Is the outcome of a revision carpal tunnel release as good as those of a primary release? A matched cohort study

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Summary *Objective:* This study aimed to compare primary and revision carpal tunnel release outcomes in all patients with carpal tunnel syndrome and when corrected for baseline severity and demographics.

Methods: A total of 903 hands of primary and 132 hands of revision patients underwent carpal tunnel release and patients completed online questionnaires on demographics, clinical severity, and satisfaction. The primary outcome measure, the Boston Carpal Tunnel Questionnaire (BCTQ), was administered at intake and six months after surgery.

Results: The BCTQ total score at six months was better in primary (1.55±0.58) than revision patients (1.94±0.73, p=<0.001), and primary patients improved more on the BCTQ total score (1.10±0.71 vs. 0.90±0.72, p=0.003). In patients matched on similar baseline characteristics using propensity score matching, the BCTQ total score at six months was also better in primary patients (1.65±0.63) than in revision patients (1.92±0.73, p=0.002), and primary patients still had more improvement in BCTQ total score (1.18±0.73 vs. 0.89±0.73, p=0.004).

Conclusions: This study shows that the outcome after revision carpal tunnel release is only 16% worse compared to primary carpal tunnel release. Preoperative symptom severity, functional status, and demographics may play a role since correcting for these factors reduces the difference in outcome between primary and revision CTR.

Introduction

Carpal tunnel syndrome (CTS) affects up to 7% of the population and is the most common upper extremity neuropathy.[1,2] Although carpal tunnel release (CTR) is successful, up to 31% of patients remain symptomatic or have recurring symptoms, of whom revision surgery is needed in up to 12%.[3-5]

The persistence or recurrence of symptoms after CTR is considered more challenging to treat than primary CTS.[5,6] Previous studies have shown the outcome for both primary and revision CTR, and when comparing mean outcomes, it seems primary surgery is more successful in reducing symptoms and improving function.[7-10] For example, Kleermaeker et al.[11] found an average postoperative symptom severity score of 1.54 in primary patients (n=179), while Cobb et al.[9] found an average postoperative symptom severity score of 1.92 in revision patients (n=132). Demographic and clinical factors may influence this difference, as patients with revision CTS may have higher preoperative symptom severity, worse hand functioning, and more comorbidities.[12-14]

No previous research has directly compared the outcome of primary and revision CTR in otherwise similar cohorts nor investigated which factors may explain a possible difference in outcomes. Obtaining this knowledge could improve preoperative counseling of revision CTR patients and create realistic expectations. Therefore, this study aimed to compare the outcome of primary with revision CTR, both uncorrected and corrected for baseline disease severity and demographic factors. Additionally, subgroup analysis for recurrent and persistent CTS separately was performed.

Materials and methods

Participants

Patients that underwent primary or revision CTR for CTS between January 2012 and May 2019 at one of the 18 specialized hand and wrist surgery clinics were selected. Patients were asked to fill out online questionnaires in GemsTracker © (GEneric Medical Survey Tracker), a secure web-based application for distributing questionnaires and forms during medical research and quality registrations. The cohort and data collection have previously been reported.[15]

Adult patients who completed the outcome questionnaires at baseline and six-month follow-up were included. If patients were treated bilaterally, both hands were included. Patients with concomitant hand surgeries that could influence the outcome measures (e.g., cubital tunnel release, Guyon's canal release, and CMC1 arthroplasty surgery) were

excluded. The local Institutional Review Board approved the study. Adequate information was provided. All patients provided written informed consent.

Diagnosis and treatment

Diagnosis and decision for surgery were based on history taking and clinical findings by European board-certified hand surgeons. Nerve conduction studies or ultrasounds were not regularly performed because clinical features led to the diagnosis following the Dutch.[16] The surgery performed was an open CTR for all included patients. The incision of approximately 4 cm started proximally at the distal wrist crease along an axis defined by the radial aspect of the ring finger. In addition, neurolysis was performed in revision CTR patients if adhesions were present and additional flap surgery was only performed if there were severe adhesions, which was the case in 3 revision patients. Exact data on the additional procedures were not available. Postoperative care consisted of 3 to 5 days of bandages and a sling around the operated hand. Standardized hand therapy (tendon and nerve gliding exercises and exercises for range of motion) started after this. Progress was monitored, and sutures were removed at the postoperative check 14 days after surgery. Treatment to minimize scar formation was started, consisting of scar massage and silicone scar sheets (if indicated).

