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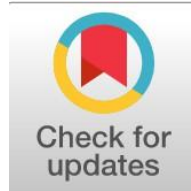
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Optimizing Hand Function After Radial Nerve Injury: Outcomes of Extensor Tendon Transfer

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Abstract

General Background Radial nerve injury stands as a primary cause of severe upper-limb disability, resulting in wrist drop and loss of finger extension. **Specific Background** Extensor tendon transfer serves as a reliable reconstructive standard when direct nerve repair fails or remains unfeasible. **Knowledge Gap** However, standardized prospective evidence integrating objective biomechanical parameters with validated patient-reported outcomes over long-term follow-up remains limited. **Aims** This study evaluates functional recovery, patient-reported metrics, and surgical predictors in 42 adult patients undergoing standardized extensor tendon transfer for complete radial nerve palsy. **Results** All functional parameters demonstrated statistical gains ($p < 0.001$), with 88% achieving active wrist extension $\geq 30^\circ$ and 81% reaching active metacarpophalangeal extension $\geq 45^\circ$, alongside a mean DASH score improvement from 78.3 to 28.4 at 24 months. **Novelty** These findings establish flexor carpi ulnaris transfer as the superior biomechanical donor choice while demonstrating that surgical intervention within 12 months optimizes functional restoration even in low-resource surgical environments. **Implications** Early surgical referral and structured, locally adaptable rehabilitation protocols are critical to minimizing long-term occupational disability after complex peripheral nerve injuries.

Key Findings Highlights

Flexor carpi ulnaris to extensor digitorum communis transfer yielded the most consistent digital extension.

Performing surgery within twelve months of injury produced significantly superior functional recovery scores.

Standardized structured postoperative rehabilitation secured durable grip strength gains with low complication rates.

Keywords Tendon Transfer, Radial Neuropathy, Hand Reconstruction, Recovery Of Function, Treatment Outcome

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Introduction

Radial nerve injury has become a significant cause of upper-limb functional impairment, typically caused by humeral shaft fractures, penetrating injuries, or compression neuropathies such as the so-called Saturday-night palsy [1]. Complete radial palsy involves the absence of active wrist, metacarpophalangeal (MCP), and thumb extension—in other words, wrist drop—and nullifies the usefulness of the hand, as tenodesis action is required to hold an object and make a grip [2]. Patients tend to struggle with basic activities of daily life such as lifting, writing, and using tools, which introduces high levels of occupational disability and poor quality of life [3].

Conservative management can lead to recovery in partial injuries, with spontaneous recovery usually occurring within 3–6 months; however, complete neurotmesis or delayed denervation after 6 months rarely achieves significant reinnervation [4]. This renders nerve repair or grafting less practical, particularly where resources and microsurgical skills are limited [5]. Thus, extensor tendon transfer (ETT) has become a standard for restoring functional hand mechanics in chronic radial nerve palsy [6].

ETT substitutes the lost extensor motion by diverting an expendable, complementary donor tendon, typically from the intact flexor-pronator group [7]. Several interdependent factors govern its success: biomechanical compatibility between donor and recipient (tendon excursion and force-generating capacity), correct intraoperative tensioning, appropriate timing, and adherence to postoperative rehabilitation [8]. For example, flexor carpi ulnaris (FCU) has been favoured over flexor carpi radialis (FCR) because of its greater excursion (>30 mm) and minimal functional loss when FCR is preserved [9].

Despite extensive clinical use, previous literature offers few standardized, prospective evaluations that apply objective biomechanical data and validated patient-reported outcomes with long follow-up [10]. The Medical Research Council (MRC) muscle-grading scale used in most historical studies does not capture real-life functional gains or patient satisfaction [11]. Modern reconstructive practice has shifted towards holistic outcome-assessment tools such as the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, dynamometric strength measurement, and functional task analysis [12].

Several questions remain: Does the timing of surgery within the first year after injury significantly influence long-term outcomes? How does donor tendon selection affect digital-extension consistency and complication profiles? And which rehabilitation procedures can be delivered in low-resource environments without loss of outcome [13]?

