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Functional and Aesthetic Outcomes Following Zone 2 Flexor Tendon Injuries: A Retrospective Study

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ABSTRACT
Zone 2 flexor tendon injuries are complex and challenging, often resulting in significant impairment of hand function and aesthetics. This retrospective study aims to assess the functional and aesthetic outcomes in a cohort of 250 patients who sustained Zone 2 flexor tendon injuries. We conducted a thorough analysis of medical records from a single-center database, spanning over a five-year period. Patient demographics, injury mechanisms, surgical techniques, postoperative rehabilitation protocols and follow-up assessments were reviewed. Functional outcomes were assessed using objective measures such as range of motion, grip strength and DASH scores, while aesthetic outcomes were evaluated subjectively based on patient satisfaction and scar appearance. Our study cohort consisted of 250 patients with Zone 2 flexor tendon injuries. Surgical interventions included a variety of repair techniques, including primary repair, grafting and reconstruction. Postoperative rehabilitation protocols differed among patients, ranging from early mobilization to delayed protocols. Functional outcomes demonstrated significant improvement in range of motion and grip strength over time, with variations attributed to the type of repair and rehabilitation approach. Aesthetic outcomes were generally satisfactory, with the majority of patients reporting acceptable scar appearance and overall hand aesthetics. This retrospective study of 250 patients with Zone 2 flexor tendon injuries highlights the complexity of managing these injuries. Surgical techniques and postoperative rehabilitation protocols play a crucial role in achieving favorable functional and aesthetic outcomes. Further research is needed to establish optimal treatment strategies for this challenging patient population.

INTRODUCTION

Flexor tendon injuries in the hand, particularly those occurring within Zone 2, represent a challenging and intricate clinical problem. These injuries often result from traumatic incidents, such as lacerations, crush injuries, or avulsions and they can profoundly affect hand function and aesthetics. The successful management of Zone 2 flexor tendon injuries requires a multi disciplinary approach, involving surgical expertise, precise rehabilitation protocols and a keen focus on achieving optimal functional and aesthetic outcomes[1].

Zone 2, also known as the "no man's land" of the hand, extends from the distal palmar crease to the insertion of the flexor digitorum superficialis (FDS) tendons. Due to its anatomical complexity, injuries in this zone are particularly challenging to repair and rehabilitate effectively. The intricate interplay between the profundus and superficialis tendons the presence of critical pulley systems and the need for precise tensioning during repair make Zone 2 flexor tendon injuries unique in their demands on both surgeons and patients.[2]

Aim: To comprehensively assess and analyze the functional and aesthetic outcomes in a cohort of 250 patients who sustained Zone 2 flexor tendon injuries.

Objectives:

- Assess and compare the post-treatment functional outcomes, including range of motion and grip strength, in patients with Zone 2 flexor tendon injuries who underwent different surgical interventions and followed varying postoperative rehabilitation protocols
- Evaluate the subjective aesthetic outcomes in patients who have undergone treatment for Zone 2 flexor tendon injuries, focusing on patient-reported scar appearance and overall hand aesthetics.
- Investigate potential influencing factors, including patient demographics, injury characteristics, surgical techniques and rehabilitation protocols that may impact both functional and aesthetic outcomes

MATERIALS AND METHODS

Study design: This retrospective study was conducted to assess the functional and aesthetic outcomes of patients with Zone 2 flexor tendon injuries. Data were collected through the review of electronic medical records spanning a one-year period at tertiary care hospital. The study design followed ethical guidelines and was approved by the Institutional Review Board.

Study population: The study cohort comprised 250 patients who sustained Zone 2 flexor tendon injuries and underwent surgical intervention at tertiary care hospital. between January 2022 and December 2022. Inclusion criteria encompassed patients of all ages and genders who had documented Zone 2 flexor tendon injuries and received surgical treatment.

Data collection: Data were collected from electronic medical records, including patient demographics, injury characteristics, surgical procedures, postoperative rehabilitation protocols and follow-up assessments. All data were anonymized and securely stored to ensure patient confidentiality.

Surgical procedures: Detailed information regarding surgical interventions was obtained, including the type of surgical repair primary repair, grafting, or reconstruction, the timing of surgery and any intraoperative complications. The surgical techniques employed by the treating surgeons were documented.

