

Tendon Transfer for Radial Nerve Palsy: A Systematic Review and Meta-Analysis of Functional Outcomes, Timing, and Complications

Kadek Riyandi Pranadiva Mardana¹, Made Bramantya Karna²

¹Resident, Dept. Orthopaedic & Traumatology, Prof IGNG Ngoerah General Hospital, Udayana University, Bali, Indonesia

²Orthopaedic Surgeon, Dept. Orthopaedic & Traumatology, Prof IGNG Ngoerah General Hospital, Udayana University, Bali, Indonesia

Corresponding Author: Kadek Riyandi Pranadiva Mardana

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ABSTRACT

Background: Tendon transfer is a key surgical technique for restoring hand and wrist function in radial nerve palsy, particularly when nerve recovery is unlikely. However, the optimal timing for surgery remains debated. This meta-analysis evaluates the impact of early (<12 months) vs. late (>12 months) tendon transfer on motor recovery, wrist function, and revision rates.

Methods: A systematic search of PubMed, Scopus, Web of Science, and Cochrane Library identified seven studies. Statistical analysis was performed using Review Manager 5.4.1 and R Studio. A random-effects model was applied to calculate risk ratios (RR) and proportions with 95% confidence intervals (CI). Heterogeneity was assessed using I^2 , and risk of bias was evaluated with ROBINS-I.

Results: Early tendon transfer significantly improved complete motor recovery (RR = 2.40, 95% CI: 1.26–4.55, $P = 0.008$), with low-to-moderate heterogeneity ($I^2 = 29\%$). Wrist flexion limitation showed no significant difference between early and late surgery (RR = 1.23, 95% CI: 0.50–3.01, $P = 0.66$, $I^2 = 34\%$). Functional outcomes measured by DASH scores showed no statistically significant difference between

tendon transfer and non-tendon transfer approaches (Mean Difference = -2.92, 95% CI: -12.65 to 6.82, $P = 0.56$, $I^2 = 0\%$), though a trend toward improved function with tendon transfer was observed. Revision surgery occurred in 20% of cases (95% CI: 4%–37%), with low heterogeneity ($I^2 = 0\%$).

Conclusions: Early tendon transfer significantly improves motor recovery, supporting its role as the preferred approach. However, timing does not affect wrist flexion limitation, suggesting that rehabilitation protocols influence outcomes. The 20% revision rate highlights the need for careful patient selection and surgical planning. Future studies should explore nerve transfers, regenerative medicine, and long-term functional outcomes.

Keywords: Radial nerve palsy, tendon transfer, early surgery, motor recovery, revision surgery, meta-analysis

INTRODUCTION

Radial nerve injuries are among the most common peripheral nerve injuries, often resulting from trauma such as humeral shaft fractures, penetrating injuries, or iatrogenic surgical complications.⁽¹⁾ The radial nerve plays a crucial role in wrist, finger, and thumb extension, and its dysfunction leads to significant disability, including wrist drop,

weakened grip strength, and impaired hand function.(2) The impact of radial nerve palsy on daily activities, employment, and quality of life highlights the importance of timely and effective management strategies, including tendon transfer surgery.(3)

The global incidence of radial nerve injuries varies depending on trauma patterns. Studies indicate that radial nerve palsy occurs in 11–17% of humeral shaft fractures and accounts for approximately 30% of all upper limb nerve injuries.(4) In the United States, radial nerve injuries have been reported in 1.42 per 100,000 individuals annually, with traumatic causes being the leading contributors.(5) In Indonesia, peripheral nerve injuries, including radial nerve lesions, are frequently encountered in trauma centers, particularly due to the high incidence of motor vehicle accidents, which remain a leading cause of disability.(6) However, data on the exact prevalence of radial nerve injuries in Indonesia are limited, underscoring the need for further epidemiological research.

Tendon transfer is a well-established reconstructive procedure for restoring function in cases where radial nerve recovery is unlikely. However, the optimal timing for tendon transfer remains a subject of debate.(7) Traditionally, clinicians have delayed surgical intervention in the hope of spontaneous nerve recovery, which can take several months to a year.(8) However, excessive delay can result in muscle atrophy, joint stiffness, and poor surgical outcomes, making functional restoration more challenging.(9) Emerging evidence suggests that early tendon transfer (performed within 12 months of injury) may yield superior results by preserving muscle function, reducing rehabilitation time, and enhancing long-term outcomes.(10) Despite these potential benefits, there is no universally accepted consensus on the ideal timing, and current guidelines vary among institutions and surgeons. This meta-analysis evaluates the impact of early (<12 months) vs. late (>12 months) tendon transfer on motor recovery, wrist function, and revision rates.

