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Edited by Ritik Kashwani

E-mail: docritikkashwani@yahoo.com

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Functional and clinical outcome for single-stage tendon reconstruction: Chronic Zone II flexor tendon injury

SK. Murad Ahmed^{1,*}, Krishna Priya Das¹, Md. Ashraful Islam¹, Nadia Zebin Khan², Md. Moniruzzaman³, Mohammad Rajib Mahmud⁴, Md. Eunus Ali⁵, Md. Ehteshamul Choudhury¹ & Mohammad Suman Sutar¹

¹Department of Orthopaedic Surgery, Bangladesh Medical University, Dhaka, Bangladesh; ²Department of Biochemistry, BIRDEM General Hospital, Shahbag, Bangladesh; ³Department of Orthopaedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh; ⁴Department of Orthopaedic Surgery, Sirajganj 250 Bed General Hospital, Sirajganj, Bangladesh; ⁵Department of Orthopaedic Surgery, Rangpur Medical College Hospital, Rangpur, Bangladesh; *Corresponding author

Affiliation URL:

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Author contact:

SK. Murad Ahmed - E-mail: drskmurad@gmail.com

Krishna Priya Das - E-mail: kpdas74@bsmmu.edu.bd

Md. Ashraful Islam - E-mail: dr_ashraf007@yahoo.com

Nadia Zebin Khan - E-mail: nadiazebin@yahoo.com

Md. Moniruzzaman - E-mail: monir65137@gmail.com

Mohammad Rajib Mahmud - E-mail: dr.mahmuddj7@gmail.com

Md. Eunus Ali - E-mail: eunusdr@gmail.com

Md. Ehteshamul Choudhury - E-mail: mechoudhury86@gmail.com

Mohammad Suman Sutar - E-mail: sumansutar@gmail.com

Abstract:

Chronic Zone II flexor tendon injuries often result in substantial functional impairment and remain surgically challenging. Therefore, it is of interest to evaluate the single-stage tendon reconstruction in 40 patients treated at a tertiary care center in Bangladesh. Most patients were young males with sharp injuries and over half underwent surgery more than 12 weeks after injury using palmaris longus or FDS tendon grafts. At 24 weeks, nail-palm distance and total active motion improved significantly ($p < 0.001$), with 80% of patients achieving excellent or good functional outcomes. Thus, single-stage tendon reconstruction provides effective functional recovery with acceptable complication rates in chronic Zone II flexor tendon injuries.

Keywords: Functional outcome, tendon reconstruction, flexor tendon injury, Zone II, hand

Background:

It is widely accepted that the evolution of the hominid lineage began when humans transitioned from a quadrupedal posture to bipedal locomotion, allowing the hands to assume a primary role in performing daily activities. As a result, the hands, functioning as the main executing organ of human activity, became increasingly susceptible to trauma and overuse injuries. The incidence of flexor tendon injury has been reported to range between 7 and 14 cases per 100,000 populations [1-3]. Traumatic injuries involving the hand flexor tendons are defined as acute mechanical disruptions affecting the flexor tendon structures of the long fingers or thumb. Such traumatic flexor tendon injuries of the hand are frequently encountered by hand surgeons in clinical practice [4, 5]. During flexor tendon repair, it is essential to recognize that the flexor mechanism represents a complex anatomical unit composed of the tendon, tendon sheath and pulley system. Historically, until the 1960s, lacerations of tendons in zone II commonly referred to as “no man’s land” were managed by excision of the injured tendon followed by grafting with a new tendon [6]. Delayed presentations of flexor tendon injuries are not uncommon in tertiary referral hand surgery settings, particularly among patients from rural regions where access to specialized hand surgeons may be limited [7]. Primary repair is generally defined as an end-to-end tendon repair performed within 24 hours of injury, whereas any repair undertaken after this period is categorized as delayed primary repair, which may extend up to four weeks’ post-injury. Evidence across various studies suggests that delayed primary