Recurrent and persistent symptoms

Patients scheduled for revision CTR can be divided into two subgroups: patients with either persistent or recurrent symptoms. We classified symptoms as either persistent or recurrent based on the medical history recorded in the medical records. We defined persistent symptoms as occurring within six months after primary surgery and recurrent symptoms as occurring after a symptom-free period of at least six months.

Baseline characteristics

Baseline characteristics were collected at intake and included age, sex, BMI, hand dominance, operated hand, persistent or recurrent symptoms, duration of symptoms, comorbidities, concomitant procedures, number of previous CTRs, workload, smoking status, and alcohol usage.

Comorbidities were divided into "systemic conditions" and "comorbidities of the hand/wrist." Comorbidities classified as "systemic conditions" were as follows: diabetes

mellitus, rheumatic arthritis, fibromyalgia, Sjögren's syndrome, polymyalgia rheumatica, gout, and pregnancy. Comorbidities classified as "comorbidities of the hand/wrist" were as follows: carpometacarpal osteoarthrosis (CMC1 arthrosis), trigger fingers, Dupuytren's disease, Quervain's disease, tendinitis, arthrosis or instability of the wrist, trauma of the wrist, ulnar nerve entrapment, Guyon's tunnel disease, cubital tunnel compression, and pronator teres syndrome.

Primary outcome measurement: BCTQ

The primary outcome measure was the Boston Carpal Tunnel Questionnaire (BCTQ) total score at six months, using the BCTQ (1=no complaints, 5=maximum complaints possible, Dutch language version). The BCTQ is a questionnaire to measure self-reported symptom severity and functional status in patients with CTS,[17,18] respectively, with the symptom severity scale (SSS) and functional status scale (FSS).

The minimally clinically important difference is a 0.92 points change in the BCTQ total score and 1.14 and 0.74 for SSS and FSS, respectively.[19]

Secondary outcomes

Secondary outcomes were complications and patient satisfaction with the outcome of treatment. Complications recorded during the follow-up period were infection treated with antibiotics, wound dehiscence, postoperative bleeding, and the median nerve and palmar cutaneous branch injury.

Patient satisfaction was measured using a validated questionnaire about satisfaction with the treatment effect at six months follow-up on a 5-point scale, with the following grades: "excellent", "good", "average", "poor", and "very poor."[20]

Statistical analysis

Descriptive statistics were calculated for all variables in both subgroups before and after matching. A proportion of the revision CTR patients (23% of unmatched patients) had missing values for BMI, smoking status, and alcohol usage due to nonresponse. Since previous research showed these variables are not related to the clinical outcome,[10,13,21] we continued the analysis without including these characteristics. Baseline characteristics before matching were compared using an unpaired t-test for continuous variables and a chi-square test for categorical variables.

We performed a non-responder analysis comparing patients with and without BCTQ scores at 6 months postoperatively to check for selection bias due to missing values (Supplementary Table 1). Baseline variables and BCTQ scores at baseline between patients with and without BCTQ scores at 6 months postoperatively were compared using chi-square tests for categorical variables and unpaired t-tests for continuous variables. After correction for multiple testing, we found no significant differences; therefore, we concluded missing data were independent of unobservable and observable variables.

Propensity score matching was used to adjust for potential confounding. Propensity score matching is a matching technique for observational data using propensity scores to estimate the effect of a treatment by accounting for the covariates that predict receiving the treatment [22,23] and was successfully used previously in patients with hand and wrist disorders.[24,25]

The following baseline characteristics were included as covariates for the propensity score: age, sex, workload, dominant side treated, comorbidities, presence of CTS on both sides, and BCTQ subscales at baseline. We matched patients on a 1-to-1 ratio using the nearest-neighbor method with a caliper width of 0.2 SD.[26] The standardized mean difference (SMD) was used to examine the balance of the covariates between the two groups. We aimed for an SMD below the 0.1 thresholds for all included covariates.[27] To account for the matched nature of the sample, paired t-tests were performed to study differences in primary outcome.[28]

Differences in complication rates between both groups were calculated using chi-square tests. Ninety-five % confidence intervals were calculated for all outcomes, and p-values less than 0.05 were considered statistically significant. We performed a power analysis for the primary analysis. A sample size of 71 matched pairs would provide a power of 80 percent, with a significance threshold of 0.05 and an expected effect size of 0.3.

