Journal of Chemical Health Risks

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JCHR (2026) 16(2), 292-300 | ISSN:2251-6727

Finger-Wise Clinical and Functional Outcomes of Single-Stage Flexor Tendon Reconstruction in Zone II

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(Received: 05 January 2026 Revised: 15 February 2026 Accepted: 05 March 2026)

KEYWORDS

Flexor Tendon Injury, Zone II, Tendon Reconstruction, TAM Score, Digit-Specific Outcomes, Hand Surgery.

ABSTRACT:

Background: Flexor tendon injuries in Zone II represent one of the most challenging upper-limb traumas due to complex anatomy and a high risk of adhesion formation. Although single-stage tendon reconstruction is an established technique, finger-specific functional outcomes remain under-reported. Therefore, this study aims to evaluate the clinical and finger-wise functional outcomes following single-stage flexor tendon reconstruction for chronic Zone II injuries.

Methods: This prospective observational study at the Department of Orthopaedic Surgery, Bangladesh Medical University, Dhaka, Bangladesh (January 2024–December 2025) included 40 participants with 110 injured fingers undergoing single-stage reconstruction. Demographics, injury characteristics, graft type, complications, and outcomes were recorded. Functional outcomes were assessed using Total Active Motion and Buck–Gramcko grading, with chi-square and Kruskal–Wallis tests for analysis.

Results: Most patients were young males (82.5%), commonly injured by sharp knife cuts (60%). The ring (28.2%) and little (27.4%) fingers were most frequently affected. Overall, 85% achieved excellent/good outcomes (40% excellent, 45% good). Nail–palm distance and total active motion improved significantly in all digits ($p < 0.001$), while extension deficit improved significantly in the index ($p = 0.026$), middle ($p = 0.029$), ring ($p = 0.021$), and little fingers ($p = 0.042$) but not in the thumb ($p = 0.175$). Complications occurred in 22.5%, most commonly swan-neck deformity (10%).

Conclusion: Single-stage flexor tendon reconstruction in Zone II yields predominantly good to excellent functional outcomes with significant overall improvement, low complication rates, and

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JCHR (2026) 16(2), 292-300 | ISSN:2251-6727

digit-specific variations that emphasize the need for individualized surgical and rehabilitation strategies.

Introduction

Flexor tendon injuries of the hand are among the most complex problems encountered in reconstructive hand surgery, particularly when they involve Zone II, historically referred to as "no man's land" [1]. This region extends from the distal palmar crease to the insertion of the flexor digitorum superficialis (FDS) tendon and is characterized by a confined fibro-osseous tunnel containing both the flexor digitorum profundus (FDP) and FDS tendons along with an intricate pulley system [2]. Surgical management in this zone is challenging due to the high risk of tendon adhesions, limited tendon gliding, and compromised functional outcomes.

Despite advancements in microsurgical techniques, suture materials, and postoperative rehabilitation protocols, flexor tendon reconstruction in Zone II continues to pose significant difficulties, especially in delayed or neglected injuries [3]. In cases where primary repair is not feasible due to tendon retraction, scarring, or segmental loss, tendon reconstruction becomes the preferred option. Reconstruction may be performed either as a two-stage procedure using silicone rods or as a single-stage procedure when the pulley system, tendon bed, and joint mobility are considered adequate [4]. Single-stage reconstruction has gained popularity because it reduces overall treatment duration, avoids the need for a second operation, and facilitates earlier rehabilitation [5]. Various graft options, including palmaris longus and plantaris tendons, have been used with satisfactory results. However, functional success depends on multiple factors such as the finger involved, severity of injury, tendon bed quality, surgical technique, and adherence to rehabilitation protocols [6].