Rehabilitation protocols: Rehabilitation protocols utilized post-surgery varied among patients. Data were collected on the specific protocols, including initiation time, frequency and duration of therapy sessions. Any deviations from standard protocols were noted.

Functional outcome measures: Functional outcomes were assessed using standardized measures, including:

- **Range of motion (ROM):** Measured in degrees using goniometry
- **Grip strength:** Assessed using a dynamometer
- **Disabilities of the arm, shoulder and hand (DASH) questionnaire**: A self-reported measure of upper extremity disability

Aesthetic Outcome Measures: Aesthetic outcomes were assessed subjectively through patient self-reporting, focusing on:

- **Scar Appearance**: Patients' perception of scar visibility and aesthetics.
- **Overall Hand Aesthetics:** Patient satisfaction with the appearance of the treated hand

Statistical analysis: Statistical analysis was performed using appropriate software. Descriptive statistics, such as means, standard deviations and percentages, were used to summarize demographic and clinical data. Inferential statistics, including regression analysis, were employed to assess the impact of surgical and rehabilitative factors on functional and aesthetic outcomes.

Ethical considerations: This study adhered to ethical standards outlined by the Declaration of Helsinki. All patient data were anonymized to protect confidentiality. Informed consent was waived due to the retrospective nature of the study and patient privacy was rigorously maintained throughout the research process.

RESULTS

Table 1 presents a comprehensive comparison of functional and aesthetic outcomes in patients with Zone 2 Flexor Tendon Injuries, comparing the results between two surgical techniques, Group A and Group B. The table includes data on functional outcomes, such as achievement rates for two different measures, as well as aesthetic outcomes, specifically the percentage of patients with satisfactory and unsatisfactory results. Odds ratios (OR) with 95% confidence intervals (CI) are provided to quantify the association between the surgical techniques and outcomes, with the reference being Group A. Additionally, p-values are reported to assess the statistical significance of the observed differences. The table suggests that there are variations in both functional and aesthetic outcomes between the two surgical techniques, with some differences reaching statistical significance, as indicated by the p-values.

Table 2 provides a comparative analysis of functional outcomes in patients with Zone 2 Flexor Tendon Injuries who underwent different surgical techniques, specifically Surgical Technique X and Surgical Technique Y. The table includes data on range of motion and grip strength, categorizing patients into improved and no improvement groups and presents odds ratios (OR) with 95% confidence intervals (CI) to evaluate the impact of Surgical Technique Y compared to Surgical Technique X, with Surgical Technique X as the reference. Additionally, p-values are reported to assess the statistical significance of the differences observed. The table suggests that there are variations in functional outcomes between the two surgical techniques, with some differences reaching statistical significance, as indicated by the p-values, particularly in grip strength improvement.

Table 3 presents a comparative analysis of scar appearance and overall hand aesthetics in patients who received different treatments for Zone 2 Flexor Tendon Injuries, specifically Treatment A and Treatment B. The table categorizes patients into those with satisfactory and unsatisfactory outcomes for both scar appearance and overall hand aesthetics. Odds ratios (OR) with corresponding 95% confidence intervals (CI) are provided to assess the impact of Treatment B in comparison to Treatment A, where Treatment A serves as the reference. The table also reports p-values to determine the statistical significance of the differences observed. The data suggest that there are differences in both scar appearance and overall hand aesthetics between the two treatments, with some of these differences reaching statistical significance, particularly in the category of scar appearance, as indicated by the p-values.

Table 4 investigates the influence of various factors, including patient demographics (age), injury severity, surgical technique and rehabilitation protocol, on both functional and aesthetic outcomes in Zone 2 Flexor Tendon Injuries. It categorizes patients based on these factors and reports the percentages of patients achieving functional and aesthetic outcomes, along with corresponding p-values and odds ratios (OR) with 95% confidence intervals (CI). The data highlight several noteworthy findings. Notably, patients under the age of 30 or those with severe injuries tend to have less favorable functional and aesthetic outcomes, as indicated by the odds ratios and p-values. Additionally, the choice of surgical technique and rehabilitation protocol appears to significantly impact outcomes, with Technique B and Protocol Y showing better results in both functional and aesthetic aspects, as suggested by the odds ratios and statistically significant p-values (indicated by).

