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Original Research

Prognostic Factors in Open Triangular Fibrocartilage Complex (TFCC) Repair

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Purpose: Patients with triangular fibrocartilage complex (TFCC) injury report ulnar-sided wrist pain and impaired function. Open TFCC repair aims to improve the condition of these patients. Patients have shown reduction in pain and improvement in function at 12 months after surgery; however, results are highly variable. The purpose of this study was to relate patient (eg, age and sex), disease (eg, trauma history and arthroscopic findings), and surgery factors (type of bone anchor) associated with pain and functional outcomes at 12 months after surgery.
Methods: This study included patients who underwent an open TFCC repair between December 2011 and December 2018 in various Xpert Clinics in the Netherlands. All patients were asked to complete Patient-Rated Wrist Evaluation (PRWE) questionnaires at baseline as well as at 12 months after surgery. Patient, disease, and surgery factors were extracted from digital patient records. All factors were analyzed by performing a multivariable hierarchical linear regression.
Results: We included 274 patients who had received open TFCC repair and completed PRWE questionnaires. Every extra month of symptoms before surgery was correlated with an increase of 0.14 points on the PRWE total score at 12 months after surgery. In addition, an increase of 0.28 points in the PRWE total score at 12 months was seen per extra point of PRWE total score at baseline.
Conclusions: Increased preoperative pain, less preoperative function, and a longer duration of complaints are factors that were associated with more pain and less function at 12 months after open surgery for TFCC. This study arms surgeons with data to predict outcomes for patients undergoing open TFCC repair.
Type of study/level of evidence: Prognostic II.

The triangular fibrocartilage complex (TFCC) is an important structure situated between the radius, ulna, and carpalia. The TFCC both absorbs axial forces on the wrist and acts as a stabilizer of the distal radioulnar joint (DRUJ).[1]

A TFCC lesion after trauma or after a degenerative process may result in ulnar-sided wrist pain and instability of the DRUJ. If the primary nonsurgical treatment of a TFCC tear fails, surgical repair of the TFCC may be considered.

Although we know that open TFCC repair considerably reduces pain and improves function for most patients 1 year after surgery, we do not know which factors influence the outcome.[2] No comparative data on prognostic factors in TFCC repair could be identified in literature.

The prognostic factors for hand function and pain at 12 months after open TFCC repair have not yet been determined. The purpose of this study was to evaluate potential patient (ie, age, sex, duration of complaints, type of labor, dominant hand, second opinion), disease (ie, ulnar variance, baseline Patient-Rated Wrist Evaluation [PRWE], prior hand therapy, type of TFCC tear), and surgery (ie, type

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of bone anchor used, combined procedure) characteristics that can influence outcomes in function or pain in patients at 12 months after an open TFCC repair. Our hypothesis was that a longer duration of symptoms would be associated with worse postoperative outcomes as measured by the PRWE.

Materials and Methods

Ethical approval of the study protocol

The ethics committee of Erasmus University Medical Center approved our study protocol (NL/sl/MEC-2018-1088). All patients provided written consent for their data to be used in this study. Our institution comprises 21 surgeons who are certified by the Federation of European Societies for Surgery of the Hand and has over 150 hand therapists.[3]

Patients

In this prospective cohort study, we included patients who elected to undergo open repair of TFCC between December 2013 and December 2018. Patients were invited to be a part of a routine system for outcome measurements after their first consultation with a surgeon. If they agreed, they received internet-based questionnaires before and at 3 and 12 months after surgery. In addition, the range of motion was measured at 3- and 12-month follow-ups as a part of standard care at our outpatient clinics. Three reminders were sent to patients for each round of questionnaires. Patients who failed to complete questionnaires at baseline or the 12-month follow-up were excluded. The clinical and research setting of our study group is described in more detail elsewhere.[3]

The indication for open TFCC repair is a tear with the instability of the DRUJ.[4] The management of ulnar-sided wrist problems follows specific steps. Briefly, nonsurgical treatment was initiated by short immobilization, followed by a rigorous program of wrist exercise. If symptoms persisted for longer than 3 months, instability of the DRUJ was evident, and clinical symptoms and/or radiographs with a flake or nonunion of the ulnar styloid were present, proceeding to direct open repair of TFCC was considered. In all other cases, arthroscopy or magnetic resonance imaging (MRI) of the wrist was performed to confirm that a TFCC injury was present.