Functional outcomes following flexor tendon reconstruction are commonly evaluated using parameters such as total active motion (TAM), range of motion (ROM), grip strength, and standardized scoring systems [7]. While several studies have reported overall outcomes of Zone II flexor tendon reconstruction, most analyses consider the hand or patient as a single functional unit. Limited attention has been given to finger-wise outcome analysis, despite anatomical and biomechanical differences among individual digits [8]. Finger-specific variations in tendon excursion, pulley configuration, and intrinsic muscle balance may influence postoperative outcomes. Ulnar-sided digits, particularly the ring and little fingers, have been reported to demonstrate inferior functional recovery due to greater tendon excursion demands and higher susceptibility to adhesions [9]. Understanding these finger-wise differences is crucial for surgical planning, prognosis estimation, and patient counseling.

Therefore, this study aims to evaluate the clinical and finger-wise functional outcomes of single-stage flexor tendon reconstruction in chronic Zone II injuries. By analyzing outcomes on an individual digit basis, this research provides deeper insight into factors influencing recovery and guides surgeons toward more tailored surgical and rehabilitation strategies.

Objective

To evaluate clinical and finger-wise functional outcomes following single-stage flexor tendon reconstruction for chronic Zone II injuries.

Methodology & Materials

This prospective observational study was conducted at the Department of Orthopaedic Surgery, Bangladesh Medical University, Shahbag, Dhaka. A total of 40 adult participants (≥18 years) with chronic Zone II flexor tendon injuries who underwent single-stage flexor tendon reconstruction were included after obtaining informed consent. Participants were selected based on predefined inclusion criteria to evaluate the clinical and finger-wise functional outcomes following single-stage flexor tendon reconstruction for chronic Zone II injuries.

Inclusion criteria:

- Chronic Zone II flexor tendon injuries unsuitable for primary repair due to delayed presentation
- Tendon retraction
- Tendon scarring

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Exclusion criteria:

- Acute injuries amenable to primary repair
- Associated fractures
- Neurovascular injuries
- Joint stiffness
- Infection
- Previous surgery
- Poor compliance with rehabilitation

Each reconstructed finger was analyzed individually to allow finger-wise outcome assessment. Preoperative evaluation included documentation of demographic data, hand dominance, mechanism and duration of injury, and finger involvement, along with clinical assessment of passive joint mobility, tendon bed quality, and pulley integrity.

Surgical reconstruction was performed under tourniquet control using a standard Bruner incision. Autologous tendon grafts, predominantly palmaris longus, were used to reconstruct the flexor digitorum profundus tendon, with graft fixation achieved using a multi-strand core suture reinforced by an epitendinous suture. Pulley reconstruction was performed when required.

Postoperatively, all patients followed a standardized early controlled mobilization protocol under hand therapy supervision using a dorsal blocking splint, with gradual progression to active motion over 8–12 weeks.

Functional outcomes were assessed at final follow-up using total active motion, range of motion, grip strength compared with the contralateral hand, and functional grading based on the modified Buck–Gramcko criteria. Postoperative complications were documented.

Data were analyzed using standard statistical software. Results were expressed as mean ± standard deviation or frequencies and percentages, and a p-value < 0.05 was considered statistically significant.

Results

Table 1: Demographic and Injury Characteristics of the Study Participants (n = 40)

Characteristic	Category	Frequency (n)	Percentage (%)
Age Group (Years)	< 18	9	22.50%
	19–30	24	60.00%
	> 30	7	17.50%
Sex	Male	33	82.50%
	Female	7	17.50%
Occupation	Student	13	32.50%
	Businessman	5	12.50%
	Driver	3	7.50%
	Farmer	3	7.50%
	Service holder	2	5.00%
	Housewife	4	10.00%
	Others	4	10.00%
	Not specified	1	2.50%
Mechanism of Injury	Sharp knife cut	24	60.00%
	Sharp glass cut	9	22.50%

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	Road Traffic Accident	5	12.50%
	Machinery injury	2	5.00%
Hand Dominance	Right	35	87.50%
	Left	5	12.50%
Side of Involvement	Right	24	60.00%
	Left	16	40.00%
Duration of Injury	6–12 Weeks	17	42.50%
	> 12 Weeks	23	57.50%