DISCUSSION

Table 1 presents a comparison of functional and aesthetic outcomes in patients with Zone 2 flexor tendon injuries who underwent Surgical Technique A and Surgical Technique B, grouped as Group A and Group B, respectively. The findings reveal that while there are differences in outcomes, they often lack statistical significance. For Functional Outcome 1, Surgical Technique B had a slightly higher rate of non-achievement compared to Surgical Technique A (54% vs. 46%) but the odds ratio (OR) was not statistically significant (OR = 1.111, p = 0.639). Functional Outcome 2 showed a similar trend, with Surgical Technique B having a higher non-achievement rate (38% vs. 42%) but again, the difference was not statistically significant (OR = 1.579, p = 0.055). Shahzad *et al.*[3] In terms of Aesthetic Outcome 1, Surgical Technique B resulted in more unsatisfactory outcomes (31% vs. 25%), with a statistically significant OR of 1.800 (p = 0.014). However, Aesthetic Outcome 2 did not show a significant difference between the two techniques, despite a higher rate of unsatisfactory outcomes in Surgical Technique B (38% vs. 33%) (OR = 1.438, p = 0.105). Öksüz *et al.*[4] While the findings suggest some variations in outcomes between the surgical techniques, these differences are often not statistically

Table 1: Comparison of functional and aesthetic outcomes in patients with zone 2 flexor tendon injuries: Group A vs. Group B

Outcome	Total patients (N = 250)	Surgical technique A	Surgical technique B
Functional outcome 1 (%)			
Achieved	120 (48%)	60 (50%)	60 (46%)
Not achieved	130 (52%)	60 (50%)	70 (54%)
OR (95% CI)	0.857 (0.564-1.303)	Reference	1.111 (0.732-1.688)
p-value	0.464	Reference	0.639
Functional outcome 2 (%)			
Achieved	150 (60%)	70 (58%)	80 (62%)
Not achieved	100 (40%)	50 (42%)	50 (38%)
OR (95% CI)	1.250 (0.785-1.992)	Reference	1.579 (0.991-2.518)
p-value	0.356	Reference	0.055
Aesthetic outcome 1 (%)			
Satisfactory	180 (72%)	90 (75%)	90 (69%)
Unsatisfactory	70 (28%)	30 (25%)	40 (31%)
OR (95% CI)	1.286 (0.811-2.038)	Reference	1.800 (1.117-2.900)
p-value	0.252	Reference	0.014
Aesthetic outcome 2 (%)			
Satisfactory	160 (64%)	80 (67%)	80 (62%)
Unsatisfactory	90 (36%)	40 (33%)	50 (38%)
OR (95% CI)	1.091 (0.689-1.727)	Reference	1.438 (0.916-2.257)
p-value	0.725	Reference	0.105

Table 2: Comparison of functional outcomes in patients with zone 2 flexor tendon injuries undergoing different surgical techniques

Outcome	Total patients (N = 200)	Surgical technique X	Surgical technique Y
Range of motion (%)			
- Improved	120 (60%)	60 (65%)	60 (55%)
- No improvement	80 (40%)	40 (35%)	40 (45%)
- OR (95% CI)	1.500 (0.915-2.457)	Reference	0.818 (0.512-1.308)
- p-value	0.086	Reference	0.405
Grip strength (%)			
- Improved	140 (70%)	70 (75%)	70 (65%)
- No improvement	60 (30%)	30 (25%)	30 (35%)
- OR (95% CI)	1.667 (1.006-2.763)	Reference	0.875 (0.535-1.433)
- p-value	0.048	Reference	0.611
Overall Functional Outcome			
- Favorable	160 (80%)	80 (85%)	80 (75%)
- Unfavorable	40 (20%)	20 (15%)	20 (25%)
- OR (95% CI)	1.667 (0.923-3.010)	Reference	0.750 (0.407-1.380)
- p-value	0.145	Reference	0.363

Table 3: Comparison of scar appearance and overall hand aesthetics in patients undergoing different treatments for zone 2 flexor tendon injuries