Diagnosis

This study was based on prospectively gathered data in daily clinical practice. No specific study protocol was in place. Imaging studies or a diagnostic arthroscopy were ordered as deemed necessary. Magnetic resonance imaging is useful as a preliminary diagnostic tool.[5] However, arthroscopy is the most accurate method of diagnosis and is, therefore, the diagnostic gold standard. We report the findings of the ulnar fovea sign, the ballottement test, the trampoline test, or the hook test and the Palmer classification.[6−8] The Palmer classification is an evaluation system that is nowadays used to categorize TFCC lesions. The system was proposed by Andrew K. Palmer[9] in 1989 and categorizes lesions into 2 main classes: class 1 includes traumatic tears and class 2 includes degenerative tears.

Procedure for open TFCC repair

All patients received a regional local anesthetic block (axillary or supraclavicular) by anesthetists who each provide >800 upper-extremity blocks per year. Surgeons undertook their preferred method of open TFCC repair. Most surgeons used a method derived from that of Garcia-Elias et al.[4] The surgical procedure and rehabilitation have been described in detail in our recent article.[2]

Table 1
Patient Characteristics

Characteristic	Value
Age, mean (SD)	38 ± 12
Sex, male (%)	79 (29%)
Duration of symptoms, months, mean ± SD	20 ± 28
Body mass index, kg/m^2, mean ± SD, n = 252	25 ± 4.0
Smoking, n (%)	52 (26%)
Profession, n (%)	
Not working, including retirement/being unable to work	41 (15%)
Light physical work (eg, office work)	97 (36%)
Moderate physical work (eg, working in a store)	75 (27%)
Heavy physical work (eg, construction, road worker)	61 (22%)
Dominant side treated	168 (61%)
Second opinion	71 (26%)
Preoperative hand therapy	174 (64%)
Positive ulnar variance	34 (12%)
Previous distal radius fracture	52 (19%)
Documented fall onto an outstretched hand	53 (19%)
Arthroscopy findings	
Tear location	187 (68%)
Central tear	6 (2%)
Lateral tear or foveal detachment	140 (51%)
Distal tear	6 (2%)
Radial tear	25 (9%)
No tear	9 (3%)
Tear in multiple locations	41 (15%)
Degenerative tear	9 (3%)
Shave TFCC tear edges during arthroscopy	45 (16%)
MRI carried out	74 (27%)
MRI positive for TFCC injury	43 (58%)

Surgery started with a Bruner incision of the dorsal and volar sheath of the fifth compartment. The 4, 5th intercompartmental supraretinacular artery (which can usually be found in the ulnar and volar parts of the fifth compartment) was protected as much as possible. Foveal reattachment was obtained with the repair of the cartilage disc to the distal ulna with a bone anchor (Mitek, Minilok abdsorbable anchors, DePuy Synthes; JuggerKnot Soft Anchor, Zimmer Biomet).[5] The JuggerKnot Soft Anchor is an all-suture device and lacks polyether ether ketone or other composite materials but uses a coreless sleeve and suture construct.[10]

Before insertion of the bone anchor, the cartilage surface of the distal ulna was roughened with a rongeur or dental hook to facilitate adhesion and repair. The threads of the anchor suture were used to tighten the dorsal capsule and then close the floor and roof of the fifth compartment firmly after the relocation of the extensor digiti minimi. Soft tissues were closed in layers with Vicryl (Ethicon). The skin was closed with Monocryl (Ethicon) or Prolene (Ethicon) based on the surgeon's preference.

The general postoperative immobilization protocol consisted of a double-slab plaster of Paris for 3−5 days, followed by a long volar wrist orthosis (below elbow) for 6 weeks. Patients were offered an extensive program of hand rehabilitation comprising 6 weeks of active mobilization followed by 6 weeks of strengthening exercises. Hand therapists started early, active extension and flexion of the wrist 2 weeks after surgery. Our centers for hand surgery and therapy are fully integrated, and postoperative hand therapy was closely monitored and standardized. Follow-ups with hand surgeons were scheduled at 3 and 12 months, and follow-ups for hand therapy were scheduled twice a week in the first 6 weeks.