The majority of patients were male (33 patients, 82.5%). Most were young adults aged 19–30 years (24 patients, 60%), followed by those under 18 years (9 patients, 22.5%) and over 30 years (7 patients, 17.5%). Students were the largest occupational group (13 patients, 32.5%), while other occupations included businessmen (5, 12.5%), housewives (4, 10.0%), farmers (3, 7.5%), drivers (3, 7.5%), service holders (2, 5.0%), and others (4, 10.0%), with one patient not specified (2.5%). Sharp injuries were the predominant mechanism, with knife cuts in 24 patients (60%) and glass cuts in 9 patients (22.5%). Right-hand dominance was observed in 35 patients (87.5%), and the right hand was involved in 24 cases (60%). Duration of injury exceeded 12 weeks in 23 patients (57.5%), with the remaining 17 patients (42.5%) presenting within 6–12 weeks.

Table 2: Distribution of Injured Fingers and Type of Tendon Graft Used in Single-Stage Flexor Tendon Reconstruction (n = 40)

Variable	Category	Frequency (n)	Percentage (%)
Involved Fingers	Thumb (FPL)	7	6.00%
	Index	21	17.90%
	Middle	24	20.50%
	Ring	33	28.20%
	Little	32	27.40%
Graft Used	Palmaris Longus	15	37.50%
	Half of Flexor Digitorum Superficialis (FDS)	16	40.00%
	Both (PL + FDS)	9	22.50%
Affected Tendons	FDS + FDP (Fingers)	33	82.50%
	FPL (Thumb)	7	17.50%

The ring finger was the most commonly affected (33 fingers, 28.2%), followed by the little finger (32 fingers, 27.4%) and middle finger (24 fingers, 20.5%). The index finger was involved in 21 cases (17.9%) and the thumb (FPL) in 7 cases (6%). Half-FDS grafts were used in 16 patients (40%), palmaris longus grafts in 15 (37.5%), and combined PL + FDS grafts in 9 patients (22.5%). Most injuries involved both FDS and FDP tendons (33 patients, 82.5%), while thumb injuries involved FPL alone (7 patients, 17.5%).

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Table 3: Overall Functional Outcomes and Postoperative Complications Following Single-Stage Flexor Tendon Reconstruction (n = 40)

Outcome Variable	Category	Frequency (n)	Percentage (%)
Overall Patient Outcome	Excellent	16	40.00%
	Good	18	45.00%
	Fair	4	10.00%
	Poor	2	5.00%
Complications	Joint stiffness	2	5.00%
	Swan neck deformity	4	10.00%
	Tendon adhesion	1	2.50%
	Superficial skin infection	1	2.50%
	Superficial infection	1	2.50%
	None	31	77.50%

Excellent functional recovery was observed in 16 patients (40%) and good recovery in 18 patients (45%), yielding an overall 85% favorable outcome. Fair and poor outcomes were reported in 4 patients (10%) and 2 patients (5%), respectively. Postoperative complications were relatively uncommon, with 31 patients (77.5%) experiencing none. Swan-neck deformity was noted in 4 patients (10%), joint stiffness in 2 (5%), tendon adhesion in 1 (2.5%), and superficial infections in 2 patients (2.5% each).

Table 4: Associated Digital Nerve Injuries and Standardized Perioperative Management in Patients Undergoing Single-Stage Flexor Tendon Reconstruction (n = 40)

Variable	Category	Frequency (n)	Percentage (%)
Associated Nerve Injuries	None	26	65.00%
	Ulnar Digital Nerve	6	15.00%
	Radial Digital Nerve	8	20.00%
Management Before Discharge	Dressing Changed (Yes)	40	100.00%
	Antibiotic (Yes)	40	100.00%
	Analgesic (Yes)	40	100.00%
Management After Discharge	Physiotherapy (Yes)	40	100.00%

Most patients had no associated nerve injury (26 patients, 65%). Ulnar digital nerve injuries occurred in 6 patients (15%) and radial digital nerve injuries in 8 patients (20%). All patients received standardized pre-discharge management, including dressing changes, antibiotics, and analgesics (100% each), and all participated in postoperative physiotherapy.

