(0.7)	3.4(0.7)
	P-value	0.53	0.07	0.38	0.43	0.05
Small finger - radial						
	Mild	3.9(1.0)	3.4(0.6)	3.3(0.7)	3.3(0.5)	3.3(0.6)
	Moderate	4.0(0.6)	4.0(1.0)	3.9(0.9)	3.8(0.9)	3.8(1.0)
	Severe	5.0(1.0)	5.0(1.3)	4.4(1.2)	3.9(0.7)	3.6(0.7)
	P-value	0.02	0.003	0.05	0.23	0.33
Small finger - ulnar						
	Mild	3.9(1.0)	3.4(0.5)	3.3(0.7)	3.3(0.5)	3.4(0.6)
	Moderate	4.1(0.5)	4.0(1.0)	4.0(0.9)	3.8(1.0)	3.8(0.9)
	Severe	5.5(1.1)	4.9(1.3)	4.2(0.9)	4.0(0.8)	3.5(0.7)
	P-value	0.001	0.004	0.06	0.20	0.38
Two point discrimination						

	Preop Dellon Score	Preop (±SD)	6-week (±SD)	3-month (±SD)	6-month (±SD)	1-year (±SD)
<i>Ring finger - radial</i>	Mild	0.5(<0.1)	0.5(0.1)	0.5(0.1)	0.5(0.3)	0.6(0.4)
	Moderate	0.5(0.2)	0.7(0.3)	0.5(0.3)	0.5(0.2)	0.6(0.4)
	Severe	0.5(0.3)	0.8(0.5)	0.5(0.3)	0.6(0.3)	0.4(0.2)
	P-value	0.81	0.14	0.82	0.57	0.59
<i>Ring finger - ulnar</i>	Mild	0.5(0.1)	0.6(0.1)	0.5(0.1)	0.5(0.3)	0.6(0.3)
	Moderate	0.7(0.3)	0.7(0.3)	0.6(0.3)	0.6(0.2)	0.7(0.4)
	Severe	0.8(0.2)	0.9(0.5)	0.6(0.2)	0.7(0.3)	0.6(0.3)
	P-value	0.17	0.10	0.28	0.64	0.60
<i>Small finger - radial</i>	Mild	0.6(0.1)	0.5(0.1)	0.5(0.1)	0.5(0.3)	0.5(0.3)
	Moderate	0.7(0.3)	0.7(0.3)	0.6(0.2)	0.5(0.2)	0.6(0.3)
	Severe	1.1(0.6)	1.4(0.9)	0.8(0.6)	0.9(0.7)	0.4(0.3)
	P-value	0.02	0.001	0.14	0.08	0.41
<i>Small finger - ulnar</i>	Mild	0.6(0.1)	0.5(0.1)	0.5(0.1)	0.4(0.2)	0.6(0.3)
	Moderate	0.8(0.3)	0.7(0.3)	0.6(0.3)	0.6(0.3)	0.7(0.3)
	Severe	1.2(0.9)	1.4(0.9)	0.9(0.7)	1(0.8)	0.5(0.3)
	P-value	0.04	<0.001	0.10	0.03	0.57

Table 4

Preoperative and postoperative patient-reported outcomes scores as measured using the CTQ, DASH, and MHQ.*

	Preop ($\pm$ SD)	6-week ($\pm$ SD)	3-month ($\pm$ SD)	6-month ($\pm$ SD)	1-year ($\pm$ SD)	p-value
Carpal Tunnel Questionnaire[†]						
CTQ Symptom Score	2.73 ($\pm$ 0.70)	2.02 ($\pm$ 0.73)	1.97 ($\pm$ 0.85)	1.90 ($\pm$ 0.75)	1.90 ($\pm$ 0.79)	<0.001
CTQ Function Score	2.10 ($\pm$ 0.78)	1.69 ($\pm$ 0.70)	1.69 ($\pm$ 0.78)	1.69 ($\pm$ 0.77)	1.72 ($\pm$ 0.72)	0.01
Disabilities of the Arm, Shoulder, and Hand^{††}						
DASH Disability Score	30.4 ($\pm$ 18.9)	22.8 ($\pm$ 18.4)	19.4 ($\pm$ 18.0)	20.8 ($\pm$ 20.3)	19.8 ($\pm$ 18.6)	<0.001
Michigan Hand Questionnaire[‡]						
Overall MHQ score	55.5 ($\pm$ 19.5)	68.0 ($\pm$ 19.3)	72.9 ($\pm$ 21.4)	74.7 ($\pm$ 19.3)	70.7 ($\pm$ 22.1)	<0.001
Overall Hand Function	49.4 ($\pm$ 22.4)	65.3 ($\pm$ 21.0)	68.4 ($\pm$ 24.2)	70.7 ($\pm$ 20.5)	68.7 ($\pm$ 23.0)	<0.001
Activities of Daily Living	65.2 ($\pm$ 23.6)	78.0 ($\pm$ 23.1)	78.2 ($\pm$ 23.8)	81.8 ($\pm$ 22.1)	76.9 ($\pm$ 24.5)	0.002
Work	60.0 ($\pm$ 25.9)	61.9 ($\pm$ 27.5)	74.5 ($\pm$ 23.9)	76.0 ($\pm$ 23.1)	70.5 ($\pm$ 27.2)	0.004
Pain	48.3 ($\pm$ 26.2)	29.5 ($\pm$ 27.3)	30.1 ($\pm$ 29.7)	31.0 ($\pm$ 31.0)	32.1 ($\pm$ 28.0)	0.01
Aesthetic	72.8 ($\pm$ 28.3)	73.7 ($\pm$ 24.0)	80.4 ($\pm$ 22.7)	82.4 ($\pm$ 20.2)	78.7 ($\pm$ 20.9)	0.03
Satisfaction	34.1 ($\pm$ 19.3)	58.7 ($\pm$ 25.4)	66.0 ($\pm$ 27.0)	67.9 ($\pm$ 25.4)	61.6 ($\pm$ 29.5)	<0.001