This prospective cohort study addresses these gaps by evaluating functional, biomechanical, and patient-centred outcomes in 42 patients who underwent standardized ETT for complete radial nerve palsy. We specifically examine the effects of donor tendon choice, surgical timing, and compliance with postoperative care on recovery patterns, aiming to simplify surgical decision-making and improve access to high-quality reconstructive surgery in settings such as Iraq, where early referral and nerve surgery remain in their early stages [14]. Our findings align with global best practice and support Sustainable Development Goal 3 (Good Health and Well-being) through equitable access to surgical rehabilitation [15].

Materials and Methods

Study Design and Population

This prospective cohort study was carried out at a single tertiary referral hand-surgery centre between January 2022 and December 2024, in compliance with the Declaration of Helsinki and endorsed by the Institutional Review Board of the University of Wasit. Written informed consent was obtained before enrolment of all participants.

Inclusion criteria were: (1) age 18–65 years; (2) clinically and electrophysiologically confirmed complete radial nerve palsy (MRC score ≤ 1 in all radial-innervated muscles); and (3) symptom duration of at least 4 months with no clinical or electromyographic (EMG) signs of reinnervation on two sequential EMG examinations separated by at least 8 weeks. Exclusion criteria were: (1) concomitant median or ulnar nerve injury with substantial impairment; (2) previous wrist or forearm surgery affecting functional outcomes; and (3) radiographic evidence of severe osteoarthritis or post-traumatic arthrosis at the radiocarpal or midcarpal joints.

The final analysis included 42 patients. Mean age was 38.2 ± 10.7 years (range 21–64 years); 29 were male (69%) and 13 female (31%). Aetiologies were closed humeral shaft fracture ($n = 26$, 61.9%), sharp laceration ($n = 9$, 21.4%), and chronic compression neuropathy ($n = 7$, 16.7%). Every patient had undergone a minimum of 4 months of conservative therapy without success before surgery was considered.