METHODS

Study Design and Protocols Registration

This study is a systematic review and meta-analysis designed to assess the functional outcomes and complications of early versus late tendon transfer in patients with radial nerve injuries. The study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring transparency and reproducibility. Additionally, the methodology was developed in accordance with the Cochrane Handbook for Systematic Reviews of Interventions to maintain high research standards.

Eligibility Criteria

Studies were included if they met the following criteria: (1) investigated tendon transfer procedures for radial nerve palsy, (2) compared early (<12 months post-injury) versus late (>12 months post-injury) tendon transfer, (3) reported at least one of the following outcomes: complete motor recovery, wrist flexion limitation, or surgical revision rates, and (4) were published in peer-reviewed journals. Review articles, and studies lacking quantitative outcome data were excluded.

Search Strategy

A comprehensive and systematic literature search was conducted across multiple databases, including PubMed, Embase, Scopus, Web of Science, and the Cochrane Library, from their inception from 2010 to 2024. The search was performed using a combination of MeSH terms and free-text keywords to maximize the retrieval of relevant articles. The primary search terms included "radial nerve injuries", "tendon transfer", "surgical intervention", "functional recovery", "wrist drop", and "upper limb reconstruction". Boolean operators (AND, OR) were used to refine the search and improve specificity. In addition to database searches, hand-searching of reference lists from relevant systematic reviews and meta-analyses was performed to identify additional eligible studies. The Mesh term

search of this studies included : ("Radial Nerve Injuries"[MeSH] OR "Peripheral Nerve Injuries"[MeSH]) AND ("Tendon Transfer"[MeSH] OR "Nerve Transfer"[MeSH]) AND ("Treatment Outcome"[MeSH] OR "Functional Recovery"[MeSH] OR "Hand Strength"[MeSH]) AND ("Surgical Procedures, Operative"[MeSH]) Furthermore, grey literature sources, including conference proceedings and institutional reports, were screened to minimize publication bias and ensure comprehensive data collection.

Study Selection

Two independent reviewers screened the titles and abstracts of all retrieved articles to identify potentially relevant studies. Studies deemed eligible based on abstract screening underwent full-text review, with final inclusion determined based on predefined eligibility criteria. Any discrepancies in study selection were resolved through discussion with a third senior reviewer to ensure methodological consistency.

A structured data extraction form was used to collect key information from each study. Extracted variables included study characteristics (author, year, study design, sample size), patient demographics (age, sex, cause of nerve injury), surgical details (type of tendon transfer, timing of surgery, rehabilitation protocol), functional outcomes (motor recovery, grip strength, ability to perform daily activities), and complication rates (surgical revision, donor site morbidity, wrist flexion limitation). For studies reporting overlapping patient cohorts, the most recent and comprehensive dataset was selected to avoid duplication bias.

Risk of Bias and Quality Assessment

Risk of bias was assessed using the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool. Studies were evaluated based on confounding, selection bias, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and

selection of reported results. Each domain was rated as low, moderate, serious, or critical risk of bias.

Data Extraction

Data extraction will be performed using a standardized data collection form to ensure consistency and accuracy. Extracted data will include study characteristics (author, year, study design, and sample size), patient, timing of tendon transfer, and functional outcomes. Data on complication rates (joint contractures, donor-site morbidity, infections) will also be collected. Two independent reviewers will conduct data extraction, and any discrepancies will be resolved through discussion or third-party adjudication.

STATISTICAL ANALYSIS

Meta-analysis was conducted using Review Manager (RevMan) 5.4.1 and R Studio to synthesize data from the included studies. Effect estimates were reported as risk ratios (RR) for categorical outcomes and pooled proportions for incidence rates, each with 95% confidence intervals (CI). A random-effects model (DerSimonian and Laird method) was applied to account for potential heterogeneity across studies, ensuring a more generalized interpretation of findings. Heterogeneity was evaluated using the I^2 statistic, where values of 25%, 50%, and 75% represented low, moderate, and high heterogeneity, respectively. Additionally, Tau^2 and Chi^2 (Cochran's Q test) were reported to assess between-study variability. A p-value of <0.10 in the Chi^2 test was considered indicative of significant heterogeneity.