Abbreviations: Preop, preoperative; CTQ, Carpal Tunnel Questionnaire; DASH, Disabilities of Arm, Shoulder and Hand; MHQ, Michigan Hand Questionnaire; SD, standard deviation

* Adjusted for Dellon Score.

[†] Both the CTQ symptom and function scores range from 0 to 5, with 5 indicating a worse score.

^{††} The DASH Disability score ranges from 0 to 100, with 100 indicating a worse score.

[‡] The MHQ domain scores (overall hand function, activities of daily living, work, aesthetic, satisfaction, and MHQ overall score) range from 0 to 100, with 100 indicating better hand performance. The MHQ-Pain score was reversed to be consistent with the other domain score scales; a higher score indicates less pain.

Table 5

Preoperative and postoperative patient-reported outcomes scores by Dellon score as measured using the CTQ, DASH, and MHQ

	Preop Dellon Score	Preop (SD)	6-week (SD)	3-month (SD)	6-month (SD)	1-year (SD)
Carpal Tunnel Questionnaire[†]						
CTQ Symptom Score	Mild	2.7(0.6)	1.9(0.4)	1.7(0.4)	1.8(0.6)	1.6(0.6)
	Moderate	2.5(0.7)	1.8(0.5)	2.1(1.0)	1.9(0.8)	2.0(1.0)
	Severe	3.2(0.6)	2.6(1.0)	2.4(0.9)	2.2(0.9)	2.2(0.7)
	P-value	0.06	0.01	0.12	0.50	0.20
CTQ Function Score	Mild	2.1(0.8)	1.6(0.8)	1.5(0.6)	1.7(0.9)	1.6(0.6)
	Moderate	1.9(0.7)	1.6(0.6)	1.8(0.9)	1.7(0.7)	1.9(0.8)
	Severe	2.5(0.8)	2.0(0.7)	2.0(0.9)	1.8(0.9)	1.9(0.8)
	P-value	0.19	0.30	0.31	0.86	0.48
Disabilities of the Arm, Shoulder, and Hand^{††}						
DASH Disability Score	Mild	28.7(16.9)	18.4(17.5)	14.4(16.3)	18.6(23.1)	16.0(18.2)
	Moderate	29.3(18.8)	24.7(17.6)	23.1(17.5)	21.9(17.5)	24.2(19.6)
	Severe	39.7(21.4)	30.6(20.2)	24.2(21.1)	27.3(22.1)	22.0(17.7)
	P-value	0.37	0.31	0.35	0.65	0.50
Michigan Hand Questionnaire[‡]						
Overall MHQ score	Mild	59.9(16.3)	70.0(15.0)	76.3(20.8)	74.6(16.9)	73.6(21.9)
	Moderate	56.7(18.9)	69.7(15.5)	71.5(19)	74.8(16.4)	67.0(21.1)
	Severe	42.1(19.8)	56.7(26.2)	65.4(26.2)	69.5(26.6)	66.6(24.2)
	P-value	0.08	0.19	0.51	0.78	0.67
Overall Hand Function	Mild	57.9(16.3)	68.8(19.9)	74.3(23.6)	73.8(19.5)	71.2(25.3)
	Moderate	50.5(18.6)	68.2(14.3)	66.5(22.8)	70.8(15.0)	68.0(19.6)
	Severe	32.2(29.2)	48.3(22.9)	56.1(23.7)	60.6(27.3)	60.0(24.1)
	P-value	0.03	0.03	0.21	0.30	0.53
Activities of Daily Living	Mild	69.2(26.6)	83.7(17.2)	85.1(20.2)	83.5(22)	79.6(26)
	Moderate	68.6(18.6)	81.0(17.8)	77.1(19.8)	85.7(15.9)	77.2(20.8)
	Severe	48.0(20.5)	59.9(31.3)	65.4(31.8)	68.6(28.8)	67.3(28.7)