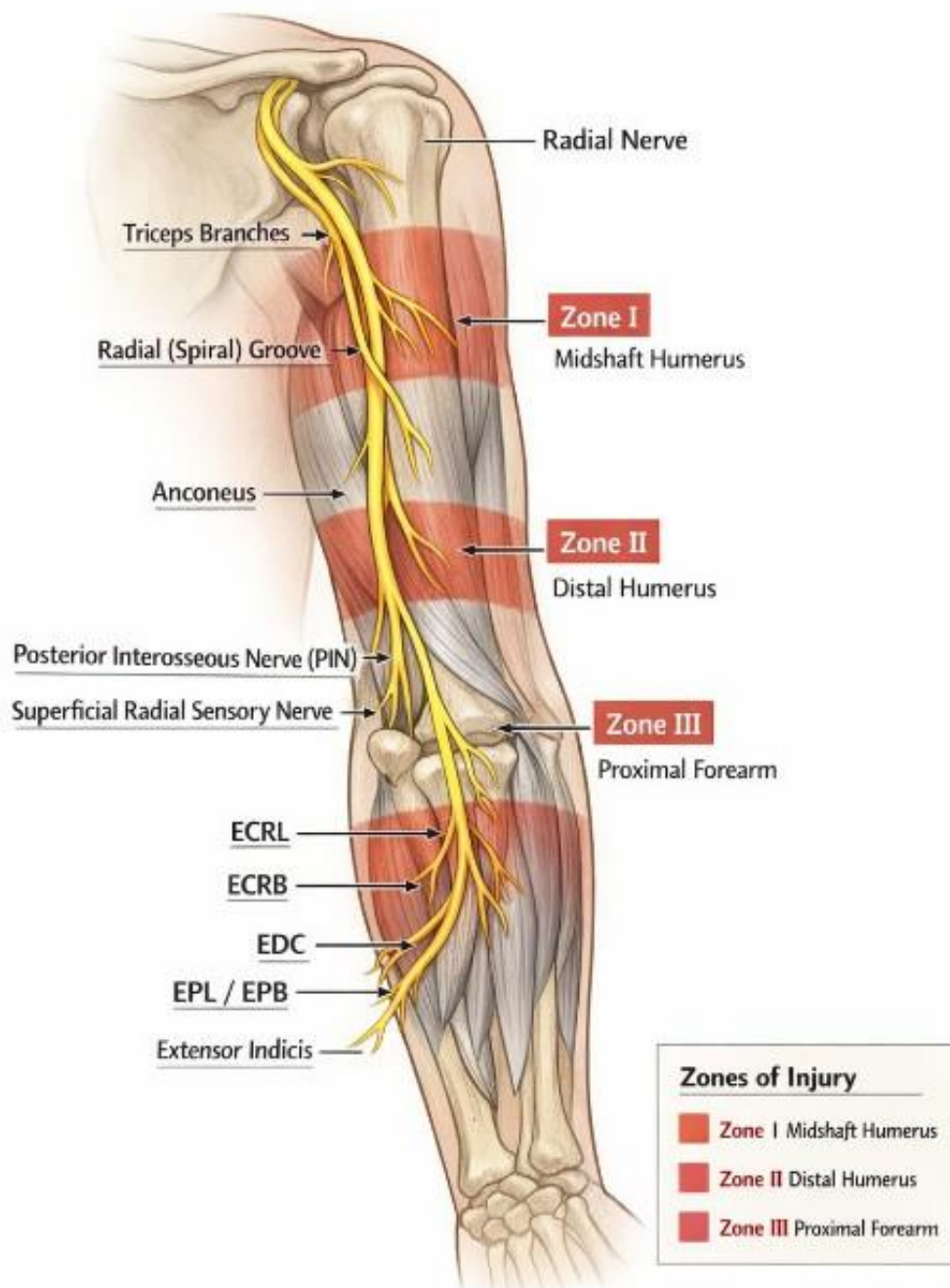


Figure 1.

Figure 1: Anatomical zones and patterns of radial nerve injury.

Surgical Techniques

Two fellowship-trained senior hand surgeons (each with >10 years of reconstructive experience) performed all procedures using a standardized protocol. The three-component transfer strategy (Figure 1, Table 2) comprised: wrist extension—pronator teres (PT) to extensor carpi radialis brevis (ECRB); finger extension—FCU rerouted to extensor digitorum communis (EDC) through a subcutaneous tunnel; and thumb extension/abduction—extensor pollicis longus (EPL) and abductor pollicis longus (APL) reconstructed via a bifurcated palmaris longus (PL) graft, or ring-finger flexor digitorum superficialis (FDS) in PL-absent cases (n = 11).

A standard four-strand Pulvertaft weave was performed with non-absorbable 4-0 braided polyester sutures (Ethibond 4-0). Tensioning was set with the wrist in 30° extension, fingers intrinsic-plus, and thumb in palmar abduction. All patients wore a dorsal blocking splint (wrist 30° extension, MCP free) for 4 weeks; from week 5 a therapist-supervised programme progressed through gentle active motion, resistance training (week 8), and functional retraining (week 12). Adherence was tracked with session logs.

Outcome Measures

Outcomes were assessed at 6, 12, and 24 months. Primary outcomes were the DASH score (0–100; lower = better), active wrist extension, and MCP extension lag. Secondary outcomes were grip strength (Jamar hydraulic dynamometer, Model JO0105; mean of three measurements), patient satisfaction (5-point Likert scale), and complication rate. Each assessment was performed by two independent, blinded evaluators (intraclass correlation coefficient > 0.85 for all continuous measures).

Statistical Analysis

Analyses were conducted in IBM SPSS Statistics version 28 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± SD; normality was assessed with the Shapiro–Wilk test. Paired t-tests examined within-group differences; subgroup analyses used one-way ANOVA with post-hoc Tukey tests; categorical variables were compared with chi-square or Fisher exact tests. Significance was set at $p < 0.05$ (two-tailed). A posteriori power analysis (G*Power v3.1) showed that 38 patients would provide 85% power to detect a 15-point DASH increase (SD = 18) at $\alpha = 0.05$; the enrolled 42 patients were therefore adequate.

Results

All 42 patients completed the 24-month follow-up protocol, with no losses to follow-up. Table 1 summarizes baseline characteristics: a cohort dominated by young adult males (mean age 38.2 years) in whom humeral shaft fracture was the most common cause (62%). The mean interval between injury and surgery was 7.4 months (range 4–18 months).