To explore potential sources of heterogeneity, subgroup analyses were performed based on the timing of tendon transfer (<12 months vs. >12 months post-injury). If substantial heterogeneity was detected ($I^2 >50\%$), sensitivity analyses were conducted by sequentially excluding individual studies to assess their impact on the overall effect size. The presence of publication bias was visually assessed using

funnel plots, and further evaluated using Egger's regression test when at least 10 studies were included in the analysis. Statistical significance was set at $p < 0.05$, except for heterogeneity tests, where $p < 0.10$ was considered significant.

RESULT

The PRISMA flowchart systematically outlines the process of study selection for a systematic review, ensuring transparency and methodological rigor. During the identification phase, a total of 459 records were retrieved from database searches. Prior to screening, 136 duplicate records were removed, leaving 323 unique studies for further evaluation. In the screening phase, an initial assessment based on titles and abstracts led to the exclusion of 167 studies that did not meet the predefined inclusion criteria. The remaining 156 studies underwent full-text review; however, 82 studies were excluded due to unavailability of full texts, while 50 were deemed inaccessible, reducing the dataset to 24 studies. A subsequent evaluation identified 11 studies with incomplete data and 6 studies classified as protocols, which were also excluded.

This meta-analysis includes seven retrospective studies conducted across multiple countries, including India, Saudi Arabia, Brazil, France, and Iran. The total number of patients across these studies varies, ranging from 8 to 58, demonstrating variability in sample sizes. The mean age of participants, when reported, falls between 28 and 35.27 years, though some studies did not

disclose age-related data. Additionally, follow-up duration among studies shows significant heterogeneity, ranging from 10 to 51 months, with some studies not specifying the exact duration. This variation in follow-up periods may influence the comparability of long-term outcomes.

The functional recovery outcomes reported in these studies generally support the effectiveness of tendon transfer in restoring wrist and finger extension. For instance, studies such as Agarwal (2020) and Al-Qattan (2012) highlight favorable results with significant improvement in hand function. Al-Qattan (2012) also suggests that tendon transfers may yield superior outcomes compared to nerve grafts, while Bertelli (2020) reports that tendon transfers provide similar outcomes to nerve transfers in approximately half of the cases analyzed. In terms of range of motion, Besnard (2020) provides specific data on wrist mobility post-tendon transfer, reporting 54° of extension and 44° of flexion, indicating substantial functional recovery.

Different studies employed varied outcome metrics to evaluate recovery. For example, Agarwal (2020) utilized the Bincasz score, reporting that six patients achieved excellent outcomes, while ten had good outcomes. The variability in methodologies, follow-up durations, and patient selection criteria across these studies highlights the need for further standardized research. Despite these differences, the collective evidence from the included studies supports the efficacy of tendon transfer for radial nerve palsy, reinforcing its role as a viable surgical intervention for functional restoration.