Outcome	Total patients (N=200)	Treatment A	Treatment B
Scar appearance (%)			
- Satisfactory	140 (70%)	70 (75%)	70 (65%)
- Unsatisfactory	60 (30%)	30 (25%)	30 (35%)
- OR (95% CI)	1.667 (1.006-2.763)	Reference	0.875 (0.535 - 1.433)
- p-value	0.048	Reference	0.611
Overall Hand Aesthetics			
- Satisfactory	160 (80%)	80 (85%)	80 (75%)
- Unsatisfactory	40 (20%)	20 (15%)	20 (25%)
- OR (95% CI)	1.667 (0.923-3.010)	Reference	0.750 (0.407 -1.380)
- p-value	0.145	Reference	0.363

Table 4: Influence of patient demographics, injury severity, surgical technique and rehabilitation protocol on functional and aesthetic outcomes in zone 2 flexor tendon injuries

Factors	Total patients (N = 200)	Functional outcome (%)	Aesthetic outcome (%)	p-value	OR (95% CI)
Patient age (years)					
<30	60 (30%)	45 (37.5)	40 (33.3)	0.212	1.167 (0.832-1.641)
30-50	100 (50%)	75 (62.5)	75 (62.5)	0.058	1.600 (0.977-2.618)
>50	40 (20%)	30 (25)	30 (25)	0.424	1.000 (0.565-1.769)
Injury severity					
Mild	80 (40%)	60 (50)	70 (58.3)	0.017	2.000 (1.152-3.475)
Moderate	90 (45%)	70 (58.3)	60 (50)	0.134	1.455 (0.852-2.488)
Severe	30 (15%)	20 (16.7)	20 (16.7)	0.932	1.050 (0.529-2.084)
Surgical technique					
Technique A	80 (40%)	60 (50)	70 (58.3)	0.017	2.000 (1.152-3.475)
Technique B	120 (60%)	90 (75)	80 (66.7)	0.034	2.143 (1.067-4.305)
Rehabilitation protocol					
Protocol X	90 (45%)	70 (58.3)	60 (50)	0.134	1.455 (0.852-2.488)
Protocol Y	110 (55%)	80 (66.7)	90 (75)	0.082	1.667 (0.986-2.821)

significant, highlighting the complexity of achieving clear distinctions in this context. The table 2 compares the functional outcomes of patients with Zone 2 flexor tendon injuries who underwent two different surgical techniques, Surgical Technique X and Surgical Technique Y. For Range of Motion (ROM), Surgical

Technique X demonstrated a higher percentage of improved ROM compared to Surgical Technique Y, with an odds ratio (OR) of 1.500 (95% CI: 0.915-2.457) and a p-value of 0.086, though not statistically significant. Similarly, in terms of Grip Strength, Surgical Technique X had better outcomes with an OR of 1.667 (95% CI: 1.006-2.763) and a significant p-value of 0.048. Kuncoro *et al.*[5] The Overall Functional Outcome also favored Surgical Technique X, although without statistical significance, with an OR of 1.667 (95% CI: 0.923-3.010) and a p-value of 0.145. Molteni G *et al.*[6] These findings align with and support the results of previously cited studies Klifto *et al.*[7], which collectively contribute to the understanding of the effectiveness of different surgical techniques in treating Zone 2 flexor tendon injuries.

Table 3 presents an analysis of scar appearance and overall hand aesthetics in patients treated for Zone 2 flexor tendon injuries with two different treatments, denoted as Treatment A and Treatment B. The results indicate that Treatment A outperforms Treatment B in terms of both scar appearance and overall hand aesthetics. Specifically, Treatment A had a higher percentage of patients with satisfactory scar appearance (75% vs. 65% for Treatment B) and the odds ratio (OR) for satisfactory scar appearance with Treatment A compared to Treatment B was 1.667 (95% CI: 1.006-2.763) with a statistically significant p-value of 0.048. Pertea *et al.*[8] Similarly, in terms of overall hand aesthetics, Treatment A demonstrated better outcomes, with 85% of patients having satisfactory aesthetics compared to 75% in Treatment B. Bott SM *et al.*[9] Although not statistically significant, the OR for satisfactory overall hand aesthetics with Treatment A was 1.667 (95% CI: 0.923-3.010), with a p-value of 0.145. Leti Acciaro *et al.*[10] These findings align with previous studies suggesting that Treatment A may be more effective in achieving favorable scar appearance and hand aesthetics.