The statistical software package R (version 3.5.2) was used for all analyses and processing of the data.

Results

A total of 903 hands of primary CTR and 132 hands of revision CTR patients were included (Figure 1). Patients, on average, had a relatively high BMI and were predominantly female (Table 1). Revision patients had more comorbidities, were less likely to drink alcohol, and had more often bilateral CTS than primary patients. The baseline BCTQ total score, FSS, and SSS subscales showed more severe symptoms in revision than primary patients.

After propensity score matching, both groups contained 128 hands. The SMD in Table 1 represents the balance of the included covariates. Besides sex and systemic comorbidities, all covariates had an SMD below the predefined threshold.

Figure 2 shows the improvement of the BCTQ total score, FSS, and SSS subscales over time for both groups, before and after matching. Before matching, the BCTQ total score at six months was better in primary (1.55±0.58) than revision patients (1.94±0.73, p=<0.001). Both the FSS and SSS subscales at six months were better in primary patients (1.55±0.63 and 1.55±0.58, respectively) compared to revision patients (1.93±0.76 and 1.95±0.77, respectively, p=<0.001).

Primary patients improved more on the BCTQ total score than revision patients (1.10 vs. 0.90, respectively, p=0.003). This difference was mainly due to more improvement in primary patients in the SSS (1.32 in primary vs. 1.03 in revision patients, p=<0.001) and to a lesser extent in the FSS (0.87 in primary vs. 0.77 in revision patients, p=0.158)

After matching, the difference between the two groups in BCTQ total scores (1.65 vs. 1.92, p=0.002), FSS subscale

Table 1 Baseline characteristics of the study population, before and after propensity score matching.

	Unmatched patients			Matched patients		
	Primary n = 903	Revision n = 132	*P-value*	Primary n = 128	Revision n = 128	*SMD*
Categorical variables	**Percentage %**			**Percentage %**		
Male Sex	30	23	0.173	30	24	0.123
Comorbidities						
Systemic = present	11	23	<0.001	16	20	0.101
Hand / wrist = present	28	45	<0.001	40	44	0.079
Concomitant procedures						
Present	10	18	0.006	20	16	0.081
Workload						
No work	37	39	0.750	38	39	0.032
Light physical work	22	22	1.000	22	23	0.019
Moderate physical work	28	26	0.643	25	24	0.032
Heavy physical work	13	14	0.966	16	14	0.044
Bilateral CTS	34	54	<0.001	55	52	0.047
Dominance			0.588			
Left	7	9		4	9	
Right	90	86		94	87	
Ambidextrous	4	5		2	4	
Dominant side affected	61	61	1.000	65	60	0.097
Smoking = yes*	18	21	0.649	25	20	0.110
Alcohol usage = yes*	57	45	0.025	59	45	0.277
Continuous variables	**Mean ± SD**			**Mean ± SD**		
Age (y)	55 (12.5)	56 (12.4)	0.509	55 (11.8)	56 (12.5)	0.075
BMI (kg/m^2)*	28 (5.1)	28 (4.9)	0.951	28 (4.8)	28 (4.8)	0.008
BCTQ - intake						
SSS score – intake	2.9(0.6)	3.0 (0.6)	0.046	3.0 (0.6)	3.0 (0.6)	0.004
FSS score – intake	2.4 (0.8)	2.7 (0.7)	<0.001	2.7 (0.8)	2.7 (0.7)	0.040
Total – intake	2.6 (0.6)	2.8 (0.6)	0.001	2.8 (0.6)	2.8 (0.6)	0.022
Duration of complaints (mo)	26 (52.1)	26 (37.0)	0.968	26 (34.6)	26 (37.5)	0.006
Number of previous CTR's (Revision group)		1.1 (0.4)			1.1 (0.4)	