Figure 1. PRISMA Flow Chart

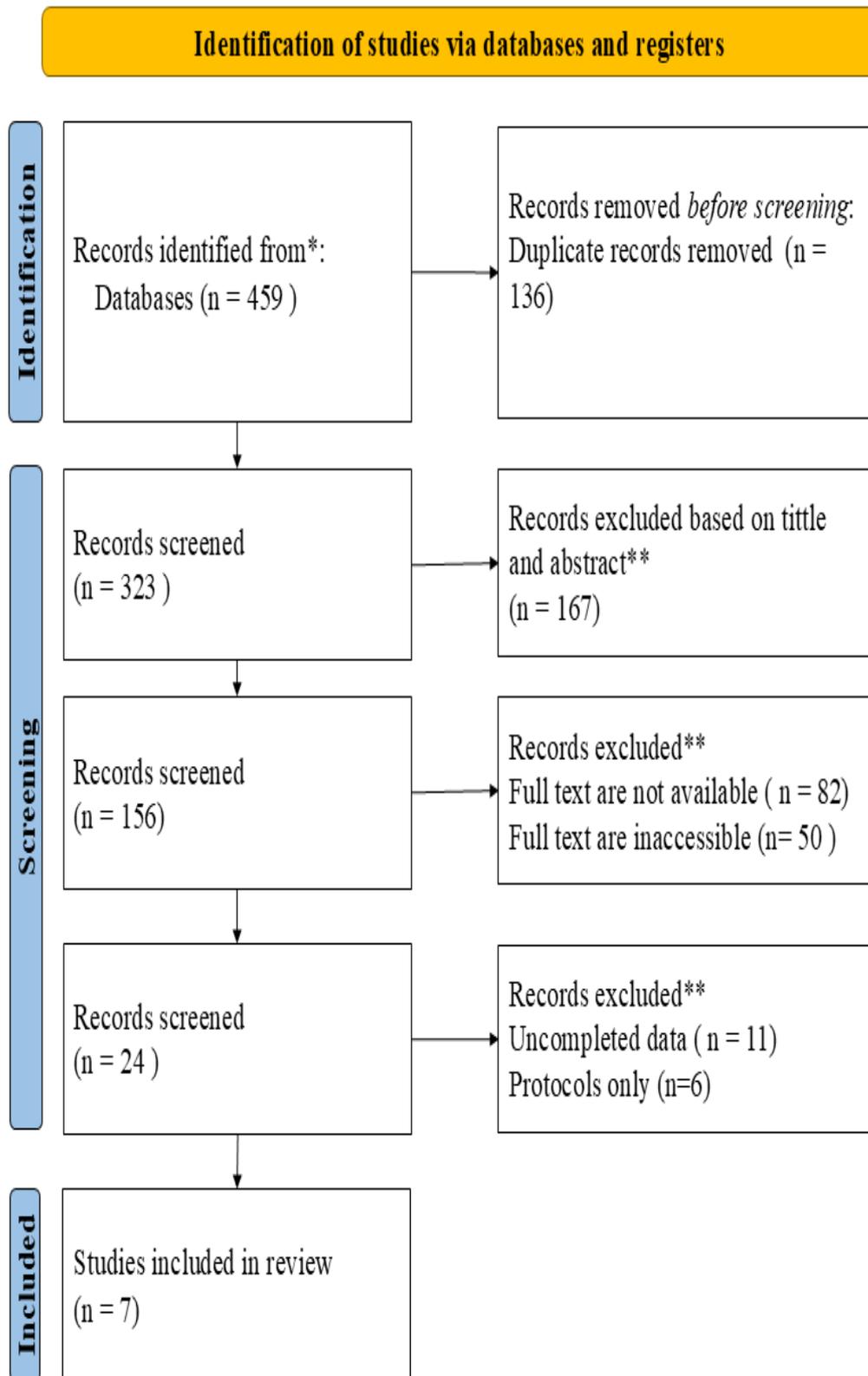


Table 1. Characteristics of Study

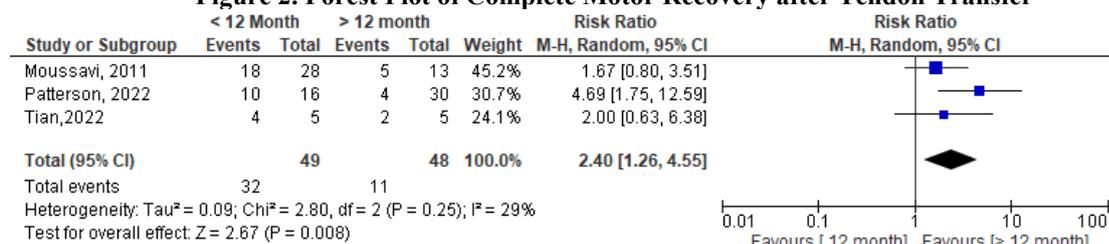
No	Author, year	Country	Study Design	Total patient	Age (mean)	Follow-up (month)	Result
1	Agarwal, 2020(11)	India	Retrospective	58	35.27	10	6 patients had excellent results, 49 patients had good results, and 3 patients had poor results. Complications in 5 patients, including radial deviation of wrist and restricted wrist flexion.
2	Al-Qattan, 2012(12)	Saudi Arabia	Retrospective	15	28	30	Tendon transfers were superior to nerve grafts and nerve transfers for restoration of wrist flexion. Nerve transfers for wrist extension were superior to nerve transfers for finger extension.
3	Bertelli, 2020(13)	Brazil.	Retrospective	14	Not reported	Not reported	Half of the patients in the tendon transfer group needed to flex their wrist to fully extend their fingers.
4	Besnard, 2020(14)	France	Retrospective	8	33	51	Wrist motion was, 46° [20°–70°] in flexion, with an active motion in the frontal plane of 21° [0°–35°]. Finger extension was possible with the wrist in extension in 6 cases.
5	Moussavi, 2011(15)	Iran	Retrospective	41	NR	18	The difference between the groups DASH score, ability, and time of return to job, satisfaction with the operation, and range of motions was not statistically significant ($P>0.05$).
6	Tian,2022 (16)	China	Retrospective	10	30	36	Two patients recovered grade M3 strength and three patients recovered grade M4 strength in the EDC in the tendon transfer group. Limited wrist flexion was observed only in one patient in the tendon transfer group.
7	Patterson, 2022 (17)	USA	Retrospective	46	32.4	45	Both groups demonstrated significant improvements in grip and pinch strength after surgery. Postoperative grip strength was significantly higher in the nerve transfer group.