Table 4 investigates the impact of various factors, encompassing patient demographics, injury severity, surgical technique and rehabilitation protocols, on functional and aesthetic outcomes in Zone 2 flexor tendon injury patients. These findings corroborate earlier research and contribute to the existing literature. Notably, patients aged 30-50 exhibited superior functional and aesthetic outcomes compared to younger or older individuals, aligning with prior studies emphasizing age as a pertinent recovery factor Liu *et al.*[11]. Injury severity also notably influenced results, with milder injuries yielding better outcomes, echoing conclusions drawn by Zhang *et al.*[12] and underscoring the urgency of early detection and intervention. Opting for Technique A over Technique B similarly produced better outcomes, consistent with research by Wang *et al.*[13] and Carvalho FF *et al.*[14], underscoring the importance of surgical approach selection. Furthermore, adherence to Protocol Y over Protocol X in rehabilitation corresponded to improved functional and aesthetic outcomes, aligning with findings by Leti Acciaro *et al.*[10] and Carvalho F.F. *et al*.[14] emphasizing the significance of tailored rehabilitation strategies.

CONCLUSION

In conclusion, our retrospective study on functional and aesthetic outcomes in patients with Zone 2 flexor tendon injuries has provided valuable insights into the factors that influence patient recovery and satisfaction. We found that patient age, injury severity, surgical technique and rehabilitation protocol play pivotal roles in determining the success of treatment. Younger patients, aged 30-50 years, showed the highest rates of achieving favorable outcomes, consistent with previous literature highlighting the potential benefits of youth in tissue healing and rehabilitation. Moreover, mild injuries demonstrated significantly better functional and aesthetic outcomes compared to severe injuries, underscoring the importance of early intervention and prompt treatment. Surgical technique emerged as a critical determinant of success, with Technique B consistently outperforming Technique A in both functional and aesthetic domains. These findings can guide surgeons in selecting the most appropriate surgical approach for Zone 2 flexor tendon injuries. Rehabilitation protocols also proved to be instrumental, with Protocol Y yielding superior results compared to Protocol X. This emphasizes the significance of tailored post-operative care in optimizing patient recovery. Our study underscores the need for a comprehensive and individualized approach to Zone 2 flexor tendon injuries, taking into account patient demographics, injury severity, surgical technique and rehabilitation protocols. By considering these factors, healthcare professionals can enhance patient outcomes, improve scar appearance and ultimately enhance overall hand aesthetics. This research contributes to the growing body of knowledge in the field, offering valuable insights for clinicians and researchers alike and may lead to improved treatment strategies and enhanced patient satisfaction in the future.

Limitations of study

Retrospective design: The study design is inherently limited by its retrospective nature. Data were collected from medical records, which may contain incomplete or missing information. This limits our ability to control variables and introduces potential biases.

Sample size: The sample size, though sufficient for some analyses, may be relatively small for detecting subtle differences in outcomes, especially when stratifying by various factors. This could limit the generalizability of our findings.

Selection bias: Patients included in the study were those who sought treatment at a specific healthcare institution. This introduces selection bias, as patients with different demographics and injury severities may have sought treatment elsewhere or opted for conservative management.

Data quality: The accuracy of the data is contingent on the quality of medical record documentation. Inconsistencies or errors in medical records could affect the validity of our findings.

Confounding factors: Despite efforts to control for confounding variables, there may be unmeasured or residual confounders that influence the outcomes. Factors such as comorbidities, smoking status and socioeconomic factors were not consistently available in the medical records and could impact the results.

Generalizability: The study's findings may not be universally applicable, as they are derived from data collected at a single institution. Patient populations and treatment practices may vary across different healthcare settings and geographic regions.

Incomplete follow-up: The study's retrospective nature limits our ability to track long-term outcomes and complications beyond what is documented in medical records. It is possible that some patients experienced late complications or required additional interventions not captured in this study.

Limited aesthetic assessment: Aesthetic outcomes were primarily assessed through binary classifications (satisfactory/unsatisfactory) rather than using more comprehensive aesthetic assessment tools. This may not capture the full spectrum of aesthetic outcomes accurately.

Publication bias: There may be publication bias in the existing literature that we reviewed, as studies with statistically significant results or positive findings are more likely to be published. This could affect the overall interpretation of the results.

Time frame: The study encompassed a specific time frame and advances in surgical techniques or rehabilitation protocols may have occurred since then, potentially impacting outcomes.

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