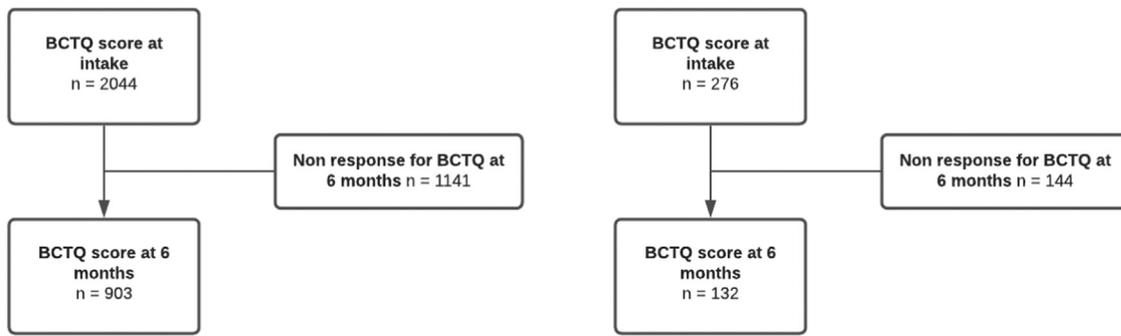* Revision group: Smoking/Alcohol usage/BMI, before matching n = 101, after matching n = 98

Figure 1 Study flowchart hands of primary and revision patients.
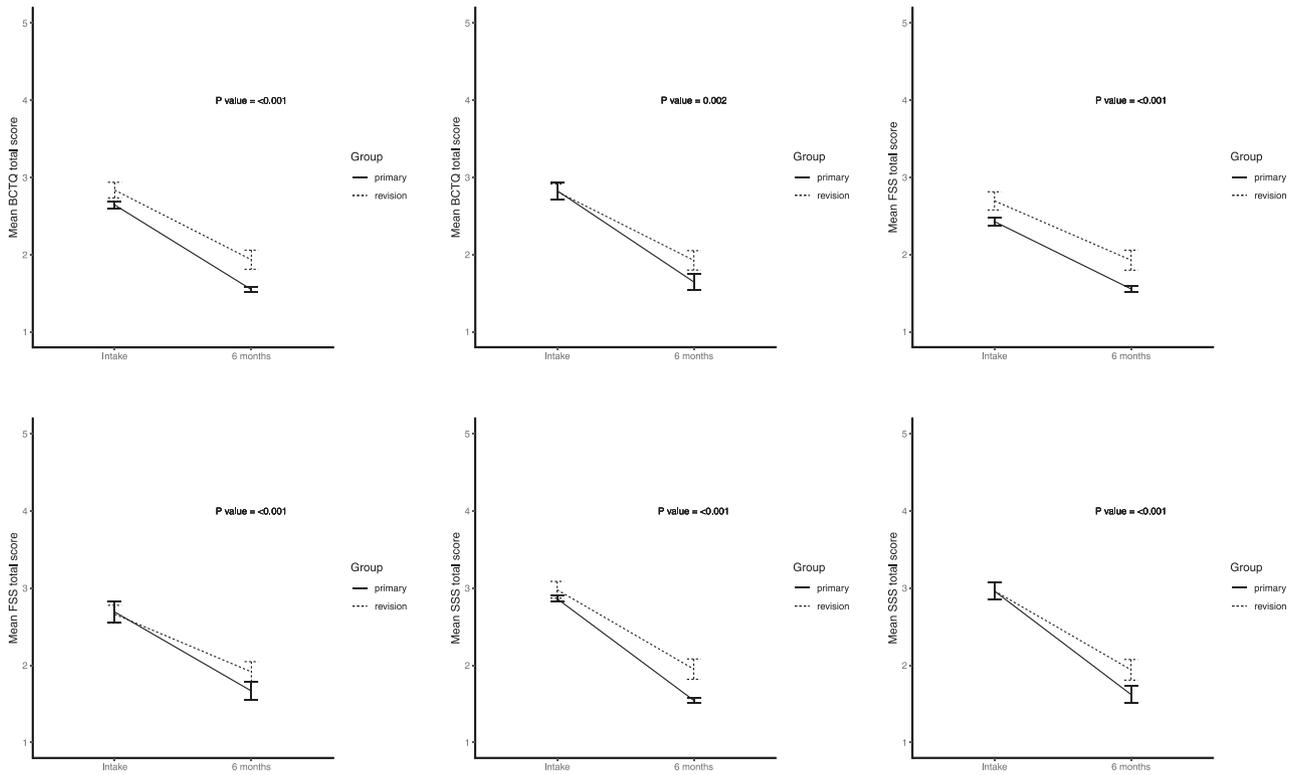

Figure 2 Postoperative course of the BCTQ total score (A-B), FSS (C-D) and SSS (E-F) subscales at intake and six months postoperative for both groups, before and after matching. Error bars represent the 95% confidence intervals.