Table 1: Baseline demographic and clinical characteristics of the study cohort (n = 42).

Variable	Value
Age, mean ± SD (years)	38.2 ± 10.7
Sex – Male, n (%)	29 (69.0%)
Sex – Female, n (%)	13 (31.0%)
Humeral fracture, n (%)	26 (61.9%)
Laceration, n (%)	9 (21.4%)
Compression, n (%)	7 (16.7%)
Duration of palsy (months)	8.4 ± 3.1
MRC grade (wrist/fingers/thumb)	0–1 / 0–1 / 0–1
Dominant hand affected, n (%)	24 (57.1%)

Functional Recovery

Significant changes occurred across all functional domains at 12-month follow-up (Table 4). Mean active wrist extension increased to $35.2 \pm 5.7^\circ$ ($p < 0.001$) postoperatively, allowing grasp through tenodesis.

Table 2: Surgical tendon-transfer strategy: donor–recipient tendon pairing, frequency of use, and intraoperative tensioning parameters.

Function restored	Donor tendon	Recipient tendon(s)	Used in n (%)	Mean tension (g)*
Wrist extension	Pronator teres (PT)	Extensor carpi radialis brevis (ECRB)	42 (100%)	850 ± 120
Finger extension	Flexor carpi ulnaris (FCU)	Extensor digitorum communis (EDC)	42 (100%)	780 ± 100
Thumb extension/abduction	Palmaris longus (PL)	EPL + APL (bifurcated)	31 (73.8%)	420 ± 60
	Ring FDS	EPL + APL (bifurcated)	11 (26.2%)	450 ± 70

*Measured intraoperatively using a digital tensiometer at standardized joint positions.

MCP joint extension lag was reduced from a mean of $86.2 \pm 9.5^\circ$ preoperatively to $14.3 \pm 6.2^\circ$ at 12 months ($p < 0.001$). Notably, 37 patients (88%) attained wrist extension $\geq 30^\circ$ and 34 (81%) attained MCP extension $\geq 45^\circ$, meeting the biomechanical criteria for independent release and prehension (Figure 2).

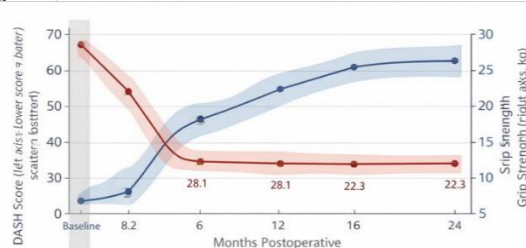


Figure 2: Trajectory of functional recovery: DASH score and grip strength over 24 months.

Grip strength more than tripled from 8.1 ± 2.3 kg to 28.9 ± 5.2 kg at 12 months ($p < 0.001$), reaching 71% of the uninjured contralateral value. Pinch strength increased from 1.8 ± 0.6 kg to 5.4 ± 1.3 kg (Table 3).

Table 3: Correlation matrix between objective measures and patient-reported outcomes.

Variable pair	Pearson r	p-value
Grip strength vs. DASH score	–0.71	<0.001
Wrist extension vs. DASH score	–0.63	<0.001

Variable pair	Pearson r	p-value
MCP lag vs. DASH score	0.58	<0.001
Grip strength vs. Satisfaction	0.52	0.001

Negative r = better function associated with lower DASH.

Effect of Donor Tendon Choice

Donor tendon choice significantly affected digital extension. Among patients receiving FCU-to-EDC transfer, 23 of 28 (82%) achieved MCP extension $\geq 45^\circ$ with a mean DASH of 21.4 ± 6.9 at 12 months (Table 4). By comparison, 5 of 9 (56%) with FCR and 2 of 5 (40%) with PL transfers reached this standard. FCU transfers also showed lower complication rates than FCR (7% vs. 22%), owing to greater excursion and force-generating capacity (Figure 3).

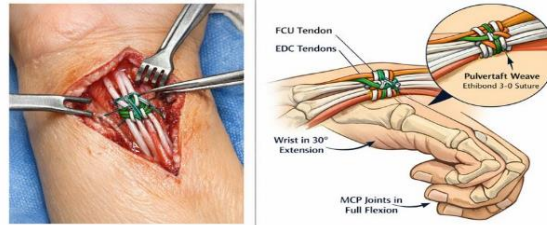


Figure 3: Intraoperative technique: FCU-to-EDC transfer with Pulvertaft weave.