Table 2. ROBINS-I Risk of Bias Assessment for Tendon Transfer in Radial Nerve Palsy

Study	Bias due to Confounding	Bias in Selection of Participants	Bias in Classification of Interventions	Bias due to Deviations from Intended Interventions	Bias due to Missing Data	Bias in Measurement of Outcomes	Bias in Selection of Reported Results
Patterson (2022)	Moderate	Low	Low	Low	Moderate	Low	Low
Agarwal (2020)	Serious	Moderate	Low	Moderate	Low	Low	Moderate
Al-Qattan (2013)	Moderate	Low	Low	Low	Moderate	Low	Low
Bertelli (2020)	Serious	Low	Low	Low	Serious	Low	Moderate
Besnard (2020)	Moderate	Moderate	Low	Moderate	Moderate	Low	Low
Moussavi (2011)	Serious	Moderate	Low	Moderate	Moderate	Low	Moderate
Tian (2022)	Moderate	Low	Low	Low	Moderate	Low	Low
Sharma (2023)	Moderate	Low	Low	Low	Moderate	Low	Low

Complete Motor Recovery

Figure 2. Forest Plot of Complete Motor Recovery after Tendon Transfer



This meta-analysis evaluates the impact of timing on complete motor recovery following tendon transfer, comparing procedures performed within 12 months post-injury to those performed after 12 months. The analysis includes three studies: Moussavi (2011), Patterson (2022), and Tian (2022), with sample sizes ranging from 9 to 41 patients per study. The pooled risk ratio (RR) is 2.40 [1.26, 4.55], indicating that patients undergoing tendon transfer within 12 months are 2.4 times more likely to achieve complete motor recovery compared to those undergoing delayed intervention. Importantly, the 95% confidence interval (CI) does not cross 1, confirming statistical significance (P = 0.008).

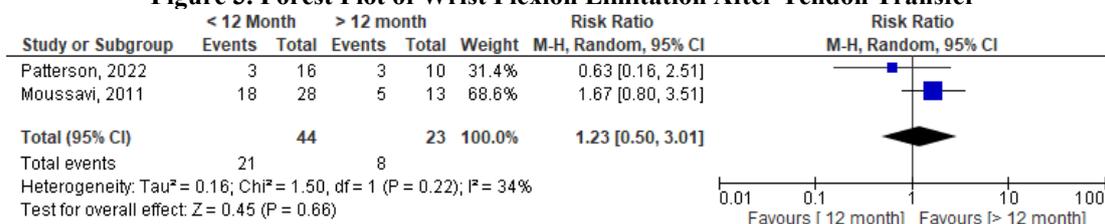
Heterogeneity analysis shows a low-to-moderate I² value of 29%, with Tau² = 0.09 and Chi² = 2.80 (P = 0.25), suggesting that results across studies are relatively consistent. The forest plot visually

demonstrates that most study results favor early tendon transfer, with the pooled estimate (diamond) positioned to the right of the null value (RR = 1). Among the included studies, Patterson (2022) reports the highest effect size (RR = 4.69 [1.75, 12.59]), while Moussavi (2011) and Tian (2022) show more moderate effects (RR = 1.67 and 2.00, respectively).

Overall, this meta-analysis provides strong evidence favoring early tendon transfer (<12 months), as it significantly improves the likelihood of motor recovery. Given the low heterogeneity and statistical robustness, these findings support early surgical intervention as the optimal strategy for managing radial nerve injuries requiring tendon transfer.