repair may still be feasible for up to approximately six weeks; however, interventions performed beyond this interval are usually discouraged due to progressive soft tissue alterations, including adhesion formation, muscular shortening and collapse of the pulley system [8]. Consequently, reconstruction of a scarred flexor tendon system in Zone II of the hand continues to present a significant challenge for the hand surgeon [9]. Primary repair remains the preferred treatment modality for flexor tendon injuries whenever feasible. In cases where this is not possible, reconstructive options have been developed. Two-stage flexor tendon reconstruction utilizing a silicone rod (flexible silicone-Dacron-reinforced gliding implant) during the first stage, followed by placement of a free tendon graft through the pseudo sheath formed around the silicone implant during the second stage, was described by Hunter and Salisbury in 1971 [10]. Hunter’s classic two-staged reconstruction technique involves insertion of a flexible silicone gliding implant in the initial stage, followed by placement of an extrinsic free donor tendon graft during the subsequent procedure. Two-stage tendon reconstruction is considered a valuable strategy in selected patients, including those with severe trauma, extensive destruction of flexor pulleys, crushing injuries associated with significant soft tissue damage or underlying fractures and extensive scarring of the flexor tendon bed [11]. A Cochrane systematic review evaluating rehabilitation outcomes following surgery for flexor tendon injuries of the hand did not identify any single management strategy that showed clearly superior results [12]. Although comparison of range of motion (ROM)

outcomes across studies remains useful for quality assurance, there is a recognized gap in the literature regarding the extent of ROM improvements over time and the specific joint movements that pose the greatest difficulty during recovery. In addition, only a limited number of investigations have incorporated patient-reported outcome measures and there is insufficient evidence establishing whether objective measures of impairment correlate with patients' subjective perception of disability following flexor tendon repair. While some prior research has described patient-reported limitations at six weeks after repair [13-15], there remains a paucity of studies assessing these limitations beyond the early restrictive post-operative phase. Therefore, it is of interest to report the functional outcomes of single-stage tendon reconstruction in patients with old flexor tendon injuries at Zone II of the hand.

Methodology and Materials:

This quasi-experimental study was conducted at the Department of Orthopaedic Surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from March 2021 to September 2023. A total of 40 patients with old flexor tendon injuries in Zone II of the hand were enrolled after obtaining written informed consent. Participants were selected based on specific inclusion and exclusion criteria to evaluate the functional outcomes of single-stage tendon reconstruction.

Inclusion criteria:

- [1] FDS and FDP tendon injuries of the fingers in Zone II of the hand.
- [2] FPL tendon injuries of the thumb in Zone II of the hand.
- [3] Patients of any sex.
- [4] Duration of injury from 6 to 52 weeks.
- [5] Normal or near-normal passive range of motion of finger joints.
- [6] Good digital circulation with at least one intact digital vessel.
- [7] At least one intact digital nerve.

Exclusion criteria:

- [1] Extensive scarring.
- [2] Stiffness of finger joints.
- [3] Malunion of small hand bones.
- [4] Fixed flexion deformity of digits.

A structured questionnaire was used to record a thorough history and perform a physical examination for all patients. Post-operative outcomes, complications and follow-ups were systematically documented. In each case, reconstruction of the FDP/FPL tendons in Zone II was performed using palmaris longus or FDS tendon grafts. The pulley was reconstructed using an FDS tendon sleeve. Post-operatively, a dorsal slab was applied below the elbow with the wrist in 20° palmar flexion, the MCP joint in 70° flexion and the PIP and DIP joints in near full extension. Passive flexion and active extension exercises were initiated on the second post-operative day according to the Ganga Hospital rehabilitation protocol for flexor tendon repair

or reconstruction. Patients received follow-up care at 2, 4, 6, 12 and 24 weeks, with a minimum of six months of post-operative care. Complications were recorded at each visit. Functional outcomes were evaluated at 24 weeks post-operatively using the Buck-Gramcko functional criteria. Data were analyzed using SPSS version 26. Descriptive statistics were used to summarize the data. Categorical variables were reported as frequency and percentage and numerical variables as mean $\pm$ standard deviation. Chi-square tests were used for categorical data and paired t-tests were used for numerical data. A p-value <0.05 was considered statistically significant. Results were presented in tables and graphs with appropriate interpretation.