*Before matching: n = 903 for primary patients and n = 132 for revision patients

†After matching: n = 128 for primary patients and n = 128 for revision patients

‡ P values represent the significance of differences at six months after surgery between the primary and revision group

A. BCTQ total before matching
B. BCTQ total after matching
C. FSS before matching
D. FSS after matching
E. SSS before matching
F. SSS after matching

(1.67 vs. 1.92, p=0.011), and SSS subscale (1.62 vs. 1.94, p=<0.001) at six months was smaller, but symptoms remained higher in the revision group. In addition, primary patients also still had more improvement in BCTQ total score (1.18 vs. 0.89, p=0.004), FSS (1.02 vs. 0.75, p=0.013), and SSS (1.34 vs. 1.02, p=0.003) after matching.

Overall, 95% of unmatched primary patients improved the BCTQ total score compared to 89% of unmatched re-vision patients (p=0.04). This was similar for matched patients: 95% of primary and 89% of revision patients (p=0.17). Considering the MCID, 59% of unmatched primary and 50% of unmatched revision patients reported improvement (p=0.05) versus 64% and 48% of primary and revision matched patients, respectively (p=0.02).

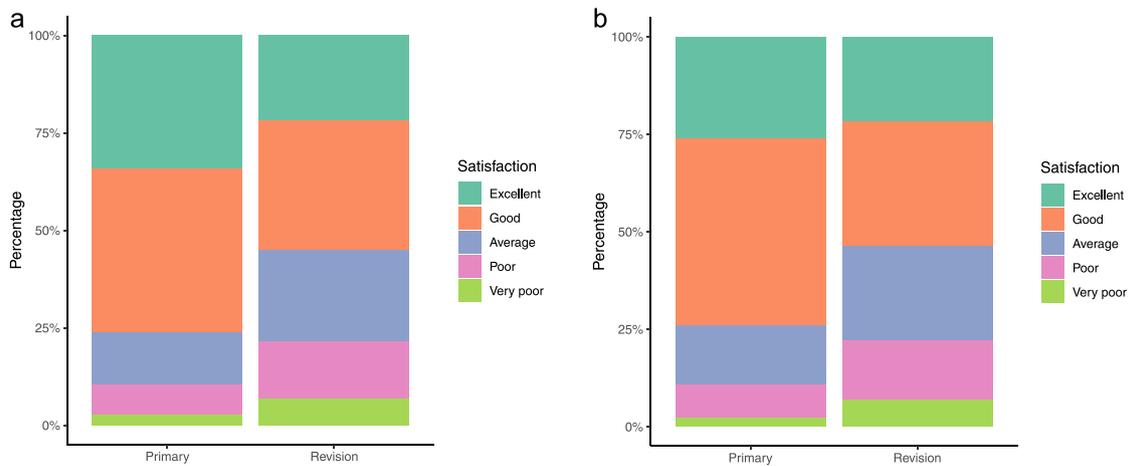Before matching, 18% of primary patients achieved a BCTQ total score of 1 (i.e., no complaints) at six months

Figure 3 Outcome in satisfaction with the treatment result measured at 6 months follow up in both groups, before matching (A) and after matching (B). *Before matching: n = 898 for primary patients and n = 129 for revision patients. (B) *After matching: n = 127 for primary patients and n = 125 for revision patients

Table 2 Subgroup analysis of recurrent versus persistent CTS.

Outcome	Recurrent (n = 63)	Persistent (n = 69)	P value
	Score (SD)		
BCTQ total (6mo)	1.96 (0.8)	1.91 (0.7)	0.637
FSS (6mo)	1.94 (0.8)	1.91 (0.7)	0.826
SSS (6mo)	2.01 (0.58)	1.90 (0.7)	0.430
BCTQ difference	0.87 (0.7)	0.93 (0.7)	0.616
FSS difference	0.78 (0.8)	0.76 (0.8)	0.893
SSS difference	0.94 (0.8)	1.11 (0.8)	0.242

compared to 10% of revision patients (p=0.03). After matching, 17% of primary patients achieved this BCTQ total score of 1 at six months compared to 10% of revision patients (p=0.15).