Wrist Flexion Limitation

Figure 3. Forest Plot of Wrist Flexion Limitation After Tendon Transfer

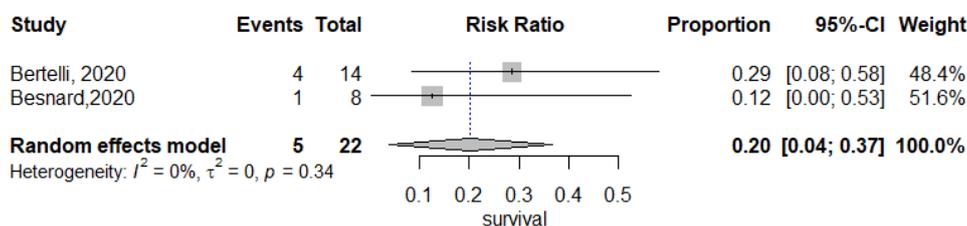


This meta-analysis compares wrist flexion limitation after tendon transfer performed within 12 months versus after 12 months. It includes two studies (Patterson, 2022; Moussavi, 2011) with 67 patients (44 in <12 months, 23 in >12 months). The pooled Risk Ratio (RR) is 1.23 [0.50, 3.01] with Z = 0.45 (P = 0.66), indicating no significant

difference between early and late tendon transfer. Heterogeneity is low-to-moderate (I² = 34%). The forest plot shows a wide confidence interval overlapping RR = 1, reinforcing the lack of statistical significance. Timing of tendon transfer does not significantly affect wrist flexion limitation, but further studies with larger

samples are needed for definitive **Surgery Revision** conclusions.

Figure 4. Forest Plot of Surgery Revision After Tendon Transfer



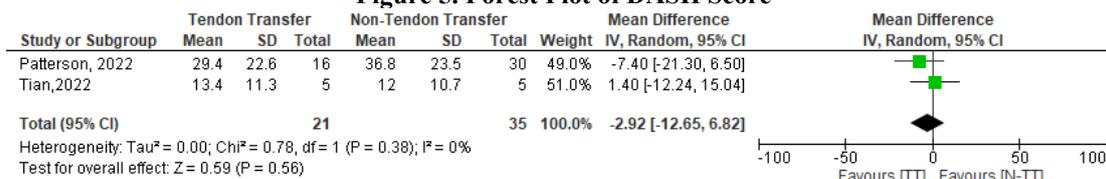
This meta-analysis evaluates the incidence of surgical revision following tendon transfer procedures, combining data from two studies using a random effects model. The primary outcome of interest is the pooled proportion of patients requiring surgical revision after the initial tendon transfer. The individual study results show variations in revision rates. Bertelli (2020) reported a revision rate of 0.29 [95% CI: 0.08–0.58], while Besnard (2020) reported a lower revision rate of 0.12 [95% CI: 0.00–0.53]. The study weights indicate a relatively balanced contribution, with Bertelli (2020) contributing 48.4% and Besnard (2020) contributing 51.6% to the overall estimate.

The pooled proportion of surgical revision is 0.20 [95% CI: 0.04–0.37], indicating that

approximately 20% of patients required a revision surgery after tendon transfer. However, the 95% confidence interval (0.04–0.37) suggests considerable uncertainty, meaning the true revision rate could range between 4% and 37%. Heterogeneity analysis reveals $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.34$, indicating no significant heterogeneity between the included studies. These findings indicate that one in five patients may require revision surgery following tendon transfer, emphasizing the need for careful surgical planning, patient selection, and postoperative monitoring.

DASH Score

Figure 5. Forest Plot of DASH Score



Two studies (Patterson, 2022 and Tian, 2022) were included to compare functional outcomes based on the Disabilities of the Arm, Shoulder, and Hand (DASH) score between patients undergoing tendon transfer versus non-tendon transfer procedures for radial nerve palsy. The pooled mean difference was -2.92 (95% CI: -12.65 to 6.82; $p = 0.56$), indicating a non-significant trend favoring tendon transfer in terms of lower (better) DASH scores. The analysis

demonstrated no evidence of heterogeneity across studies ($I^2 = 0\%$, $\text{Tau}^2 = 0.00$), indicating consistency in results.