Measurements

Patients were asked to complete the Dutch version of the PRWE before and at 3 and 12 months after surgery.[11] The PRWE is a validated questionnaire comprising 15 questions: 5 questions for pain and 10 for disability.[12] All questions are answered on a scale

Table 2
Multivariable Regression*

Category	Variable	β	95% CI	*P* Value
Patient characteristics	Age	−0.05	−0.27 to 0.17	.64
	Sex, male	3.00	−3.43 to 9.44	.36
	Duration of complaints, months†	0.15	0.04−0.25	<.01
	Type of labor (reference: no paid labor)			
	Light physical labor	−7.06	−15.25 to 1.14	.09
	Moderate physical labor	−4.99	−13.52 to 3.54	.25
	Heavy physical labor	−5.40	−14.31 to 3.51	.24
	Dominant side treated	−2.85	−8.45 to 2.76	.32
	Second opinion	2.19	−4.06 to 8.43	.49
Disease characteristics	Preoperative hand therapy	0.93	−5.01 to 6.86	.76
	Preoperative PRWE total score†	0.30	0.14−0.45	<.01
	Positive ulnar variance	−3.78	−12.19 to 4.63	.38
	Trauma in history	1.90	−3.78 to 7.58	.51
	Tear location (reference: no tear)			
	Central	7.75	−17.17 to 32.67	.54
	Dorsal	−0.41	−23.67 to 22.85	.97
	Fovea	2.47	−13.27 to 18.21	.76
	Radial	13.52	−4.62 to 31.66	.15
	Unknown	3.52	−12.26 to 19.31	.66
	Tear in multiple locations	−0.30	−8.34 to 7.73	.94
	Degenerative tear	−5.62	−21.19 to 9.94	.48
	Shave TFCC during arthroscopy	−7.52	−15.75 to 0.72	.07
Surgical characteristics	Type of fixation (reference: none)			
	JuggerKnot	−9.88	−31.63 to 11.87	.37
	Mitek	0.13	−19.84 to 20.09	.99
	Combined surgery	7.22	−2.01 to 16.45	.13

* The table shows the multivariable regression model used to predict the PRWE total score, with the 95% CIs of the β coefficients and the corresponding *P* values.
† Statistically significant variables.

from 0 (“no pain or dysfunction”) to 10 (“severe pain or dysfunction”). For both subscales, a score between 0 and 50 is calculated. Patients were also asked to use a visual analog scale to score their pain and function concurrently. Pain and function were rated on a scale from 0 (“no pain or function”) to 100 (“severe pain and no function”).

Records research

We analyzed the medical records of all included patients to extract relevant patient, disease, and surgical factors. These variables were clustered into 3 subgroups before analysis (Table 1). The variable of profession was categorized into 4 groups, sorted by the level of physical effort: not working (including retirement or being unable to work), light physical work (eg, office work), moderate physical work (eg, working in a store), and heavy physical work (eg, working in construction). A combined surgery was defined as an open TFCC repair that was directly preceded or followed by another type of hand or wrist procedure in the same theater session on the same hand.

Statistical analyses

We performed a stepwise linear regression model to test the adjusted associations between the patient, disease, and surgical factors and the total PRWE score at 12 months after surgery. The variables were added to the model in 3 steps to simultaneously test how much a group of variables could explain the variance in the PRWE total score. First, patient factors (eg, age and sex), second, disease factors (eg, trauma history and arthroscopic findings), and finally, surgical factors (eg, type of bone anchor) were added to the model. A complete list of all factors in each group is provided in Table 2.

A power analysis was done to calculate the minimum number of patients needed to reach a medium effect size (0.15) with 25 potential prognostic variables. This showed that we needed a power sample of 242 patients. To assess any differences between the included patients and the excluded patients because of missing data, we performed an unpaired *t* test, a chi-square test, and a Wilcoxon rank-sum test to compare the baseline characteristics. *P* values less than 0.05 were considered statistically significant.

Results

Between December 2011 and December 2018, a total of 544 patients had received an open TFCC repair at our centers. We excluded 61 patients because of incomplete or missing PRWE questionnaires at baseline. Another 204 patients were excluded because of incomplete or missing PRWE questionnaires at 12 months after surgery or because a second operation was performed on the same hand within 12 months after the open TFCC repair. A total of 11 patients had additional surgery because of a failed initial treatment. In total, 274 patients were included in our study. A flow diagram of the exclusion process can be found in the Figure 1. Condition of the patients improved significantly from the baseline to 3 months after surgery, with a PRWE total score (mean ± SD) of 63 ± 18 at baseline to 36 ± 21 at 3 months after surgery ($P < .001$).