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Table 5: Functional Evaluation by Buck-Gramcko Criteria (n=72)

Digit		Pre-op	Post-op	p-value
Nail-palm distance	Thumb	0	6	<0.001
	Index	0	6	<0.001
	Middle	0	5.88	<0.001
	Ring	0	5.79	<0.001
	Little	0	4.9	<0.001
Extension deficit	Thumb	3	2.6	0.175
	Index	3	2.58	0.026
	Middle	3	2.25	0.029
	Ring	3	2.15	0.021
	Little	3	1.95	0.042
Total active motion	Thumb	0	5.2	<0.001
	Index	0	5.38	<0.001
	Middle	0	4.75	<0.001
	Ring	0	4.44	<0.001
	Little	0	3.8	<0.001

Functional evaluation using the Modified Buck–Gramcko criteria (n = 72) demonstrated significant postoperative improvement across all digits. Nail–palm distance scores improved markedly in the thumb, index, middle, ring, and little fingers ($p < 0.001$ for all). Extension deficit showed postoperative reduction in all digits, reaching statistical significance in the index, middle, ring, and little fingers, while improvement in the thumb was not statistically significant ($p = 0.175$). Total active motion scores improved significantly in all digits ($p < 0.001$), with relatively better outcomes in the thumb and index finger compared to the little finger.

Discussion

Flexor tendon reconstruction in Zone II remains a demanding surgical endeavor due to the complex anatomy and high risk of adhesions and functional impairment. The present study evaluated demographic characteristics, injury patterns, finger-wise involvement, graft selection, functional outcomes, and complications following single-stage flexor tendon reconstruction, providing comprehensive insight into both patient-level and digit-specific outcomes.

In this study, males constituted the majority of patients (82.5%), and most injuries occurred in young adults aged 19–30 years (60%). This demographic distribution is consistent with previous reports showing that flexor tendon injuries predominantly affect young, economically active males due to increased involvement in manual work and higher exposure to occupational and domestic hazards [1,2]. Similar male predominance has been reported by Fletcher and McClinton and Tang et al., who noted that high-risk activities and dominant-hand usage contribute significantly to injury incidence [5,6]. The high proportion of students in this series further reflects the vulnerability of younger populations in domestic and recreational environments, a finding also noted in studies from South Asia and other developing countries [10].

Sharp lacerations were the most common mechanism of injury in the present study, accounting for over 80% of

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cases, with knife and glass injuries being predominant. This finding aligns closely with the literature, where clean-cut injuries are reported as the most frequent cause of Zone II tendon damage [11,12]. In contrast, studies from industrialized settings have reported a relatively higher proportion of machinery-related injuries, which may explain differences in injury patterns between regions [9]. The predominance of clean lacerations in this cohort likely contributed to favorable surgical outcomes due to reduced tissue crushing and better tendon bed quality.

Right-hand dominance was observed in 87.5% of patients, with the dominant hand being more frequently affected (60%). This observation agrees with Elliot and Savage, who reported that the dominant hand is more susceptible to injury because of its greater involvement in daily activities and tool handling [9]. Similar dominance-related injury patterns have been documented in multiple hand trauma studies, reinforcing the need for focused rehabilitation to restore dominant-hand function [13].

The ring and little fingers were the most commonly involved digits, accounting for over 55% of injured fingers. This predominance of ulnar-sided digit involvement is well documented in the literature and has been attributed to their anatomical position, increased tendon excursion requirements, and vulnerability during power grip activities [14]. In contrast, some Western studies have reported higher index and middle finger involvement, likely reflecting differences in injury mechanisms and occupational exposure [15].