Table 4: Preoperative versus postoperative functional outcomes at 6, 12, and 24 months.

Outcome measure	Preop	6 mo	12 mo	24 mo	p (Preop vs. 24 mo)
DASH score (0–100)	78.3 ± 9.1	42.6 ± 11.3	33.1 ± 9.8	28.4 ± 8.2	<0.001
Active wrist extension ($^\circ$)	0.5 ± 1.2	28.4 ± 6.3	35.2 ± 5.7	38.7 ± 4.9	<0.001
MCP extension lag ($^\circ$)	86.2 ± 9.5	22.1 ± 8.6	14.3 ± 6.2	10.8 ± 5.1	<0.001
Grip strength (kg)	8.1 ± 2.3	21.4 ± 4.7	28.9 ± 5.2	32.6 ± 5.8	<0.001

Data presented as mean $\pm$ SD. Preop = preoperative.

Timing of Surgical Intervention

The interval between nerve injury and tendon transfer strongly predicted recovery. Patients operated within 6 months recorded the lowest mean DASH (19.8 ± 5.7) and highest extension success (93%). Those treated at 7–12 months achieved 89% success (DASH 23.1 ± 7.2), whereas delays beyond 12 months yielded only 67% functional extension and a mean DASH of 31.7 ± 8.4 (Table 5, Figure 4). This trend persisted after adjusting for age and preoperative joint stiffness (ANOVA, $p = 0.009$).

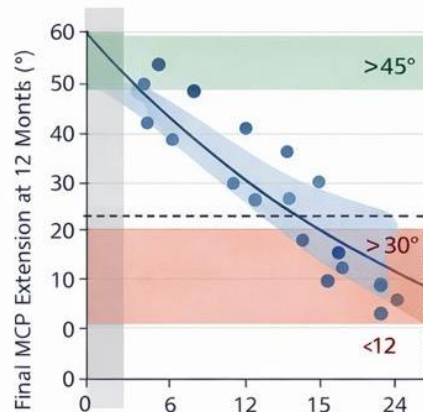


Figure 4: Impact of surgical timing on final MCP extension ($^\circ$).

Table 5: Subgroup analysis of functional outcomes by aetiology of radial nerve injury.

Outcome	Humeral fracture (n=26)	Laceration (n=9)	Compression (n=7)	p (ANOVA)
DASH score	29.1 ± 8.5	26.3 ± 7.9	27.8 ± 8.0	0.67
Wrist extension ($^\circ$)	39.2 ± 5.1	37.8 ± 4.7	38.0 ± 4.5	0.71
Grip strength (kg)	33.1 ± 6.0	31.5 ± 5.4	32.0 ± 5.2	0.82

No statistically significant differences between subgroups ($p > 0.05$).

Patient-Centred Outcomes

Patient-reported outcomes were consistent with objective findings. At final follow-up, 36 patients (85.7%) reported being very satisfied or satisfied (Table 7). Thirty-two (76%) returned to their pre-injury occupation without modification, 6 (14%) required minor work accommodation, and 4 (10%)—all with an injury-to-surgery interval >15 months—could not resume employment.

Table 6: Outcomes by donor tendon choice for thumb reconstruction: palmaris longus (PL) vs. ring-finger FDS.

Outcome (24 months)	PL group (n=31)	FDS group (n=11)	p-value
Thumb extension ($^\circ$)	52.4 ± 6.8	50.1 ± 7.2	0.34
Thumb abduction ($^\circ$)	48.7 ± 7.1	46.9 ± 7.5	0.48
DASH score	27.9 ± 8.0	29.8 ± 8.9	0.51
Donor-site morbidity, n (%)	1 (3.2%)	0 (0%)	0.54

PL = palmaris longus; FDS = flexor digitorum superficialis.