All patient characteristics are shown in Table 1. The vast majority of the included patients were middle-aged women. In 187 patients (68%), a diagnostic wrist arthroscopy was performed prior to surgery; 140 (75%) of these patients had a Palmer class 1B tear. Furthermore, 74 patients had received an MRI prior to the operation date. Of these 74 patients, only 43 (58%) had a visible TFCC tear. Of the 74 patients with an MRI examination, 51 had an arthroscopy as well. Magnetic resonance imaging findings suggestive of a TFCC injury were confirmed in 26 cases via arthroscopy. Negative MRI scans (25 patients) leading to arthroscopy resulted in 24 positive findings for a TFCC injury. In 17 patients, MRI scan was positive and direct open repair was elected (no arthroscopy prior to surgery). In 6 patients, MRI scan was negative but clinical suspicion indicated direct open repair without a prior wrist arthroscopy. All types of TFCC tears in this cohort were repaired by foveal reattachment and dorsal capsule tightening. We prospectively collected data on consecutive patients in daily practice, and no study guidelines were present. As a consequence, the indications and work-up for surgery were decided by each individual surgeon. A few cases of combined

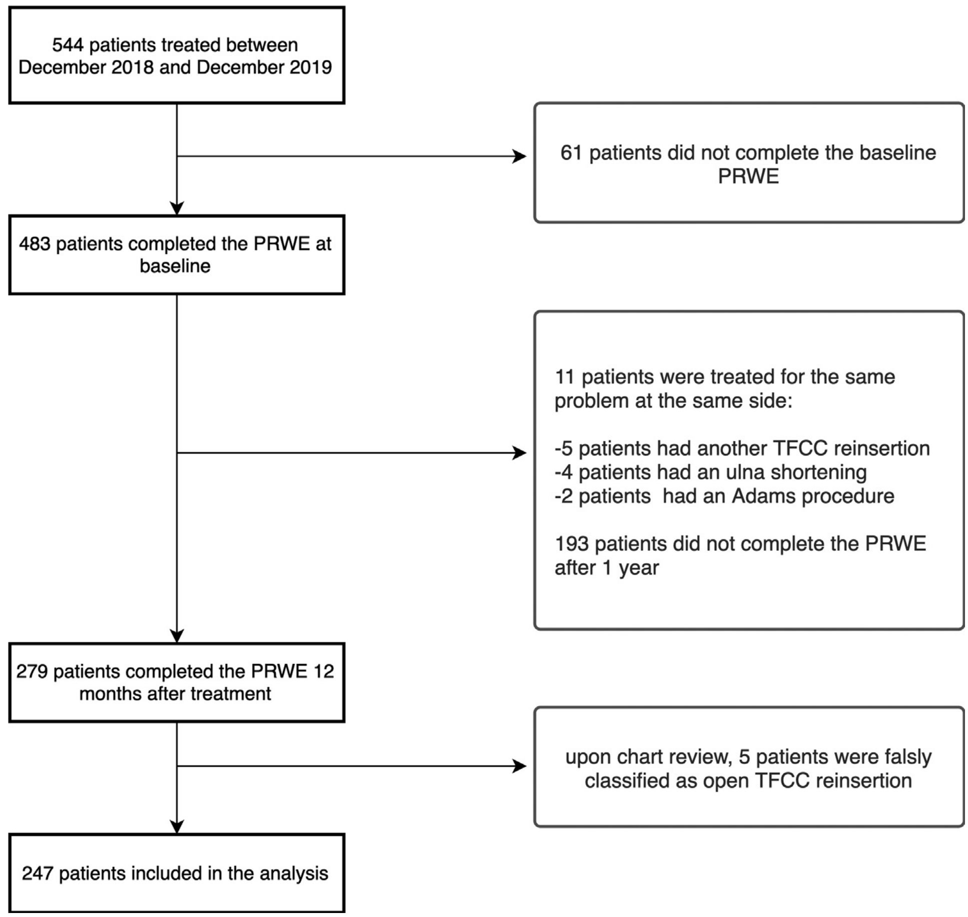

Figure 1. Flow diagram of included patients.

tears, positive ulnar variance, and degenerative tears were reported.

Table 3 shows that included and excluded patients had similar characteristics. The only difference was a longer median duration of complaints before the surgery in the included patients ($P < .001$).