The complication rate did not differ between primary and revision patients (3.4% vs. 3.0%, respectively, p=0.963). After matching, 5.5% of primary and 3.1% of revision patients had complications(p=0.538). Most complications were wound infections treated with antibiotics, except for 16 primary patients with wound dehiscence.

Figure 3 presents patient satisfaction with the treatment outcome six months after surgery, with similar results before and after matching. Primary patients were more satisfied compared to revision patients (excellent/good (before matching): 76% vs. 55%, p=<0.001). Additionally, 86% of primary patients would have opted for CTR again than 82% of revision patients.

When comparing the subgroups of recurrent and persistent symptoms within the revision group, we found similar BCTQ scores and improvement at six months between patients of both subgroups (Table 2).

Discussion

Ten Heggeler showed the outcome after revision CTR is only 16% less than primary CTR after correcting for confounding using propensity score matching. The BCTQ total score at six months was better in primary(1.55±0.58) than revision patients (1.94±0.73, p=<0.001). Differences in baseline illness severity and demographics can partly explain the difference in BCTQ total score at 6 months between the groups since matching patients with similar baseline characteristics reduces the difference from 0.39 to 0.27 points. When comparing the subgroups of recurrent and persistent symptoms within the revision group, we found similar BCTQ scores at six months and improvements in the BCTQ scores between patients.

This study is the first to compare the outcome of primary and revision CTR directly. Our study's postoperative BCTQ scores of patients who underwent primary CTR are consistent with a previous study by Kleermaeker et al.[8] While our patients had postoperative scores of 1.55±0.58 for both the FSS and SSS subscales, they reported postoperative scores at six months of 1.54±0.65 on the FSS subscale and 1.54±0.66 on the SSS subscale. In addition, the mean postoperative BCTQ scores of our revision group were in line with a previous study by Cobb et al.[9] Our revision patients had postoperative scores of 1.93±0.76 on the FSS subscale and 1.95±0.77 on the SSS subscale, and they reported a score of 1.95±0.90 on the FSS subscale and 1.92±0.82 on the SSS subscale; however, it is not clear at what time after surgery this was measured.

The difference between primary and revision patients in BCTQ total score declined from 0.39 points to 0.27 points after propensity score matching. This means that

matched patients with similar baseline severity and demographics have more similar outcomes than the general (unmatched) study population. Therefore, we conclude that the variables on which we matched the patients might be associated with the postoperative outcome. This is in line with previous research that preoperative symptom severity, functional status, comorbidities, and work-related factors are predictors of the outcome.[13,14,29] Nonetheless, the difference between the average BCTQ total scores at six months of primary and revision patients (0.39 unmatched and 0.27 matched) was below the MCID regardless of matching.[19] While this difference is statistically significant, the clinical relevance may be less evident; this contrasts with our experience that many surgeons believe revision CTR's outcome is less good than primary CTR.

Nevertheless, the slight difference between the groups remains significant after matching, indicating that other factors contribute to this difference. A reason might be that revision patients have already had previous surgery, followed by persistent symptoms or redevelopment of symptoms. Moreover, recurrent and persistent CTS may have multiple etiologies, such as an incomplete release, a misdiagnosis, or perineural fibrosis.[7,30] While these factors could make revision surgery more complex and essential to keep in mind, they have not yet been investigated as predictors of the outcome after revision surgery. We were unable to include these factors in this study because these factors do not play a role in primary patients.

Furthermore, psychological factors like depression, pain catastrophizing, and patients' expectations of treatment have been proven to affect the outcome after surgery.[31] They could, therefore, influence the difference in self-reported effectiveness between the two groups in our study.[29,32-34] We did not include these factors in this study because we did not have enough data. It would be interesting to analyze this in further research.