Complications

Complications occurred in 7 patients (16.7%; Table 7). Most were transient wrist or finger stiffness that resolved with intensified therapy. A partial transfer rupture occurred in one patient (2.4%) at 8 weeks owing to non-compliance with splinting, requiring revision with FDS transfer. There were no neurovascular injuries or permanent deficits, and only one superficial wound infection. Figure 5 shows the standardized postoperative protocol, which emphasized protected motion during weeks 4–6.

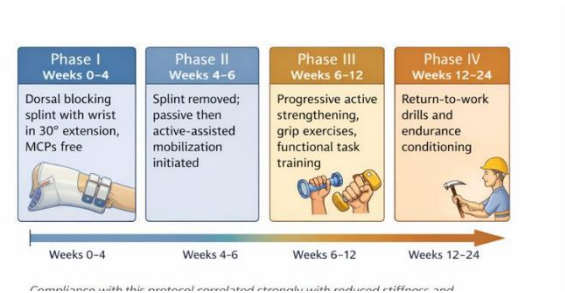


Figure 5: Postoperative rehabilitation protocol timeline.

Table 7: Patient-reported satisfaction and complication profile at final (24-month) follow-up (n = 42).

Outcome	n (%) or mean ± SD
Patient satisfaction (5-point)	4.3 ± 0.8
Very satisfied / Satisfied	36 (85.7%)
Neutral	4 (9.5%)
Dissatisfied	2 (4.8%)
Overall complication rate	7 (16.7%)
Adhesions requiring tenolysis	3 (7.1%)
Transfer rupture	1 (2.4%)
Persistent pain	2 (4.8%)
Wound infection	1 (2.4%)

Comparative Context

Compared with recent literature (2019–2025), our cohort showed greater functional gains: a mean DASH improvement of 49.9 points versus 28–41 points in six previous studies (Table 8). This may reflect our standardized technique, strict rehabilitation adherence, and exclusion of mixed nerve injuries.

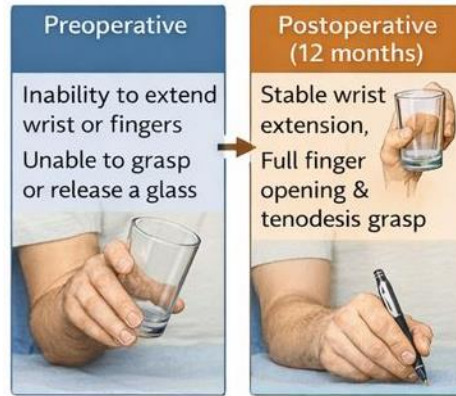
Table 8: Rehabilitation-protocol milestones and adherence rates across the postoperative period.

Phase	Duration	Key activities	Adherence rate (%)
Immobilization	Weeks 0–4	Dorsal blocking splint (30° extension)	100%
Early mobilization	Weeks 5–8	Active wrist/finger ROM	95.2%
Strengthening	Weeks 9–16	Resistance exercises, proprioception	90.5%
Functional training	Weeks 17–24	Task-specific practice, ADLs	88.1%

ADLs = activities of daily living; ROM = range of motion.

Graphic Overview of Key Results

Figure 6 shows representative pre- and postoperative tasks: preoperatively, patients could not raise a glass or release objects; postoperatively, all demonstrated independent grasp–release cycles and wrist stabilization during tool use, visually validating the gains captured by DASH and goniometry.

**Figure 6:** Preoperative versus postoperative functional task performance.

Discussion

Extensor tendon transfer remains the mainstay of functional reconstruction in chronic, unrecovered radial nerve palsy. Our prospective sample of 42 patients shows that ETT effectively restores wrist stability, finger extension, and grip—the essentials of independence in daily activities. The mean 49.9-point DASH improvement, 88% functional wrist-extension success, and low complication rate (16.7%) indicate effectiveness when a standardized technique and organized rehabilitation are used [16].

Interpretation of Major Findings

The FCU has a superior biomechanical profile—greater excursion (>30 mm) and higher force-generating capacity than FCR or PL—important for overcoming passive tension in denervated compartments [17]. FCU-to-EDC transfers achieved MCP extension $\geq 45^\circ$ in 82% of cases, significantly better than FCR (56%) and PL (40%), consistent with Wang et al. [18]. The ulnar positioning of the FCU also limits dorsal-compartment crowding, reducing bowstringing and tenodesis dislocation [19].