In the final multivariable analysis (Table 2), the duration of complaints ($\beta = 0.15$; 95% confidence interval [CI], 0–0.3; $P < .01$) and the PRWE total score at baseline ($\beta = 0.30$; 95% CI, 0.1–0.5; $P < .01$) were independently associated with the PRWE total score at 12 months. For example, patients who had complaints for 1 year longer than average scored 1.8 points (12×0.15) higher on the PRWE at 12 months (0.15 points higher per additional month). The tear location, positive ulnar variance, and the presence of traumatic tears were not significantly associated with the outcome at 12 months, (See Table 2, for P values).

Table 4 shows the complete stepwise model. Performing a shave of the edges of the TFCC tear during arthroscopy in a prior procedure was significant ($P = .04$, Table 4) in the second model, demonstrating a positive prognostic factor on the outcome. However, this was not significant in the third and final model ($P = .07$, Table 4). Patient, disease, and surgical factors explained 4%, 8%, and 2%, respectively, of the PRWE total score at 12 months after surgery.

Discussion

This study shows that a longer period of symptoms, higher pain, and a higher functional PRWE total score at baseline lead to inferior hand function (a higher PRWE) and more pain at 12 months after TFCC repair. The PRWE score at 12 months will be 0.15 points higher for each additional month of complaints. Patient, disease, and surgical factors explained 4%, 8%, and 2%, respectively, of the PRWE at 12 months; thus, the percentage of explained variation in outcomes remained below 10%. Baseline patient-reported outcome measurements may prove valuable in hand surgery for selecting the best patients for a particular procedure, in the same manner as knee and hip surgeons report these tools to be of value in patient selection or optimization before electing surgery.[13,14] We experienced good results with conservative management of TFCC tears and although we find a prolonged duration of symptoms to be associated with worse outcomes, we still consider conservative treatment as the first treatment option. Our findings can aid surgeons in counseling patients considering open TFCC repair, specifically regarding their expectations on the outcomes for pain and function after surgery.

The findings support the prediction of surgical outcomes by patient characteristics. Previous research with the same cohort showed that patients who undergo TFCC repair for ulnar-sided wrist pain can expect clinically significant improvements in pain and function 12 months after surgery ($P < .001$).[2] Nearly 80% of these patients experienced reduction in pain and improvement in function at least as large as the assumed minimally clinically important difference for PRWE (14 points for TFCC repair).[2] In addition, this study provides insight into possible factors that may lead to suboptimal outcomes at 12 months after surgery. In the literature, no relevant article could be identified on prognostic factors in open or arthroscopic repair; therefore, comparison to other studies was not possible.

Table 3
Comparison of Included and Excluded Patients

	Nonresponders*	Responders	*P* Value
Number	270	274	
Age, mean ± SD	36.3 ± 12	38.2 ± 13	.07
Sex, male (%)	91 (34)	79 (29)	.25
Duration of symptoms in months, median (interquartile range: Q3–Q1)	7 (12–5)	12 (24–6)	<.001†
Labor status, n (%)			.09
Not working	42 (16)	41 (15)	
Light physical work (eg, office work)	88 (33)	97 (36)	
Moderate physical work (eg, working in a store)	97 (36)	75 (27)	
Heavy physical work (eg, construction, road worker)	43 (16)	61 (22)	
Affected side, right (%)	171 (63)	165 (60)	.48

PROM, Patient Reported Outcome Measurements.
* Patients that were excluded for failing to provide PROM data such as PRWE questionnaires.
† Statistically significant variables.