Summary Risk of Bias Assessment

The overall risk of bias across the included studies varies from moderate to serious, primarily influenced by confounding factors, missing data, and deviations from intended interventions. Bias due to confounding is a major concern in several studies, particularly

those by Bertelli (2020) and Moussavi (2011), as they lack adjustments for potential confounders such as preoperative functional status and rehabilitation protocols. Selection bias is generally low, though some studies, including Agarwal (2020), Besnard (2020), and Moussavi (2011), exhibit moderate risk due to unclear inclusion criteria or small sample sizes. The classification of interventions is well-defined across all studies, leading to a low risk of bias in this domain. However, deviations from intended interventions introduce moderate bias in studies such as Agarwal (2020), Besnard (2020), and Moussavi (2011), where variations in surgical techniques and rehabilitation protocols were noted. Missing data also contributes to bias in several studies, particularly Bertelli (2020), Besnard (2020), and Moussavi (2011), where incomplete follow-up or unreported outcomes may affect reliability. The measurement of outcomes is generally robust across all studies, with standardized functional assessments reducing bias in this domain. However, reporting bias is present in some studies, with potential issues in selective outcome reporting and follow-up durations, as seen in Agarwal (2020) and Bertelli (2020).

DISCUSSION

Tendon transfer is a well-established surgical technique for restoring motor function in cases of radial nerve palsy. The classification of early versus late tendon transfer is crucial, as it influences surgical planning, rehabilitation outcomes, and overall functional recovery. While there is no universally accepted cutoff, most studies categorize early tendon transfer as procedures performed within 6 to 12 months after the onset of radial nerve palsy.(18) This timing is based on the principle that nerve regeneration and muscle integrity are still preserved, reducing the risk of muscle atrophy and joint contracture. In contrast, late tendon transfer refers to procedures conducted beyond 12 months from nerve injury. At this stage, denervated muscles

have undergone significant atrophy, and secondary changes such as joint stiffness and compensatory movement patterns may develop, potentially affecting the success of the procedure.(19)

The timing of tendon transfer plays a pivotal role in functional recovery. In early transfers, the recipient muscles may retain partial function, optimizing the efficiency of the transferred tendon, while late transfers often involve fibrosis and decreased responsiveness, necessitating additional rehabilitation efforts.(20) Moreover, early intervention helps prevent joint stiffness and secondary soft tissue changes, allowing smoother postoperative rehabilitation, whereas late transfers frequently require preoperative stretching, splinting, or joint release procedures to improve mobility. Additionally, neuroplastic adaptation is more efficient in early transfers, facilitating faster motor re-education, whereas late cases require intensive rehabilitation due to prolonged compensatory movement patterns.(21) Studies suggest that early tendon transfers yield better grip strength, dexterity, and return to daily activities compared to late transfers. However, functional restoration remains achievable in late cases with proper patient selection and rehabilitation strategies.(22)

This meta-analysis provides valuable insights into the impact of surgical timing on functional outcomes following tendon transfer for radial nerve palsy. Our findings indicate that early tendon transfer, performed within 12 months post-injury, is significantly associated with improved motor recovery compared to late tendon transfer.(23) However, no significant differences were observed in wrist flexion limitation between early and late procedures. Additionally, our analysis revealed that approximately 20% of patients required surgical revision, underscoring the importance of meticulous surgical planning, appropriate patient selection, and structured postoperative rehabilitation.(24) These results align with existing literature, which highlights the role of early intervention in optimizing functional

recovery while emphasizing the multifactorial nature of surgical complications and postoperative stiffness. (25)

The significant improvement in complete motor recovery following early tendon transfer aligns with previous studies emphasizing the importance of early intervention in nerve injuries. Neuromuscular plasticity and the ability of muscles to reinnervate decline over time, with prolonged denervation leading to irreversible atrophy and fibrosis. Previous found that tendon transfer performed within 6 to 12 months post-injury leads to superior functional outcomes due to the preserved contractility of target muscles.(26) Similarly, one of the previous studies has demonstrated that delayed interventions are associated with a decline in motor endplate viability, limiting the potential for neuromuscular recovery. The present findings support these conclusions, as patients who underwent tendon transfer within 12 months were 2.4 times more likely to achieve complete motor recovery compared to those undergoing delayed intervention.(27) Furthermore, our study reinforces the conclusions drawn by research before emphasized that early surgical intervention improves the likelihood of functional success, particularly when combined with structured rehabilitation protocols.