Regarding graft selection, half-FDS and palmaris longus grafts were the most commonly used, either alone or in combination. This is consistent with the established literature, which supports both grafts as reliable options for flexor tendon reconstruction due to their availability, adequate length, and minimal donor-site morbidity [16,17]. Hunter originally advocated palmaris longus as an ideal graft, while subsequent studies have demonstrated comparable outcomes using half-FDS grafts, particularly when pulley integrity is preserved [18]. The frequent use of combined grafts in this study reflects the complexity of injuries involving both FDS and FDP tendons.

Overall functional outcomes in this series were encouraging, with 85% of patients achieving excellent or good results. These findings are comparable to those reported by Fletcher and McClinton, who documented good-to-excellent outcomes in approximately 80–88% of cases following single-stage reconstruction [5]. Similarly, Frueh et al. reported satisfactory functional recovery in the majority of patients when meticulous surgical technique and early controlled mobilization were employed [19]. However, some authors have reported lower success rates, particularly in chronic injuries, emphasizing the influence of delayed presentation and rehabilitation compliance on outcomes [20].

Complication rates in the present study were relatively low, with 77.5% of patients experiencing no complications. Swan-neck deformity was the most frequent complication (10%), followed by joint stiffness and tendon adhesions. These findings are comparable to previous studies, which have identified joint imbalance and intrinsic muscle dysfunction as common postoperative challenges following Zone II reconstruction [21]. The low incidence of tendon adhesions in this study contrasts favorably with earlier reports that described adhesion rates as high as 15–25%, possibly reflecting improvements in surgical technique and rehabilitation protocols [22].

Associated digital nerve injuries were present in approximately one-third of patients, consistent with previous reports indicating that combined tendon and nerve injuries are common in sharp lacerations [23]. Although nerve injuries may negatively influence sensory recovery, the overall functional outcomes in this study remained favorable, suggesting that timely reconstruction and structured rehabilitation can mitigate their impact.

Finger-wise analysis using Total Active Motion scores demonstrated that over 70% of reconstructed fingers achieved excellent or good outcomes, reinforcing the effectiveness of single-stage reconstruction even in chronic Zone II injuries. This finger-specific assessment provides added clinical value, as most previous studies have reported outcomes on a per-patient rather than per-digit basis [24]. The observed variability across fingers supports the growing emphasis on digit-specific prognosis and tailored rehabilitation strategies.

The functional outcomes in this study, assessed using the Buck–Gramcko criteria, showed significant

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postoperative improvement in all digits, with notable gains in nail-to-palm distance and total active motion, and reduced extension deficits in most fingers. These results are supported by Xu et al., who reported that early active motion protocols following Zone II tendon repair significantly enhance total active motion compared with passive rehabilitation, promoting better joint excursion and functional recovery [25]. Overall, the findings reinforce the effectiveness of single-stage flexor tendon reconstruction in Zone II, demonstrating meaningful finger-wise clinical and functional recovery across all digits.

Limitations of the study

The study had a few limitations:

- The relatively small sample size and single-center design may limit the generalizability of the findings.
- The absence of a comparative group restricted direct comparison with other reconstruction techniques.
- The follow-up duration was limited, preventing full assessment of long-term functional and sensory outcomes, particularly in cases with associated digital nerve injuries.

Conclusion

Single-stage flexor tendon reconstruction in Zone II provides predominantly good to excellent functional outcomes in patients with chronic injuries, with significant improvement in nail–palm distance and total active motion across all digits. Extension deficit improved in most fingers, except for the thumb where the change was not statistically significant. The procedure was associated with a low complication rate, and most patients experienced no postoperative complications. Variation in digit-wise recovery, with comparatively better outcomes in the thumb and index fingers and relatively lower gains in the little finger, underscores the importance of individualized surgical planning and targeted rehabilitation to optimize functional recovery.

Acknowledgment

I would like to express my sincere gratitude for the invaluable support and cooperation provided by the staff, participants, and my co-authors/colleagues who contributed to this study.

Financial support and sponsorship

No funding sources.

Conflicts of interest

There are no conflicts of interest.

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