Results:

A total of 40 patients participated in this study, with most aged 11–30 years (77.5%), including 16 patients (40%) aged 11–20 years and 15 (37.5%) aged 21–30 years; smaller proportions were 31–40 years (10%) and 41–50 years (12.5%), with a mean age of 25.75 ± 11.00 years. Males predominated (31, 77.5%) over females (9, 22.5%), yielding a male-to-female ratio of 3.4:1. Students formed the largest occupational group (32.5%), followed by businessmen (17.5%), housewives (15%), farmers (10%), drivers (7.5%), service holders (5%) and others (12.5%) (**Table 1**). Sharp knife cuts were the most common mechanism of injury (22, 55%), followed by sharp glass cuts (10, 25%), road traffic accidents (5, 12.5%) and machinery injuries (3, 7.5%); the right hand was involved in 28 patients (70%) and was dominant in 34 (85%). The interval between injury and surgery exceeded 12 weeks in 22 patients (55%) (**Table 2**). The ring and little fingers were most affected (19 each, 26.4%), followed by the middle (16, 22.2%), index (12, 16.7%) and thumb (6, 8.3%), with no digital nerve injury in most fingers (56, 77.8%), while radial and ulnar digital nerve injuries occurred in 10 (13.9%) and 6 fingers (8.3%), respectively (**Table 3**). Post-operative complications were observed in 9 patients (22.5%), including swan neck deformity (4, 10%), joint stiffness (2, 5%), superficial skin infection (2, 5%) and tendon adhesion (1, 2.5%) (**Figure 1**). Functional evaluation by Buck-Gramcko criteria showed significant improvement in nail-palm distance and total active motion ($p < 0.001$), with extension deficit improving in all digits except the thumb; post-operative total active motion scores ranged from 3.80 ± 0.89 (little finger) to 5.38 ± 0.96 (index) (**Table 4**). Final functional outcomes were excellent in 13 patients (32.5%), good in 19 (47.5%), fair in 5 (12.5%) and poor in 3 (7.5%) (**Figure 2**).

Table 1: Demographic profile of the study subjects (n=40)

Variable	Frequency (n)	Percentage (%)
Age (years)	11–20	40
	21–30	37.5
	31–40	10
	41–50	12.5
	Mean $\pm$ SD	25.75 $\pm$ 11.00
Gender	Male	31
	Female	9
Occupation	Student	13
	Service holder	2
	Housewife	6
	Driver	3
	Farmer	4
	Businessman	7
	Others	5

Table 2: Injury characteristics of the study subjects (n=40)

Variable		Frequency (n)	Percentage (%)
Mechanism of injury	Sharp glass cut	10	25
	Sharp knife cut	22	55
	Machinery injury	3	7.5
	Road traffic accident	5	12.5
Side of involvement	Right	28	70
	Left	12	30
Hand dominance	Right	34	85
	Left	6	15
Interval between injury and operation (weeks)	6-12	18	45
	>12	22	55
	Mean ± SD	21.0 ± 4.0	

Table 3: Distribution of finger involvement and associated digital nerve injuries among the study subjects (n=72)

Variable		Frequency (n)	Percentage (%)
Finger involvement	Thumb	6	8.3
	Index	12	16.7
	Middle	16	22.2
	Ring	19	26.4
	Little	19	26.4
Nerve injury	Radial digital nerve	10	13.9
	Ulnar digital nerve	6	8.3
	None	56	77.8

Table 4: 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

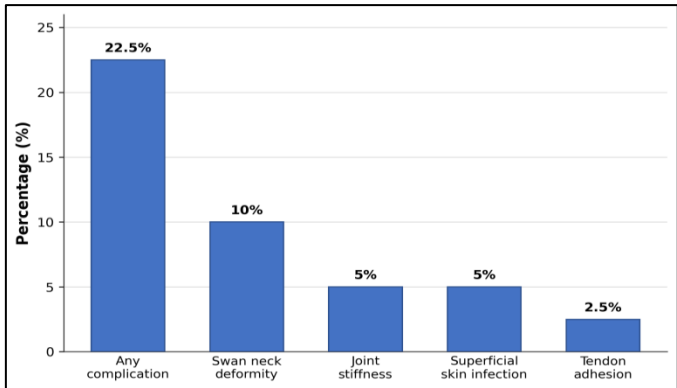


Figure 1: Frequency and types of post-operative complications following single-stage tendon reconstruction (n=40)