It is essential to consider the clinical relevance of the difference in BCTQ total score between primary and revision CTR. A clinically important improvement in the BCTQ total score was reached in 59% of unmatched primary patients and 50% of unmatched revision patients. Before matching, 10% of revision patients had a BCTQ total score of 1.00 at six months (i.e., no complaints) compared to 18% of primary patients. Previous studies by Cobb et al.,[9] Beck et al.,[10] and Jones et al.[7] reported complete relief of symptoms in revision patients in 34%, 54%, and 57% of patients. Kleermaeker et al.[8] noted complete relief of symptoms in 57.5% of primary patients. The discrepancy in rates between these studies and our study might be due to the definition of complete relief; they used unspecified definitions, while we used a strict BCTQ total score of 1.00. Hence, looking into patients without any improvement might be more generalizable. In our study, 5.5% of unmatched primary patients and 11.6% of unmatched revision patients did not notice any improvement after surgery. These rates are lower than those reported in previous studies.[7,9,10]

Considering postoperative satisfaction, a higher percentage of primary patients (excellent/good: 76%) were satisfied with CTR outcomes than revision patients (55%). This difference seems higher than the differences in BCTQ outcome rates between the groups. This suggests that primary patients may be more likely to be satisfied with similar results than revision patients. Previous studies have suggested that psychological factors like depression, anxiety, and coping mechanisms influence perceived symptom severity and adaptation to objective dysfunction and, therefore, satisfaction after surgery.[32,33] In addition, Kadzielski et al.[33] stated that fulfilling expectations best predict patient satisfaction. Thus, it would be interesting for future research to focus on differences in psychological factors between primary and revision CTR.

Strengths of this study include the relatively large sample size and the broad range of prospectively gathered questionnaires used as our outcome measures. Our study also has several limitations. First, some of the comorbidities and concomitant procedures were collected retrospectively from the medical records; therefore, we might be missing out on information that was not well documented by the physician. Second, a proportion of the revision patients (23%) had missing values for BMI, smoking, and alcohol usage. We did not include these variables in the matching procedure since this would decrease the number of patients. Previous studies showed that these variables are not related to the clinical outcome.[10,13,21] As a sensitivity analysis, we did perform an additional analysis (not reported), where we also matched these variables and found similar results in the BCTQ total score at six months: better outcome in primary patients (1.65±0.62) than revision patients (1.86±0.69, p=0.031). Third, exact data on additional procedures performed in the revision group was not available in a standardized format. Although an additional hypothenar fat pad flap procedure seems successful,[35,36] Pace et al.[37] showed no difference in self-reported symptom severity or functional scores between patients undergoing revision CTR with or without a fat pad transposition. Fourth, we did not evaluate the surgeon's experience, which may affect surgical outcome.[11] However, it is unlikely that this influenced the outcome in our study, considering patients of both groups were treated by the same surgeons in the same clinics.[13,38] Fifth, nerve conduction studies and ultrasound were not reported in a standardized format and therefore could not be used in the analysis. However, nerve conduction studies can be false-positive after the previous surgery,[39,40] making the reliability of these studies, especially in revision CTR patients, debatable. Since nerve conduction studies and ultrasound can remain abnormal after CTR, regardless of complaints, the diagnosis of recurrent and persistent CTS is difficult. Misdiagnosis of CTS may cause (revision) CTR to fail, which may influence the outcome of this study. However, our results are comparable to previous literature; thus, even if misdiagnosed patients are present in this cohort, this seems like something that cannot be prevented by a diagnostic workup. Sixth, although we tried to reduce differences in baseline characteristics between the groups using propensity score matching, we could not correct for residual confounding.

Finally, research into recurrent CTS is limited because there is no unambiguous classification for recurrent CTS, and it is therefore difficult to make comparisons between studies. We have taken a complaint-free period of 6 months as a cut-off point, but it would perhaps be better to classify based on intraoperative findings if these are correctly described by the surgeon.

In conclusion, we found that the outcome after revision CTR is only 16% worse than primary CTR. Our propensity score-matched analysis results indicate that worse baseline symptom severity, worse functional status, and preoperative demographics (age, sex, workload, dominant side treated, comorbidities, and the presence of CTS on both sides) may play a role in this difference. However, differences are relatively small and below the MCID. Revision CTR still offers a clinically and significant benefit in terms of function. Moreover, the complication rates for CTR are equal in primary and revision groups. All in all, this makes revision surgery a safe and effective treatment, also compared to primary surgery. These results can serve as a design for more accurate counseling of patients prior to surgery and provides new insights for future research. Future research should focus on the influence of pathophysiological changes after primary surgery on the outcome of revision CTR and investigate differences in psychological factors between patients undergoing primary and revision CTR.

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Ethical approval

Ethical approval was obtained by the CMO of the Erasmus MC.

Declaration of Conflicting interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2022.08.056.

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