Table 4
Stepwise Regression*

Category	Variable	First Model			Second Model			Third Model		
		β	95% CI	*P* Value	B	95% CI	*P* Value	β	95% CI	*P* Value
Patient characteristics	Age	−0.03	−0.25 to 0.18	.78	−0.01	−0.24 to 0.21	.90	−0.05	−0.27 to 0.17	.64
	Sex, male	−2.01	−7.92 to 3.91	.51	3.64	−2.79 to 10.06	.27	3.00	−3.43 to 9.44	.36
	Duration of complaints, months†	0.11	0.01–0.21	<.05	0.16	0.06–0.26	<.01	0.15	0.04–0.25	<.05
	Type of labor (reference: no paid labor)									
	Light physical labor	−4.34	−12.48 to 3.81	.30	−6.40	−14.63 to 1.84	.13	−7.06	−15.25 to 1.14	.09
	Moderate physical labor	−3.83	−12.36 to 4.71	.38	−4.53	−13.11 to 4.05	.30	−4.99	−13.52 to 3.54	.25
	Heavy physical labor	−2.87	−11.8 to 6.05	.53	−5.64	−14.61 to 3.33	.22	−5.40	−14.31 to 3.51	.24
	Dominant side treated	0.04	−5.49 to 5.58	.99	−2.57	−8.21 to 3.06	.37	−2.85	−8.45 to 2.76	.32
	Second opinion	4.05	−2.2 to 10.3	.21	3.55	−2.66 to 9.76	.26	2.19	−4.06 to 8.43	.49
Disease characteristics	Preoperative hand therapy				0.62	−5.27 to 6.51	.84	0.93	−5.01 to 6.86	.76
	Preoperative PRWE total score†				0.32	0.17–0.48	<.01	0.30	0.14–0.45	<.01
	Positive ulnar variance				−2.40	−10.81 to 6	.58	−3.78	−12.19 to 4.63	.38
	Trauma in history				2.00	−3.71 to 7.7	.49	1.90	−3.78 to 7.58	.51
	Tear location (reference: no tear)									
	Central				7.17	−17.92 to 32.27	.58	7.75	−17.17 to 32.67	.54
	Dorsal				2.06	−21.29 to 25.41	.86	−0.41	−23.67 to 22.85	.97
	Fovea				2.37	−13.45 to 18.19	.77	2.47	−13.27 to 18.21	.76
	Radial				12.19	−6.04 to 30.41	.19	13.52	−4.62 to 31.66	.15
	Unknown				4.35	−11.53 to 20.23	.59	3.52	−12.26 to 19.31	.66
	Tear in multiple locations				−0.59	−8.64 to 7.45	.89	−0.30	−8.34 to 7.73	.94
	Degenerative tear				−3.14	−18.6 to 12.32	.69	−5.62	−21.19 to 9.94	.48
	Shave TFCC during arthroscopy†				−8.86	−17.08 to −0.63	.04	−7.52	−15.75 to 0.72	.07
Surgical characteristics	Type of fixation (reference: none)									
	JuggerKnot							−9.88	−31.63 to 11.87	.37
	Mitek							0.13	−19.84 to 20.09	.99
	Combined surgery							7.22	−2.01 to 16.45	.13
R^2			4%			12%			14%	

R^2, multiple correlation coefficient.
* The table shows the stepwise regression model, 95% CIs of the β coefficients, the corresponding *P* values, and how covariates changed when another group of variables was added. In the first model, only patient characteristics were used. In the second model, disease characteristics were added. In the final model, surgical characteristics were added. We calculated the total explained variance (R^2) for each step.
† Statistically significant variables.

Our study has several limitations. We followed our heterogeneous patient population only for 1 year after surgery. We would be interested to see the long-term effects of open repair on hand function and pain, as full recovery of open repair might take longer than 12 months. Pain and dysfunction may still change and most likely will continue to improve after this period, as patients move out of the operative period and return to their daily routines. Subsequently, it would also be interesting to see whether pain and dysfunction can be evaluated with a measurement scale other than the PRWE, such as the return-to-work rate after open TFCC repair. In addition, we only have complete data for 47% of our intentioned cohort. The remaining 53% was not lost to follow-up but failed to respond to the questionnaires. The median duration of complaints in our patient group was 12 months. This was significantly higher than in the excluded patient group, which had a median duration of 7 months, $P < .01$. It is thus possible that excluded patients with a shorter duration of symptoms had better postoperative outcomes. With our patient group, we found that a longer duration of complaints is associated with more pain and dysfunction after open TFCC repair. Consequently, we do not know whether this is also the case in patients who have a shorter duration of complaints than that of our patients.

The total explained variance of the factors that we added in the analysis is low. With the current factors in our model, it remains difficult to predict outcomes of open TFCC repair. This could imply that other factors, which we did not include in our model, are influencing hand function and pain at 12 months after open TFCC repair. It would be of interest if future research could investigate other factors, such as body mass index, psychological factors, and comorbidities such as diabetes, to see whether they can predict the functional and pain outcomes of open TFCC repairs to a greater degree.

In conclusion, the preoperative pain and function and the duration of complaints are factors that are associated with pain and function outcomes at 12 months after open TFCC repair. These findings can inform surgeons while predicting outcomes for open TFCC repair.

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