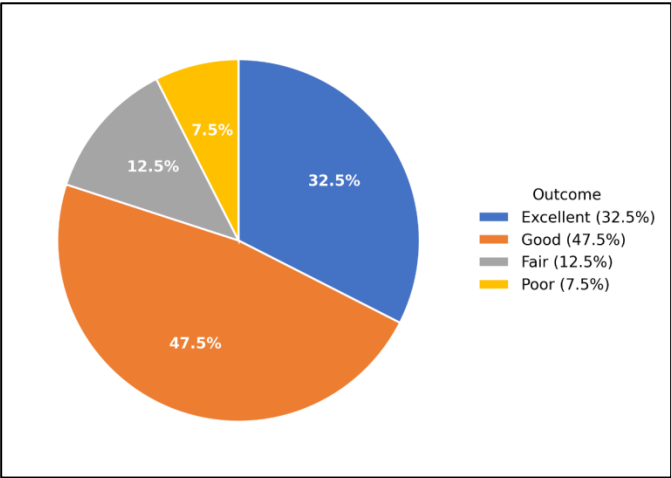


Figure 2: Final functional outcome according to buck-gramcko criteria (n=40)

Discussion:

Zone II flexor tendon injuries are challenging due to complex anatomy and high risk of adhesions, especially in delayed cases with scarring and pulley system collapse. Single-stage tendon reconstruction aims to restore tendon continuity and function while minimizing complications. In this study of 40 patients with old Zone II injuries, reconstruction using FDS or palmaris longus grafts followed by structured early rehabilitation led to significant functional improvement, low complication rates and favorable outcomes, supporting the effectiveness of this approach in delayed presentations. The demographic profile of the study cohort reflects patterns reported in previous studies on delayed Zone II flexor tendon injuries. In our study, the majority of patients were young adults aged 11-30 years (77.5%) with a mean age of 25.75 ± 11.00 years and males predominated (77.5%), consistent with Labib *et al.* [16], who reported a mean age of 25 years and 70% male predominance among 12 patients undergoing delayed primary repair. Students and manual workers comprised the largest occupational groups in our cohort, similar to Labib *et al.*'s observation that 40% of patients were manual workers [16]. The predominance of young males in both studies likely reflects the higher risk of hand trauma in this demographic. Furthermore, knife lacerations were the most common mechanism of injury in both our cohort and Labib *et al.*'s study, supporting the consistency of injury patterns in Zone II flexor tendon trauma [16]. These demographic similarities, together with Munz *et al.*'s finding that early mobilization protocols can achieve excellent and good functional outcomes even with surgical delays [10], provide context for interpreting our results and suggest that age, sex and occupation may influence both injury patterns and recovery potential following delayed tendon reconstruction. The injury characteristics observed in this study align closely with previous research on delayed Zone II flexor tendon injuries. Sharp knife cuts were the most common mechanism of injury (55%), followed by sharp glass cuts (25%), consistent with findings reported by Emir *et al.* [7], where sharp lacerations predominated in delayed