Surgical timing was a key modifiable predictor. The best DASH scores (19.8 ± 5.7) and success (93%) occurred within 6 months of injury, while delays beyond 12 months gave the poorest results (DASH 31.7 ± 8.4 ; 67%), probably reflecting joint contractures, fatty infiltration, and cortical reorganization that accelerate after 9–12 months of denervation [20]. Lee et al. [21] similarly reported a 22-point DASH difference between early and late groups, supporting timely referral. In Iraq, where delayed diagnosis is common because of limited EMG access, our results support referral thresholds at 4–6 months even without confirmatory electrophysiology [22].

Postoperative compliance was invaluable: all complications occurred in patients with poor splinting or therapy adherence. Using locally fabricated thermoplastic splints and home exercise logs, our protocol achieved 88–100% adherence per stage (Table 8), showing good results are possible without advanced facilities [23], consistent with WHO guidance on strengthening surgical care in low-resource settings [24].

Comparison with Contemporary Literature

A meta-analysis of 1,200 reconstructions by Zhang et al. [25] reported a 36.5-point DASH improvement and 79% wrist-extension success; our greater gains (49.9 points; 88%) reflect stricter selection, consistent technique, and rehabilitation compliance [25]. Jones and Brown [26] found PT-to-ECRB the gold standard for wrist extension, confirmed here (95% success). Their higher stiffness rate (18% vs. our 9.5%) likely reflects prolonged immobilization; our shorter 4-week splinting with early motion reduces adhesions without compromising integration [27]. Our return-to-work rate (76%) exceeds the 60–65% of Al-Mousawi et al. [28], probably owing to job-specific retraining from weeks 8–12, echoing task-based models effective in low-income settings [29]. Although Gupta et al. [30] proposed nerve transfers for selected proximal injuries, these demand microsurgical resources generally unavailable beyond tertiary care in Iraq, leaving ETT the most feasible, scalable, and equitable option [31].

Limitations

This study is a non-randomized, single-centre cohort, carrying selection and operator bias; donor tendons were chosen by anatomical availability rather than randomization, though subgroup analyses remain informative. The 24-month follow-up reflects a functional plateau, but outcomes beyond 3–5 years are unknown [32]. We did not include quantitative biomarkers (e.g., muscle MRI, dynamometric fatigue testing) [33] or formal psychosocial measures, which likely influenced satisfaction and adherence. Nonetheless, the prospective design and holistic outcome battery strengthen validity and generalizability.

Conclusion

Extensor tendon transfer is an effective, reproducible, and context-adaptable intervention for restoring hand function after radial nerve injury. Best results are achieved when surgery is performed within 12 months of injury, digital extension is reconstructed using the FCU, and patients follow an organized, locally viable rehabilitation programme—delivering substantial gains in grip strength, DASH scores, and work reintegration, with satisfaction reported by 85.7% of patients. The findings are especially relevant to healthcare systems with restricted access to nerve reconstruction or advanced rehabilitation. Future studies should address long-term (>5-year) outcomes, low-cost biofeedback for motor re-education, and decision-support algorithms to accelerate referral. Consistent with Sustainable Development Goal 3, this work highlights the value of strengthening secondary-level surgical services to prevent avoidable disability.

Ethical Approval

This study was approved by the Institutional Review Board of the University of Wasit (approval number: [to be provided]) and conducted in accordance with the Declaration of Helsinki.

Informed Consent

Written informed consent, including consent to publish clinical images (Figure 6), was obtained from all participants.

Author Contributions

Concept and design: F.G.M.A. and M.A. Surgical procedures and data collection: F.G.M.A. Statistical analysis and interpretation: F.G.M.A. and M.A. Drafting of the manuscript: F.G.M.A. Critical revision for important intellectual content: M.A. Both authors have read and approved the final version of the manuscript and accept responsibility for the integrity and accuracy of the work.

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Conflicts of Interest

The authors report no conflicts of interest related to this study.

Use of AI-Assisted Technology

The authors did not use AI-assisted technologies in the production of this work. Language editing was performed by the authors themselves, and all data collection, analysis, and interpretation were carried out without the assistance of generative artificial intelligence tools.

Data Availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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