In contrast, our analysis found that wrist flexion limitation did not differ significantly between early and late tendon transfer groups. This suggests that factors other than timing—such as surgical technique, intraoperative tendon tensioning, and postoperative therapy—may play a more substantial role in determining postoperative wrist mobility.(28) Previous research presents conflicting results regarding the impact of timing on wrist stiffness. Other study has suggested that early tendon transfer prevents secondary joint stiffness by preserving soft tissue elasticity. However, one of previous study has argued that postoperative wrist mobility is largely dependent on rehabilitation adherence rather

than surgical timing.(29) Additionally, Patterson et al. (2022) emphasized that extended immobilization following surgery, rather than delayed intervention itself, may contribute to postoperative stiffness. These studies collectively indicate that while early surgery may have some advantages, postoperative rehabilitation remains the key determinant of wrist mobility.(30) Future research should explore whether early mobilization protocols, adjunctive physical therapy techniques, or regenerative therapies can further optimize wrist function in patients undergoing tendon transfer.

The finding that 20% of patients required surgical revision after tendon transfer is clinically significant and highlights the need for careful surgical planning. The variability in revision rates, ranging from 12% to 29% across studies, suggests that multiple factors contribute to postoperative complications. (22) Previous study has suggested that improper tendon tensioning and technical errors increase the risk of poor functional outcomes, leading to the need for revision surgery. Similarly, one of the study has reported that inadequate postoperative rehabilitation predisposes patients to adhesions and tendon rupture, both of which necessitate secondary surgical interventions. (7) Previous study shows further noted that revision rates are higher in patients with pre-existing soft tissue fibrosis or a history of failed nerve repair, suggesting that preoperative tissue quality plays a critical role in surgical success. The low heterogeneity observed in our meta-analysis ($I^2 = 0\%$) indicates that revision rates are relatively consistent across studies, reinforcing the need for standardized surgical protocols to reduce the likelihood of complications.(24) Given these findings, future research should investigate strategies to enhance tendon healing, such as the use of platelet-rich plasma (PRP), mesenchymal stem cell therapy, or bioengineered scaffolds, which have shown promise in improving tendon integrity and reducing the risk of reoperation.(13)

From a clinical perspective, these results emphasize that early tendon transfer should be the preferred approach for patients with radial nerve palsy, as it significantly improves motor recovery without increasing the risk of complications. However, given that wrist flexion limitation was not significantly affected by surgical timing, efforts should be directed toward optimizing rehabilitation strategies rather than relying solely on early intervention.(31) The relatively high revision rate (20%) further underscores the importance of meticulous surgical technique, intraoperative precision in tendon balancing, and structured postoperative rehabilitation protocols to improve long-term outcomes.(17)

Moving forward, several areas warrant further investigation. First, randomized controlled trials (RCTs) comparing early and late tendon transfer would provide stronger evidence regarding the optimal timing for surgery. Second, long-term follow-up studies are needed to evaluate the durability of functional recovery beyond the typical follow-up periods reported in current literature. Third, biomechanical analyses comparing different tendon transfer techniques could help refine surgical approaches and identify the most effective procedures for specific patient populations. Fourth, regenerative medicine approaches, such as biological adjuncts and nerve growth factors, should be explored to enhance tendon healing and prevent postoperative complications. Lastly, personalized rehabilitation strategies tailored to individual patient needs may help mitigate wrist stiffness and optimize overall functional recovery.

LIMITATION

Despite the strengths of this meta-analysis, several limitations must be acknowledged. First, the number of studies included was relatively small, which may affect the generalizability of the findings. Second, the risk of bias assessment (ROBINS-I) indicated that some studies had a moderate to serious risk of bias, particularly due to

confounding variables and incomplete data reporting. Third, variations in surgical techniques and rehabilitation protocols across studies introduce potential heterogeneity that may influence the observed outcomes. Lastly, due to data limitations, we were unable to perform meta-regression analyses to examine the potential effects of age, injury severity, and surgical technique on functional outcomes. Future systematic reviews should incorporate larger datasets, individual patient-level data analyses, and machine learning-based predictive modeling to enhance the precision of clinical decision-making.

CONCLUSION

This meta-analysis provides strong evidence that early tendon transfer (within 12 months of injury) significantly improves complete motor recovery in patients with radial nerve palsy. However, the timing of surgery does not appear to influence wrist flexion limitation, suggesting that rehabilitation plays a crucial role in optimizing wrist mobility. Additionally, approximately one in five patients required revision surgery, emphasizing the need for surgical precision, careful patient selection, and structured rehabilitation. Given these findings, early surgical intervention should be prioritized, while future research should explore novel surgical techniques, regenerative medicine approaches, and personalized rehabilitation strategies to further enhance tendon transfer outcomes.

Declaration by Authors

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