presentations. The right hand was more frequently involved (70%) and corresponded with hand dominance in most patients (85%), reflecting typical patterns of hand usage and associated injury risk in clinical practice. Furthermore, the interval between injury and surgical intervention exceeded 12 weeks in 55% of patients, highlighting a substantial proportion of chronic injuries. Comparable outcomes have been reported by Munz *et al.*, who observed that despite delays ranging from 4 to 37 days, early active mobilization enabled 87% of digits to achieve excellent or good functional recovery [10]. Similarly, Emir *et al.* showed that delayed repairs extending up to six months could still result in excellent total active motion outcomes when controlled early mobilization protocols, such as WALANT, were applied [7]. These findings underscore that even in cases with prolonged injury-to-surgery intervals; meticulous surgical technique combined with structured postoperative rehabilitation can yield satisfactory functional outcomes in Zone II flexor tendon injuries. The distribution of finger involvement and associated digital nerve injuries in this study aligns closely with findings from previous research on Zone II flexor tendon injuries. In our cohort, the ring and little fingers were the most frequently affected (26.4% each), followed by the middle (22.2%), index (16.7%) and thumb (8.3%), comparable to Mortada *et al.*, who reported the little finger as the most commonly injured digit (28.3%), followed by the index (24.7%) and middle fingers (21.2%) in pooled data from multiple cohorts [17]. Regarding nerve involvement, 22.2% of fingers in our study had digital nerve injury, with radial digital nerves affected in 13.9% and ulnar digital nerves in 8.3% of cases. Although this rate is lower than that reported by Keane *et al.*, where 61% of digits sustained concomitant digital nerve injuries [18], it emphasizes that nerve involvement remains a clinically important consideration in Zone II tendon injuries. These parallels suggest that, despite variations in study populations and timing of repair, the pattern of digit vulnerability and the frequent occurrence of nerve injury are consistent, highlighting the need for careful assessment and management of both tendons and associated neurovascular structures during reconstruction. The post-operative complications observed in this study following single-stage tendon reconstruction for old Zone II flexor tendon injuries were generally infrequent and manageable. Overall, 22.5% of patients experienced at least one complication, with swan neck deformity being the most common (10%), followed by joint stiffness and superficial skin infection (both 5%) and tendon adhesion (2.5%). These findings are consistent with previously reported outcomes in the literature. For instance, Heegaard and Troest reported that 17% of patients undergoing flexor tendon surgery experienced major complications, including adhesions leading to tenolysis in 6.5% and infections requiring revision in 2.4%, showing that adhesion and infection are among the most common post-operative issues in flexor tendon repairs [19]. The slightly higher overall complication rate in the present study may reflect the chronicity of the injuries and the single-stage reconstruction approach, yet the low incidence of severe complications underscores the effectiveness of meticulous surgical technique and structured post-operative rehabilitation in minimizing

adverse outcomes. The functional outcomes observed in this study, as measured by the Buck-Gramcko criteria, demonstrated significant postoperative improvement across all digits, with nail-to-palm distance and total active motion showing marked gains and extension deficits reduced in most fingers. These results are consistent with findings from Emir *et al.*, who reported that delayed primary flexor tendon repairs, even up to six months post-injury under WALANT with controlled early active motion, led to significant improvements over time, with 93% of fingers achieving excellent total active motion and minimal extension deficits [7]. Similarly, the meta-analysis by Xu *et al.* highlighted that early active motion protocols after Zone II tendon repair significantly enhance total active motion compared with passive rehabilitation, promoting better joint excursion and functional recovery [20]. Together, these studies support the effectiveness of combining meticulous surgical technique with structured early mobilization in achieving substantial restoration of finger function, even in delayed or chronic Zone II flexor tendon injuries. The final functional outcomes in this study, assessed using the Buck-Gramcko criteria, indicated that the majority of patients achieved excellent or good results, with 32.5% rated as excellent and 47.5% as good, while fair and poor outcomes were observed in smaller proportions. These findings align with those reported by Karagergou *et al.*, where delayed Zone II flexor tendon reconstructions using single-stage tendon grafts (FDS/PL) resulted in 55.6% of fingers achieving excellent outcomes, 22.2% good and 22.2% fair, showing that satisfactory functional recovery is attainable even in delayed presentations [21]. The consistent achievement of substantial active motion and favorable functional scores across both studies underscores the effectiveness of single-stage reconstruction combined with appropriate rehabilitation in restoring hand function following chronic or delayed flexor tendon injuries in Zone II.

Conclusion:

Flexor tendon injuries in Zone II can cause significant functional impairment if untreated. Single-stage tendon reconstruction provided satisfactory restoration of hand function, with most patients achieving excellent or good outcomes and minimal post-operative complications. These results support its effectiveness for managing chronic flexor tendon injuries in this region.

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