	Preop Dellon Score	Preop (SD)	6-week (SD)	3-month (SD)	6-month (SD)	1-year (SD)
	P-value	0.06	0.04	0.17	0.16	0.50
Work	Mild	66.2(21.0)	60.8(31.7)	78.1(21.1)	77.3(23.1)	79.6(23.9)
	Moderate	55.0(28.9)	63.7(24.9)	70.0(25.2)	71.7(23.3)	58.3(28.6)
	Severe	52.2(24.4)	56.1(28.9)	71.1(26.4)	76.1(24.6)	71.1(24.1)
	P-value	0.37	0.82	0.65	0.80	0.11
Pain	Mild	51.9(20.6)	29.8(26.3)	29.6(32.3)	41.3(34.9)	31.9(28.5)
	Moderate	41.3(29.7)	27.5(26.5)	33.5(31.2)	28.2(29.4)	36.0(28.7)
	Severe	57.2(28.6)	38.3(31.6)	29.4(27.9)	25.0(29.7)	31.7(29.0)
	P-value	0.33	0.64	0.93	0.42	0.91
Aesthetic	Mild	77.4(25.3)	76.4(25.1)	82.7(20.0)	83.7(15.2)	81.2(18.8)
	Moderate	73.3(29.7)	74.2(21.8)	81.7(22.3)	82.1(22.3)	75.8(23.0)
	Severe	59.0(29.5)	66.0(28.1)	70.8(27.8)	77.1(24.6)	75.0(21.4)
	P-value	0.32	0.60	0.44	0.76	0.73
Satisfaction	Mild	40.4(19.3)	59.9(26.8)	67(32.1)	70.5(23.6)	62.2(29.4)
	Moderate	34.2(15.7)	58.6(18.8)	67.1(22.8)	66.9(23.2)	58.5(30.2)
	Severe	18.5(14.0)	48.1(29.5)	58.3(28.9)	59.7(31.8)	58.0(29.5)
	P-value	0.02	0.50	0.72	0.63	0.93

Abbreviations: Preop, preoperative; CTQ, Carpal Tunnel Questionnaire; DASH, Disabilities of Arm, Shoulder and Hand; MHQ, Michigan Hand Questionnaire; SD, standard deviation

[†] Both the CTQ symptom and function scores range from 0 to 5, with 5 indicating a worse score.

^{††} The DASH Disability score ranges from 0 to 100, with 100 indicating a worse score.

[‡] The MHQ domain scores (overall hand function, activities of daily living, work, aesthetic, satisfaction, and MHQ overall score) range from 0 to 100, with 100 indicating better hand performance. The MHQ-Pain score was reversed to be consistent with the other domain score scales; a higher score indicates less pain.

Table 6

Construct validity as measured by the correlation between outcomes instrument scores and traditional functional and sensory measures at 3-months following ulnar nerve decompression.

	Grip Strength	Key Pinch Strength	Semmes Weinstein Monofilament		2-Point Discrimination	
			Ring	Small	Ring	Small
Carpal Tunnel Questionnaire						
CTQ Symptom Score	-0.37 (P=.03)	-0.27 (P=.12)	0.37(P=.04)	0.42 (P=.02)	0.31 (P=.07)	0.35 (P=.04)
CTQ Function Score	-0.39 (P=.03)	-0.13 (P=.49)	0.36 (P=.04)	0.38 (P=.03)	0.44 (P=.01)	0.47 (P=.01)
Disabilities of the Arm, Shoulder, and Hand						
DASH Disability Score	-0.44 (P=.01)	-0.02 (P=.90)	0.45 (P=.03)	0.44 (P=.03)	0.38 (P=.01)	0.37 (P=.01)
Michigan Hand Questionnaire						
Overall Hand Function	0.34 (P=.05)	0.07 (P=.68)	-0.26 (P=.14)	-0.28 (P=.11)	-0.30 (P=.09)	-0.26 (P=.14)
Activities of Daily Living	0.32 (P=.07)	0.10 (P=.57)	-0.32 (P=.06)	-0.31 (P=.07)	-0.35 (P=.05)	-0.32 (P=.06)
Work	0.28 (P=.13)	0.01 (P=.95)	-0.37 (P=.09)	-0.30 (P=.09)	-0.47 (P=.01)	-0.49 (P=.003)
Pain	-0.19 (P=.29)	0.11 (P=.54)	0.41 (P=.02)	0.35 (P=.04)	0.37 (P=.03)	0.25 (P=.15)
Aesthetic	0.33 (P=.06)	0.14 (P=.45)	-0.22 (P=.22)	-0.23 (P=.20)	-0.27 (P=.13)	-0.25 (P=.16)
Satisfaction	0.33 (P=.07)	0.01 (P=.96)	-0.38 (P=.03)	-0.32 (P=.06)	-0.47(P=.006)	-0.33 (P=.06)
MHQ Overall Score	0.34 (P=.06)	0.03 (P=.86)	-0.38 (P=.03)	-0.35 (P=.05)	-0.43 (P=.01)	-0.37 (P=.04)

Abbreviations: CTQ, carpal tunnel questionnaire; DASH, Disabilities of the Arm, Shoulder, and Hand Questionnaire; MHQ, Michigan Hand Questionnaire